Research on the Forecast of Jiangxi's Digital Economy Scale Based on EWM and BP-Neural Network Models

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Abstract: Accurately judging the future development trend of the digital economy is the premise of exploring the realization path of strengthening the digital economy of Jiangxi. We use EWM model to measure the digital economy development index of Jiangxi Province from 2011 to 2020. Secondly, we build a predictive model for the scale of Jiangxi's digital economy based on BP neural network method. Finally, we use scenario analysis and the prediction model to simulate the development path and predict the scale of Jiangxi's digital economy. The results show that: First, during 2011-2020, the scale of digital economy development in Jiangxi Province has grown steadily, with the fastest month-on-month growth rate of 46.29% in 2017. Secondly, the independent variables selected in this paper can positively affect the development of the digital economy in Jiangxi Province. The correlation between residents' wage level and digital economy scale index is the strongest. Third, the scale of Jiangxi's digital economy can achieve sustainable growth on the premise of maintaining the current development trend or changing the development path during 2021-2025, and the digital economy gains is the most significant under the development mode of path 4.

1 INTRODUCTION

The digital economy is a new economic form following agricultural economy, industrial economy and service economy. It is significant to the transformation and upgrading of China's industrial structure, coordinated employment quantity and quality promotion, and high-quality economic development. In January 2022, Chinese State Council issued *the "Fourteenth Five Year" Digital Economy Development Plan*. It is proposed in the plan that by 2025, the added value of the core industries of the digital economy will account for 10% of GDP, the data element market system will be initially established, the digital transformation of the industry will reach a new level, the level of digital industrialization will be significantly improved, the digital public services will be more inclusive and equal, and the digital economy governance system will be more perfect. To follow up *the "Fourteenth Five Year" Digital Economy Development Plan*, Jiangxi Province responded promptly, actively seized the opportunities of digital economy development, and introduced policies and measures tailored to local conditions. In May 2022, Jiangxi Province issued *the "Fourteenth Five Year" Digital Economy Development Plan of Jiangxi Province*, which takes the deep integration of digital technology and real economy as the main line, deeply promotes the "No. 1 Development Project" to make the digital economy better and stronger, focuses on the essential tracks such as electronic information industry, focuses on cultivating new tracks for VR, Internet of Things, UAV, and other industries, and promotes the digital transformation of traditional industries such as agriculture, manufacturing, logistics. We will strive to build a new highland for developing the national digital economy and a digital industry development cluster in the central region to achieve high-quality leapfrog development.

The methods for measuring the scale of the digital economy mainly include direct measurement algorithm, indicator system method and satellite account method (Wang S 2021). The first category

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uses the direct measurement method to measure the scale of the digital economy. The US Department of Commerce first released a report measuring the digital economy in 1998 to analyze the impact of IT and e-commerce development on the US economy. China first measured the total amount of digital economy based on growth accounting in 2008 (Kang T.x 2008). The second category uses the indicator system method to measure the scale of the digital economy. From the provincial level, Liu Jun et al. (2020) selected indicators according to the three dimensions of information technology development, Internet development, and digital transaction development to establish a quality evaluation system for China's digital economy development. Zhao Tao et al. (2020) measured the comprehensive development level of the digital economy from the aspects of Internet development and digital financial inclusion from the perspective of city-level data. The third category uses the satellite account method to measure the scale of the digital economy. Yang Zhongshan and Zhang Meihui (2019), referring to the research progress of the International Digital Economy Satellite Account (DESA), set out from the broad concept of digital economy and take the characteristics of digital economic activities as the core to build a DESA that conforms to China's national conditions. Xiang Shujian and Wu Wenjun (2019) believed that digital economic satellite accounts should be added based on the existing central system, and a digital economic accounting framework including production accounting, income distribution accounting and accumulation accounting was built.

In terms of forecasting the scale of the digital economy, the relevant research in China is still lagging, and there is less literature involved. In forecasting the development of China's digital economy, Li Dong et al. (2022) used principal component analysis, multiple linear regression, balance optimizer and other methods to build a forecasting model by analyzing the data from 2013 to 2019. Xian Zude and Wang Tianqi (2022) observed the time series data of the core industries of the digital economy and found that the growth of the core industries of the digital economy was rapid. They chose the index model to predict the subsequent development trend. Li Yingjie and Han Ping (2022) measured the development trend of China's digital economy from 2010 to 2018 based on the entropy method and established a gray prediction model to predict the development trend of the digital economy from 2019 to 2028. In terms of regional digital economy development prediction, Ji Xiaoyan (2020) chose to use the gray Markov model to predict the comprehensive index of digital economy development in Zhejiang Province from 2019 to 2023, and believed that the overall development of digital economy in Zhejiang Province was growing, but it could be improved better.

To sum up, scholars at home and abroad have made beneficial explorations on the measurement methods of the scale of the digital economy, but few have been involved in the prediction of the scale of the digital economy and the research on the prediction of the development level of the regional digital economy is even less. Therefore, this paper takes Jiangxi Province as the research object and combines the entropy method to construct a comprehensive development index of digital economy from the Internet development and digital financial inclusion to measure the development level of digital economy in Jiangxi Province. Based on the original data, combined with Holt's linear trend model and fixed annual growth rate, the BP neural network is used to predict the development trend of Jiangxi's digital economy in the future for a while, and six development paths are designed to explore the optimal path of Jiangxi's digital economy development, to enrich the research on China's digital economy prediction and provide decision-making basis for the vigorous development of Jiangxi's digital economy.

2 METHODS AND MATERIALS

2.1 BP Neural Network Model

BP neural network is a method different from the traditional regression model, characterized by exploring the correlation between data through parameters and activation functions. In the application process of neural network, three types of information processing neurons are mainly involved: input neurons, output neurons, and hidden neurons. The specific structure is shown in Figure 1.

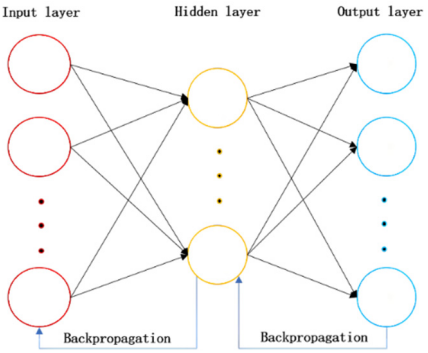

Figure. 1: Structure of BP neural network.

The mathematical language description is as follows: let $X=(X_1,X_2,...,X_i,...,X_m)$ be the training set, $xi=(x_{i0},x_{i1},x_{i2},...,x_{in})$ be the input value, $yi=(y_{i1},y_{i2},y_{i3},...,y_{il})$ be the prediction value , $zi=(z_{i1},z_{i2},z_{i3},...,z_{il})$ be the real value. Denote the threshold and weight from the input layer to the hidden layer as $b_p^{(1)}$ and v_{rp} respectively, the threshold and weight from the hidden layer to the output layer as $b_q^{(2)}$ and v_{jq} respectively, and the expected accuracy of the model as a. When the input data reaches the threshold, the outputs of the hidden layer and the output layer are:

$$z_k = f(I_j) = f(\sum_{k=0}^{n} v_{rk} * x_{ir}) \quad (1)$$

$$z_t = g(I_t) = g(\sum_{t=0}^{l} v_{jq} * z_{ij}) \quad (2)$$

…where I_j is the input of the hidden layer, I_t is the input of the output layer, Z_k is the output of the hidden layer, Z_t is the output of the output layer, f and g are the activation functions. Then, the mean square error E is:

$$E = \frac{1}{2}\sum_{t=0}^{l}(y_{it} - z_{it})^2 \quad (3)$$

If $E>a$, the model will carry out step-by-step error backpropagation. The model iteration process is as follows:

$$v_{jp}(c+1) = v_{jp}(c) - \eta\frac{\partial E}{v_{jp}} \quad (4)$$

…where η is the learning rate and c is the number of iterations. The iterative formula from the output layer to the hidden layer is the same as (4).

2.2 Digital Economy Measurement Framework

Based on the connotation of digital economy and the availability of data, this paper uses the research methods of Zhao Tao and other scholars (Zhao T. 2020, Min L.l. et al. 2022) to measure the comprehensive development level of digital economy by selecting indicators from two aspects of Internet development and inclusive development of digital finance, and determines the weight of each indicator through entropy weight method to design a digital economy index measurement system as shown in Table 1 to measure the current level of digital economy development in Jiangxi Province. For the measurement of Internet development, Huang Qunhui 's method (2019) was used for reference, and four indicators were selected: Internet penetration rate, number of Internet-related practitioners, Internet-related output and number of mobile Internet users. To measure inclusive development of digital finance, refer to the method of Guo Feng et al. (2020), and select China's digital inclusive financial index to measure inclusive development of digital finance. The index is jointly compiled by the Digital Finance Research Center of Peking University and Ant Group.

Table 1: Digital Economic Index Measurement System.

Level I indicators	Level II indicators	Level III indicators	Indicator attribute
Comprehensive development index of digital economy	Internet penetration (IP)	Number of Internet users of 100 people	+
	Number of Internet-related practitioners (IRP)	Proportion of computer service and software practitioners	+
	Internet-related output (IRO)	Total telecom services per capita	+
	Number of mobile Internet users (MIU)	Number of mobile phone users with 100 people	+
	Inclusive development of digital finance (DF)	China Digital Inclusive Financial Index	+

2.3 Data Description

This paper conducts research on the scale of digital economy development in Jiangxi Province. The time period is selected as 2011-2020. The data on influencing factors and digital economy index measurement indicators are mainly from China Urban Statistical Yearbook, China Statistical Yearbook, Jiangxi Statistical Yearbook, Beijing University Digital Finance Research Center and the database of Prospective Industry Research Institute.

3 MODEL CONSTRUCTION AND EMPIRICAL ANALYSIS

3.1 Evaluation of Digital Economy Development Scale

Table 2: Shows the scale evaluation model of digital economy based on entropy weight method:

Table 2: Data Similarity Measurement Table of Various Indicators of Digital Economy.

Year	Metrics (weight)					Composite value
	IP (0.19)	IRP (0.15)	IRO (0.1)	MI (0.37)	DF (0.19)	Comprehensive development index of digital economy (DES)
2011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2012	0.0498	0.6877	0.0085	0.1252	0.2001	0.1989
2013	0.0820	0.7532	0.0268	0.2388	0.3744	0.2917
2014	0.1020	0.8999	0.0439	0.3012	0.4695	0.3605
2015	0.3351	0.6010	0.0917	0.3412	0.5745	0.3995
2016	0.4276	0.4844	0.0411	0.3893	0.6241	0.4219
2017	0.5716	1.0000	0.1245	0.5376	0.7638	0.6172
2018	0.8448	0.0516	0.4134	0.8324	0.8572	0.6802
2019	0.9493	0.4988	0.7877	0.8821	0.9309	0.8370
2020	1.0000	0.6592	1.0000	1.0000	1.0000	0.9483

It can be seen from Table 2 that the development of digital economy in Jiangxi Province is on the rise steadily. The development level of the digital economy (standardization coefficient) is from 0 in 2011 to 0.9483 in 2020. Among them, the fastest growth rate was in 2017, with a year-on-year growth of 46.29%. This is mainly because Jiangxi Provincial Government held a plenary meeting in September 2016, and proposed to accelerate the transformation and upgrading of industrial digitalization closely around the strategies of "Internet plus", "Made in China 2025", "mass entrepreneurship, innovation", etc. The relative decline in the development speed in 2018 is the external manifestation of the connotation of the coupled development model of the real economy and the digital economy. In 2019, all fields of the digital economy began to work together, and the development of the digital economy turned around.

Table 3: Drivers of Jiangxi's Digital Economy Scale Index.

Variable	Meaning	Definition
Pgdp	Level of economic growth	Ratio of GDP to total population
Fdi	Foreign capital dependence	Ratio of foreign direct investment to GDP
Gov	Degree of government intervention	Ratio of government expenditure to GDP
Edu	Human capital level	Ratio of the number of students in secondary institutions of higher learning to the total population of the region
Str	Industrial structure level	Proportion of tertiary industry in GDP
Pwage	Residents' salary level	Average wage of urban non private employees in the region

Based on the relevant research on digital economy by Liu Jun and others (2020), this paper selects six core factors that may affect the scale of digital economy in Jiangxi Province: economic growth level, dependence on foreign capital, government intervention, human capital level, industrial structure level, and residents' wage level as the primary independent variables. Pearson and Spearman correlation analysis of the above six variables and Jiangxi's digital economy scale variables is conducted, respectively, and Table 4 is obtained. It can be seen that the above six independent variables are significantly positively correlated with Jiangxi's Digital Economy Scale (DES). The upper right of the main diagonal is Spearman correlation coefficient, and the lower left is Pearson correlation coefficient in Table 4.

Table 4: Correlation coefficient

	DES	Pgdp	Fdi	Gov	Edu	Str	Pwage
DES	1	1.000***	0.673**	0.818***	0.358	1.000***	1.000***
Pgdp	0.986***	1	0.673**	0.818***	0.358	1.000***	1.000***
Fdi	0.639**	0.632*	1	0.515	0.697**	0.673**	0.673**
Gov	0.818***	0.787***	0.343	1	0.406	0.818***	0.818***
Edu	0.672**	0.671**	0.948***	0.330	1	0.358	0.358
Str	0.965***	0.992***	0.633**	0.777***	0.668**	1	1.000***
Pwage	0.987***	0.999***	0.634**	0.800***	0.666**	0.993***	1

3.2 Construction of Jiangxi's Digital conomy Scale Prediction Model

The six factors screened above are selected as the input variables of BP neural network prediction, and comprehensive development index of digital economy is the output. The data from 2011 to 2016 are used as the training set, and the data from 2017 to 2020 are used as the verification set and test set, respectively, to build BP neural network machine learning samples; Levenberg-Marquardt algorithm method is selected as the training method, and the maximum training times are 10000. The model structure is shown in Figure 2:

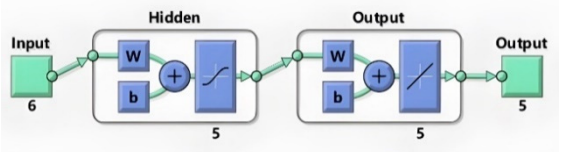

Figure 2: Structure of BP neural network model

The trained BP neural network is used to predict the validation and test samples, and the mean square error is 0.064. The results show that the model has an excellent fitting effect and a small mean square error (MSE) in forecasting the scale of Jiangxi's digital economy.

3.3 The Design of Digital Economy Development Path in Jiangxi Province

By changing the change rate of six influencing factors that affect the development scale of Jiangxi's digital economy one by one, this paper explores the growing trend of Jiangxi's digital economy development scale in the future under different paths:

Present status 1: Estimate the value of the independent variable from 2021-2025 based on the Holt linear trend model. Keep the development trend of Jiangxi's digital economy from 2021-2025 the same as 2011-2020, and predict the scale of Jiangxi's digital economy from 2021-2025.

Present status 2: calculate the average growth rate from 2011 to 2020, use this value as the fixed growth rate to calculate various factor values from 2021 to 2025, and predict the scale of the digital economy in the next five years.

Path 1: The level of economic growth will affect the development of the digital economy. Path 1 is set as follows: from 2021-2025, the average annual GDP per capita growth rate in Jiangxi Province will be 12.18%, and other factors will maintain the current development level.

Path 2: Attracting foreign direct investment (FDI) can promote the development of digital economy. Path 2 is designed as follows: from 2021-2025, the ratio of foreign direct investment (FDI) to GDP of Jiangxi Province, that is, the average annual growth

rate of foreign investment dependency, is set to 14.88%, and other factors remain unchanged.

Path 3: Government regulation and support is an essential guarantee for improving digital infrastructure. Path 3 is designed as follows: from 2021-2025, the ratio of government fiscal expenditure to regional GDP, that is, the average annual growth rate of government intervention, is set to 22.30%, and other factors remain unchanged.

Path 4: The development of digital economy urgently needs a high-level labor force. Path 4 is designed as follows: from 2021-2025, the proportion of students in secondary and higher education institutions to the total population of Jiangxi Province, that is, the average annual growth rate of human capital level is set to 18.23%, and other factors remain unchanged.

Path 5: The level of industrial structure will play a positive role in developing the digital economy. Path 5 is designed as follows: from 2021-2025, the ratio of the tertiary industry to the regional GDP, that is, the average annual growth rate of the industrial structure level is set to 13.53%, and other factors remain unchanged.

Path 6: The digital economy cannot be separated from the digital transaction behavior of residents. Path 6 is designed as follows: from 2021-2025, the average wage of urban non-private employers in the region, that is, the average annual growth rate of residents' wage level, is set to 1.35%, and other factors remain unchanged.

Table 5 shows the parameter changes of the above six paths:

Table 5: Parameter Changes under Each Path.

Path / Indicators (%)	Path1	Path2	Path3	Path4	Path5	Path6
Economic growth level growth rate	12.18	9.18	9.18	9.18	9.18	9.18
The growth rate of foreign capital dependence	3.49	14.88	3.49	3.49	3.49	3.49
The growth rate of government intervention	2.11	2.11	22.30	2.11	2.11	2.11
The growth rate of human capital level	1.95	1.95	1.95	18.23	1.95	1.95
Industrial structure level growth rate	4.13	4.13	4.13	4.13	13.53	4.13
The growth rate of household wages	10.00	10.00	10.00	10.00	10.00	1.35

3.4 Analysis of BP Neural Network Prediction Results

Based on the above path design, the predicted value of Jiangxi's digital economy scale from 2021-2025 obtained by BP neural network prediction model is shown in Table 6 below:

Table 6: 2021~2025 Digital Economy Comprehensive Development Index Forecast under Each Path.

Year	Present status 1	Present status 2	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
2021	1.0881	1.0316	1.0316	0.9771	0.9808	1.0897	1.0085	1.0128
2022	1.1934	1.0739	1.1061	0.9974	1.0171	1.1859	1.0698	1.0768
2023	1.2648	1.1187	1.1640	1.0092	1.0489	1.2259	1.1249	1.1314
2024	1.3098	1.1661	1.2029	1.0144	1.0743	1.2389	1.1693	1.1726
2025	1.3334	1.2165	1.2253	1.0141	1.0936	1.2435	1.2014	1.2000

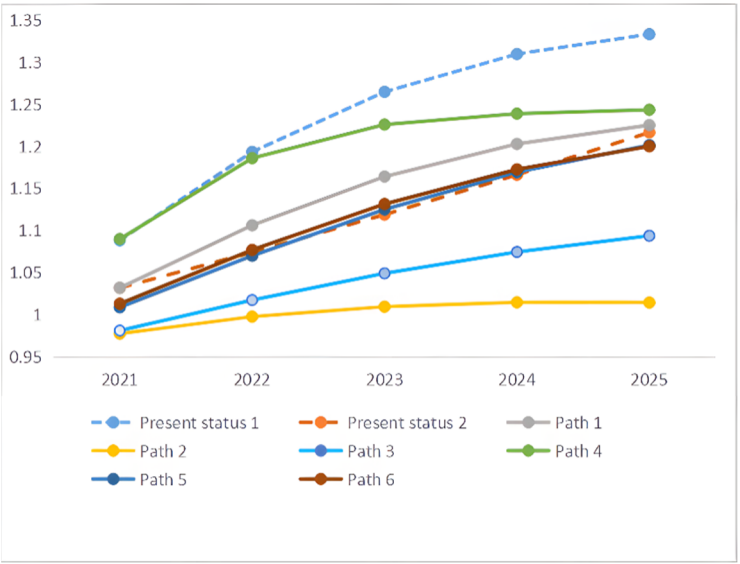

Figure 3 Jiangxi's Digital Economy Scale Forecast Index under Different Paths

The following conclusions can be drawn from the above table 6 and the discount chart of predicted value changes under different paths (Figure 3):

Present status 1: According to the independent variable values estimated by Holt's linear trend model from 2021-2025, if the current development trend is maintained, the digital economy scale index of Jiangxi Province will continue to grow between 2021 and 2025, eventually reaching 1.33.

Present status 2: The digital economy scale index of Jiangxi Province in 2025 calculated based on the fixed annual growth rate is 0.117 lower than that of present status 1, which is caused by the prediction method of impact factors.

Path 1: Improve the level of economic development. The digital economy scale index of Jiangxi Province will reach 1.225 by 2025, which will exceed the digital economy scale index achieved by maintaining the current development trend path. This is because good performance of economic growth can promote the healthy development of digital economy, which is mainly reflected in the perfection of digital infrastructure in the province, the prosperity of digital-related industries and the level of overall digitalization.

Path 2: Increase the dependence on foreign capital. The digital economy scale index of Jiangxi Province will increase year by year from 2021 to 2025 and finally reach 1.0141. Foreign investment means additional capital investment and foreign advanced digital technology and digital management concept, which can accelerate the digital construction of Jiangxi Province.

Path 3: Strengthen government intervention, and the digital economy scale index of Jiangxi Province will reach 1.0936 by 2025. At present, the development level of Jiangxi's digital economy is at a low stage, the role of market resource allocation may fail, and government intervention can help the healthy development of the digital economy.

Path 4: Improving the level of human capital will enable the digital economy scale index of Jiangxi Province to continue to rise from 2021 to 2025 and reach 1.2435 in 2025, which is more than the index that can be reached by the path of maintaining the status quo. The development of the digital economy requires a high-level talent team. High-quality labor can promote the long-term sustainable development of the digital economy. The software and hardware required for digitization need high-quality labor support.

Path 5: Improve the industrial structure. The digital economy scale index of Jiangxi Province will reach 1.2014 by 2025. The gradual evolution of traditional industries from labor-intensive to capital-intensive, technology-intensive, and knowledge-intensive industries will have a huge impact on the development of digital economy.

Path 6: On the premise of ensuring the steady increase of residents' wages, Jiangxi's digital economy scale index will reach 1.2000 by 2025. Based on the connotation of digital economy, the development of digital economy cannot be separated from residents' digital trading behavior. Therefore, to some extent, the residents' wage level controls the development of the digital economy.

4 CONCLUSIONS

This paper uses EWM method to measure the digital economy comprehensive development index of Jiangxi Province from 2011 to 2020 based on building the scale measurement index system of digital economy. Next, this paper sets multiple development paths combined with the driving factors of digital economy development. It uses digital economy scale prediction model of Jiangxi Province to predict the future development scale of Jiangxi's digital economy under different paths. The following conclusions are reached: First, the level of economic growth, dependence on foreign capital, government intervention, the level of human capital, the level of industrial structure and the level of residents' wages can positively affect the development of digital economy in Jiangxi Province, among which the level of residents' wages has the strongest correlation with the scale index of digital economy. Second, from 2021-2025, the scale of Jiangxi's digital economy can achieve sustainable growth on the premise of maintaining the current development trend or changing the development path. And under the development mode of path 4, the digital economy gains most significantly.

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