Research on the Measurement of National Digital Economy Development Based on AHP-Topsis Model

Yiyan Chen*

AIEN Institute, SHANGHAI OCEAN UNIVERSITY, Shanghai, China.

3096559865@qq.com

Abstract. The digital economy has become a crucial driving force for global economic growth, which promotes the transformation and upgrading of the economic structure of various countries. Strengthening the digital economy development can not only enhance national competitiveness, but also boost technological innovation, optimize resource allocation and enhance high-quality social and economic development. Based on the analytic hierarchy process (AHP) and Topsis comprehensive evaluation, this paper constructs an evaluation model of China’s digital economy development from four dimensions, including digital infrastructure, digital industry environment, digital living environment and digital education environment. It aims to quantitatively measure the digital economy development of 31 provinces and cities from 2014 to 2023, and predicts the development trend from 2025 to 2030 through multiple linear regression models. It was found that China’s digital economy as a whole is presenting a steady upward trend, but the uneven regional development is still prominent. Based on the empirical results, this paper puts forward suggestions such as strengthening innovation, promoting industrial integration, improving infrastructure and optimizing policy coordination to drive the high-quality development of the digital economy.

Keywords: Digital Economy; Analytic Hierarchy Process; Topsis Comprehensive Evaluation; Linear Regression; Influencing Factors.

1. Introduction

With the rapid development of information technology, the digital economy has become an integral engine of global economic growth. China regards the digital economy as a national strategy and promotes economic structural optimization and high-quality development. According to the *14th Five-Year Plan for Digital Economy Development*, the added value of core industries of the digital economy will account for 10% of GDP by 2025, significantly higher than the 7.8% in 2020. In the report to the 20th National Congress of the Communist Party of China, President Xi emphasized the need to “optimize the allocation of data and build a digital economy with data as the key element”, further clarifying the core position of the digital economy in national development. However, the current development of China’s digital economy still faces challenges such as talent shortage, insufficient supply of new production factors, and uneven regional development. In particular, obvious shortcomings exist in the utilization of data resources, independent controllability of core technologies and infrastructure construction.

On this basis, in order to systematically evaluate the development of China’s digital economy, this paper constructs a digital economy development evaluation model. From the four dimensions of digital infrastructure, digital industry environment, digital living environment and digital education environment, AHP is used to give weights, and digital infrastructure is determined as the key factor. Then, the Topsis comprehensive evaluation aims to quantitatively measure and rank the development of the digital economy in various provinces and cities across the country. Besides, the regional development gap is analyzed. Finally, based on time series regression analysis, combined with the data from recent ten years, the development trend in the next five years is predicted to provide suggestions for the government.

2. Literature Review

2.1 Research on Influencing Factors of the Digital Economy

In the international environment, Russian researchers Aleksei V. Bogoviz, Svetlana V. Lobova and Julia V. Ragulina [1] used correlation analysis to evaluate the development of the digital economy by traditional economic characteristics (such as profit rate and risk) and foreign investment, which points out the importance of government intervention in enhancing the influence of the country's digital economy; Azu, Jelivov, Aras et al. [2] revealed the serious negative impact of the loosening digital industry and the inadequate digital education through empirical model fitting analysis of unemployment rate in West Africa; Suhendra, Istikomah, Anwar et al. [3] used linear model and fixed effect analysis to analyze some relevant indicators of the digital economy. They figured out the promotion role of human capital and digital infrastructure in the digital economy, and put forward corresponding suggestions. In addition, at the 8th ICDE conference, Jalloul, Anis, Belkhir, etc. [4] also proposed the role of emerging technologies such as the Internet of Things and 5G in prospering the digital economy.

In China's domestic environment, Liu Ke, Lu Shulong, Liu Wenli et al. [5] used the entropy method and Thiel index to analyze the panel data of 30 provinces in China, which found that government investment and economic level are vital factors affecting the development of digital economy. Thus, they suggested strengthening the cultivation of digital talents and increasing government investment. In addition, Qu Ying and Zhang Shanshan [6] used meta-analysis to study the influencing factors of the integration and development of the digital economy and the real economy, which concluded that the urban development status and industrial level significantly impact the development of the digital economy. Based on the former analysis, they advocated to improve industrial quality. Wang Jinwei, Wang Qixiang and Lu Dadao [7] used the entropy method and coupled system analysis to analyze some cities, which supported the adaptability of the digital economy and urban development and people's quality of life development. In terms of talent education, Cai Wenbo and Zhou Ziqing [8] verified the two-way promotion effect of digital talent education and digital economy development through a benchmark regression model.

2.2 Research on the Development Trend of the Digital Economy

The digital economy evolution is the history of the continuous development of information technology. The global digital economy began to sprout in about the 1990s. Especially in Europe, the popularity of the Internet has promoted the rise of e-commerce and online services. According to Marino and Paolo [9], the development trend of the digital economy in Europe is mainly reflected in accelerating technological innovation, narrowing the digital divide and promoting the construction of a digital single market. Countries further promote economic growth and social progress by investing in digital infrastructure and upgrading human capital. Taking Russia in Asia as an example, Julia V et al. [10] believe that the country's digital economy development has experienced a deepening process from initial digital transformation to all-round innovation-driven based on digital facilities and digital education, so as to achieve innovation and digital technology-driven economic transformation. In short, the global development trend is divided into these stages in the research of Jiang [11] et al.: the rise of e-commerce and online services, the penetration of social media platforms and mobile payments, and the deep integration with traditional industries at present.

Regarding the development of the digital economy in China's environment, Hu Wen proposed in Retrospect and Prospect of China's Digital Economy Development [12] that the development rate of the digital economy in China is basically consistent with the international environment. First of all, it was the embryonic period (1994-2002) when China officially connected to the Internet. With news portals and mailboxes as its main business model, it began to pay attention to traffic and user accumulation. Then there was a period of rapid development (2003-2012), with the rising e-commerce and social networks, and the state issued policies to promote e-commerce. Finally, it is the mature stage (2013-to date). With the popularization of mobile Internet and the rise of big data, artificial intelligence and other technologies, the deep integration of digital economy and real economy has promoted the Internetization of traditional industries and the progress of innovative industries. Wang Jun, Zhu Jie, and Luo Xi [13] pointed out in the report that with the promotion of national policies, the imbalance gap in regional development is narrowing, and industrial digitalization is becoming more important in the transformation of primary and secondary industries.

2.3 Summary of Literature Review

To sum up, foreign research mainly focuses on the key influencing factors in the development of the digital economy, such as government policies, foreign investment, technological innovation and human capital, which discusses the role of digital infrastructure construction in promoting the digital economy. In addition, some studies have put forward the role of emerging technologies (such as the Internet of Things, 5G, etc.) in boosting the digital economy. However, foreign studies generally lack in-depth discussions on the differential impacts of the digital economy among different regions, especially in the assessment and prediction detailed at the local level. Domestic research mainly concentrates on the integration of the digital economy and the real economy, the impact of government investment on the digital economy, and the two-way promotion between digital talent education and industrial development. Domestic scholars mostly use the entropy method, Thiel index and others to analyze panel data of different provinces and cities, revealing the role of government policies and local economic levels in enhancing the digital economy. However, the existing research still has limitations, especially in terms of cross-regional comparison and timeliness (most of the research exists between 2020 and 2022), with less attention paid to the evolution trend of the digital economy at different stages.

To make up for these problems, this study constructs an evaluation index system for the digital economy development, using AHP, Topsis comprehensive evaluation and time series regression. With the data from 2014 to 2023, the digital economy is built in various provinces and cities. Comparative analysis of economic development and prediction of development trends in the next five years is conducted, which accurately grasps differential characteristics of the digital economy regionally and provide a basis for formulating preciser development policies.

3. Construction of Analytic Hierarchy Process

3.1 Preliminary Screening of Indicators and Data Sources

According to Table 1, the first-level indicator in this study is “digital economy development”, with four second-level indicators: digital infrastructure, digital industry environment, digital living environment and digital education environment. Moreover, sixteen third-level indicators exist, including the growth rate of mobile phone base stations, the number of Internet broadband access users per 10,000 people, the coverage rate of ipv4, the proportion of government fiscal expenditure on science and technology in total expenditure, and the proportion of higher education in total education.

Table 1 Construction of Digital Economy Development Indicators

First-level Indicator	Second-level Indicators	Third-level Indicators
Development of Digital Economy	Digital Infrastructure	Growth rate of mobile telephone base stations
		Number of Internet broadband access users per 10,000 people
		Coverage rate of ipv4 (number of ipv4 addresses/number of domain names)
		Proportion of government fiscal expenditure on science and technology to total expenditure
		Proportion of businesses with e-commerce

	Digital Industry Environment	Number of websites per 100 enterprises
		The proportion of patent applications in the science and technology to all patents
		E-commerce transaction volume per capita
		Growth rate of R&D personnel full-time equivalent (person-year)
	Digital Living Environment	Proportion of online retail sales of physical goods to retail sales of social consumer goods
		Growth rate of postal network
		Growth rate of digital inclusion index
		Growth rate of per capita income
	Digital Education Environment	Teacher-student ratio in colleges and universities (number of teachers = 1)
		Proportion of education budget to public budget
		Higher education as a proportion of total education

The data sources of this paper are the China Statistical Yearbook (www.stats.gov.cn) and the Digital Economy Open Research Platform (www.deor.org.cn). The data are panel data from 2015 to 2024.

3.2 Construction of Analytic Hierarchy Process

According to Saaty's [14] theory, AHP is effective in solving multi-objective and multi-criteria decision-making problems. By decomposing complex problems into different levels, the relative importance among various factors is evaluated and weighted. Researchers can establish a judgment matrix based on subjective judgment through pairwise comparison, and finally get the weight of each factor, thus providing a quantitative basis for decision-making.

In short, AHP is a better weight determination with the ability to divide various factors into complex problems into related ordered levels and make them organized. It is an effective method that combines quantitative analysis with qualitative analysis, which is suitable for application in multi-factor panel data analysis in this paper.

3.2.1 Constructing an Analytic Hierarchy Structure Model

The analytic hierarchy model is constructed as shown in Figure 1:

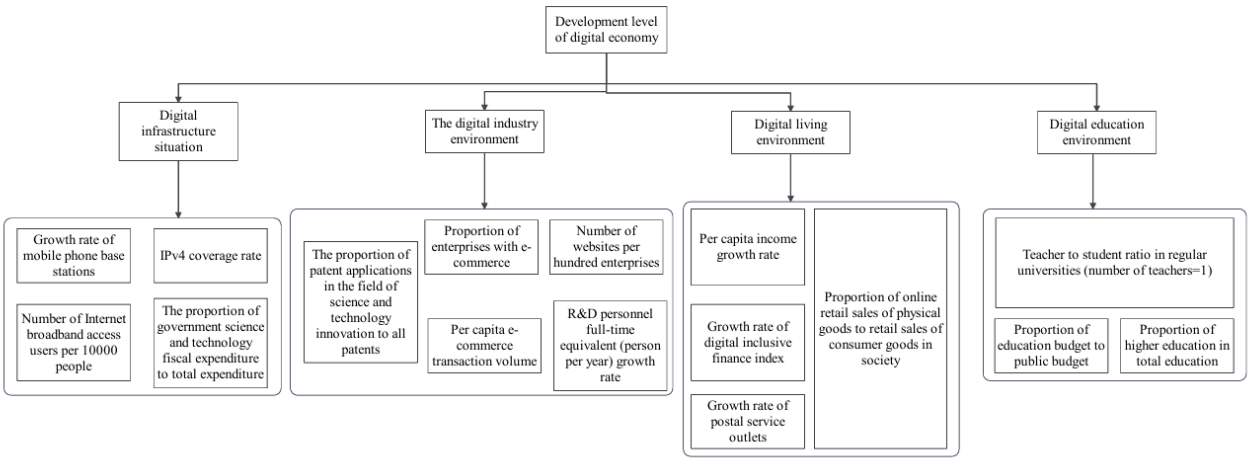

Fig1 1 Analytic Hierarchy Flow Chart

3.2.2 Construction of a Judgment Matrix

The judgment matrix is the prerequisite of AHP, with its calculation basis lying in the judgment of the mutual importance of various factors. This method helps identify the importance of different factors and directly affects the effect of decision-making. The judgment matrix usually uses a scale of 1 to 9 to compare these factors, with its scale and meaning shown in Table 2:

Tab12 Judgment Matrix Scale

Scale	Meaning
1	Indicates that the two factors are of equal importance
3	Indicates that one is slightly more important than the other in comparison to two factors
5	Indicates that one is significantly more important than the other in comparison with two factors
7	Indicates that one is more important than the other in comparison to two factors
9	Indicates that one of two factors is extremely important than the other
2，4，6，8	Represents the median value of the two adjacent judgments
Reciprocal	If the judgment B_{ij} is obtained by comparing the factors i and j, the judgment of comparing the factors j and i is $B_{ji} = 1/B_{ij}$

3.2.3 Hierarchical Single Sorting and Consistency Test

Hierarchical single ranking (AHP) is a ranking method used to determine the relative importance of factors at each level under a certain goal. The relative weights among factors are expressed by constructing a judgment matrix, in which the eigenvectors of the matrix correspond to the weights of each factor. Specifically, the eigenvalue problem of the judgment matrix A can be expressed as AW = λ max, where W is the eigenvector and λ max is the maximum eigenvalue of the judgment matrix. After normalization, the obtained weight vector is the importance ranking among hierarchical factors.

In order to ensure the consistency of hierarchical ranking, a consistency test is needed. The calculation formula of the consistency index CI is as follows:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \tag{1}$$

For the consistency of the judgment matrix, it is necessary to calculate the consistency ratio (CR) when performing hierarchical single sorting. The consistency ratio is calculated as follows:

$$\mathrm{CR} = \frac{CI}{RI} = \frac{\lambda_{\max} - n}{RI \cdot (n-1)} \tag{2}$$

Among them, the random consistency index values are shown in Table 3:

Table 3 Random Consistency Index

Judgment Matrix Order n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Only when CR < 0.1, the result of hierarchical single ranking is satisfactory. Otherwise, the values of judgment matrix elements should be adjusted.

3.2.4 Hierarchical Total Ranking and Consistency Test

In the whole process of AHP, besides the consistency check of each judgment matrix, it is necessary to check the consistency of the combination between the levels. This process ensures that the relationship between the elements in the hierarchy is reasonable in terms of consistency. The combination consistency check can be carried out after the consistency check of each level judgment matrix is completed to guarantee that the final decision result has high reliability and rationality.

The combined consistency ratio of the p-th layer to the first layer is:

$$CR^{(p)} = CR^{(p-1)} + \frac{CI^{(p)}}{RI^{(p)}}, p = 3, 4, ..., s \tag{3}$$

Only when CR < 0.1 do the hierarchical total ranking results have satisfactory consistency. Otherwise, the element values of the judgment matrix need to be readjusted.

3.3 Indicator Weight Table

The calculated indicator weights are in Table 4:

Table 4 Calculation Results of Indicator Weight

First-level Indicator	Second-level Indicators	Third-level Indicators	Weight
Development of Digital Economy	Digital Infrastructure	Growth rate of mobile telephone base stations	0.0787
		Number of Internet broadband access users per 10,000 people	0.1795
		Coverage rate of ipv4	0.0455
		Government fiscal expenditure on science and technology	0.1795
	Digital Industry Environment	Proportion of businesses with e-commerce	0.0229
		Number of websites per 100 enterprises	0.0148
		Number of patent applications in the science and technology	0.0543
		E-commerce transaction volume per capita	0.0166
		Proportion of employees in the technology industry	0.1034
	Digital Living Environment	Proportion of online retail sales of physical goods to retail sales of social consumer goods	0.0345
		Postal service outlets	0.0087
		Digital Financial Inclusion Index	0.0345
		Growth rate of per capita income	0.0152
	Digital educational environment	Teacher-student ratio in colleges and universities (number of teachers = 1)	0.0222
		Proportion of education budget to public budget	0.1350
		Higher education as a proportion of total education	0.0547

4. Topsis Comprehensive Evaluation

4.1 Construction of a Decision Matrix

In this study, the decision matrix A = $(a_{ij})_{m \times n}$ is constructed, each of which represents an evaluation index and each row represents a scheme to be evaluated.

4.2 Data Normalization Processing

In order to facilitate comparison, it is necessary to normalize the data to obtain B = $(a_{ij})_{310 \times 17}$. In this study, the range change is used to process it, that is, the optimal value of each attribute after transformation is 1 and the worst value is 0.

If x is extremely large (benefit type):

$$x^* = \frac{x - \min}{\max - \min} \quad b_{ij} = \frac{a_{ij} - a_j^{\min}}{a_{ij}^{\max} - a_j^{\min}} \tag{4}$$

If x is extremely small (cost type):

$$x^* = \frac{\max - x}{\max - \min} \quad b_{ij} = \frac{a_j^{\max} - a_{ij}}{a_{ij}^{\max} - a_j^{\min}} \tag{5}$$

4.3 Determination of the Weight Matrix

According to the different contributions of each evaluation indicator to the evaluation results, different weights (calculated from 3.3) are specified: w = $[w_1, \ldots, w_n]$, and the j-th column of B is multiplied by its weight w_j to obtain the weighted normative matrix C = $(C_{ij})_{310x17}$.

4.4 Determination of the Positive and Negative Ideal Solutions

The determination of positive and negative ideal solutions is based on the processed matrix C that has been normalized and weighted. According to the target type (benefit type or cost type) of each evaluation indicator, the positive and negative ideal solutions are constructed as follows:

Positive ideal solution:

$$c_1^+ = \begin{cases} \max\limits_i c_{ij}, & j \text{ is extremely large attribute} \\ \min\limits_i c_{ij}, & j \text{ is extremely small attribute}, \end{cases} \quad j = 1, 2, \ldots, n, \tag{6}$$

Negative ideal solution:

$$c_1^+ = \begin{cases} \min\limits_i c_{ij}, & j \text{ is extremely large attribute}, \\ \max\limits_i c_{ij}, & j \text{ is extremely small attribute}, \end{cases} \quad j = 1, 2, \ldots, n, \tag{7}$$

4.5 Calculation of the Positive and Negative Ideal Solution Distances of the Scheme to be Evaluated

Distance of alternative a_i to positive ideal solution:

$$\mathrm{d}_i^* = \sqrt{\sum\nolimits_{j=1}^{n} (c_{ij} - c_j^+)^2}, i = 1, 2, \ldots, m; \tag{8}$$

Distance of alternative a_i to negative ideal solution:

$$\mathrm{d}_i^0 = \sqrt{\sum\nolimits_{j=1}^{n} (c_{ij} - c_j^-)^2}, i = 1, 2, \ldots, m; \tag{9}$$

4.6 Calculation of Relative Closeness

Once positive ideal solutions (A^+) and negative ideal solutions (A^-) have been determined, the relative closeness of each scheme to be evaluated (per city, per year) relative to these ideal solutions can be calculated, with the formula as follows:

$$f_i = \frac{d_i^0}{d_i^0 + d_i^*}, i = 1, \ldots, m \tag{10}$$

After calculation, f_i is arranged from large to small to get the priority sequence of each scheme.

4.7 Empirical Analysis of Total Topsis and Evaluation

This study uses python3.12. 7 to output the total score of digital economy development nationwide in terms of provinces based on the above formula and steps, that is, the development of 31 provinces and cities from 2014 to 2023, which is shown in Table 5:

Table 5 Digital Economy Development Scores of 31 Provinces and Cities from 2014 to 2023

Province and City	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Beijing	0.5637	0.5344	0.5178	0.5502	0.5716	0.6185	0.6094	0.6143	0.6343	0.6248
Tianjin	0.4350	0.3925	0.3807	0.3861	0.4321	0.4669	0.5043	0.5253	0.5224	0.5133
Hebei	0.3356	0.3547	0.3749	0.3740	0.3428	0.3773	0.3662	0.3925	0.4196	0.4263
Shanxi	0.3212	0.3135	0.3237	0.3286	0.3168	0.3289	0.3393	0.3835	0.3776	0.3891
Inner Mongolia	0.2328	0.2533	0.2526	0.2587	0.2522	0.2670	0.2711	0.3193	0.3288	0.3358
Liaoning	0.3350	0.3431	0.3585	0.3520	0.3485	0.3643	0.3573	0.3577	0.3661	0.3803
Jilin	0.2725	0.2704	0.3107	0.3397	0.2980	0.3318	0.3233	0.3513	0.3467	0.3677
Heilongjiang	0.2688	0.2352	0.2781	0.2704	0.2728	0.3038	0.2862	0.3192	0.3114	0.3166
Shang Hai	0.5046	0.4506	0.4663	0.4838	0.4883	0.5188	0.5329	0.5359	0.5184	0.5651
Jiangsu	0.4625	0.4807	0.5014	0.5261	0.5485	0.5831	0.5542	0.5704	0.5727	0.5962
Zhejiang	0.4902	0.5534	0.5289	0.5556	0.5767	0.6270	0.5928	0.6097	0.6293	0.6630
Anhui	0.3635	0.3753	0.4455	0.4327	0.4664	0.5125	0.5000	0.5434	0.5682	0.5905
Fujian	0.4082	0.4215	0.4111	0.4421	0.4806	0.5013	0.5131	0.5441	0.5477	0.5396
Jiangxi	0.3181	0.3496	0.3695	0.3759	0.3936	0.4261	0.4289	0.4430	0.4474	0.4697
Shandong	0.4009	0.4040	0.4099	0.4343	0.4405	0.4917	0.4716	0.5061	0.5011	0.5100
Henan	0.3512	0.3383	0.3311	0.3446	0.3451	0.3745	0.3868	0.4436	0.4717	0.4959
Hubei	0.3456	0.3278	0.3650	0.3858	0.3934	0.4271	0.3909	0.4550	0.4808	0.4924
Hunan	0.3087	0.2927	0.2770	0.2869	0.3030	0.3502	0.3579	0.3849	0.4209	0.4418
Guangdong	0.4334	0.4404	0.5218	0.5179	0.5951	0.6095	0.5864	0.5995	0.6108	0.6236

Guangxi	0.3326	0.3408	0.3329	0.3340	0.3393	0.3722	0.3639	0.4168	0.4483	0.4615
Hainan	0.2897	0.3107	0.3094	0.3032	0.3448	0.4037	0.4079	0.4827	0.5095	0.5312
Chongqing	0.2546	0.2786	0.3104	0.3441	0.3705	0.3995	0.3937	0.4380	0.4503	0.4484
Sichuan	0.2739	0.3167	0.2970	0.3271	0.3460	0.3888	0.3913	0.4338	0.4124	0.4183
Guizhou	0.2929	0.3457	0.3562	0.3563	0.3632	0.3551	0.3594	0.3965	0.4085	0.4095
Yunnan	0.2409	0.2736	0.2890	0.2899	0.3077	0.2834	0.3026	0.3232	0.3369	0.3773
Xizang	0.2409	0.2736	0.2890	0.2899	0.3077	0.2834	0.3026	0.3232	0.3369	0.3773
Shaanxi	0.3267	0.3103	0.3581	0.3483	0.3415	0.3544	0.3635	0.4063	0.3956	0.4207
Gansu	0.2315	0.2989	0.3127	0.2981	0.2606	0.3050	0.3102	0.3520	0.3687	0.3957
Qinghai	0.2458	0.2048	0.2139	0.2441	0.2609	0.3119	0.2916	0.3109	0.3146	0.3214
Ningxia	0.2579	0.2668	0.2456	0.3056	0.3592	0.3841	0.3857	0.4128	0.4136	0.4249
Xinjiang	0.2997	0.3303	0.3376	0.3057	0.3494	0.3578	0.3715	0.4304	0.4131	0.4403

5. Multiple Linear Regression Analysis

5.1 Construction of Regression Model

The construction of this regression model aims to predict the development trend of the digital economy in various provinces and cities in China in the next five years. The dependent variable y is the digital economy development index, which is represented by the score obtained by Topsis. This dependent variable reflects the development of the digital economy in various provinces and cities in different years. The independent variable x is the year, and its purpose is to capture the changing trend of the digital economy over time. Then the univariate linear regression model of the annual digital economy development can be expressed as:

$$y = a + bx + e \tag{11}$$

Where a is the regression model constant, b is the regression model coefficient, and e is the residual term. In the previous analysis, the digital economy development index of all provinces and cities from 2014 to 2023 met the following linear relationship:

$$y_i = a + b_i x + e_i \tag{12}$$

The regression coefficients b and a are calculated as follows:

$$b = \frac{\sum (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sum (x_i - \bar{x})^2} \tag{13}$$

$$a = \bar{y} - b \cdot \bar{x} \tag{14}$$

For each data point, the residual e_i of the i-th observation point can be calculated by the following formula:

$$e_i = y_i - \hat{y} \tag{15}$$

5.2 Empirical Analysis of Linear Regression

Through the above Topsis comprehensive evaluation, the total scores of various provinces and cities in the national digital economy development were obtained. Taking the year as the independent variable and the score of digital economy development as the dependent variable, a national linear regression model is constructed, and the calculation results of model parameters are shown in Table 6:

Table 6 Calculation Results of Linear Regression Parameters

Province and City	a	b	Province and city	a	b	Province and city	a	b
Beijing	-23.34695	0.01186	Anhui	-50.05365	0.02504	Chongqing	-45.65177	0.02280
Tianjin	-32.89710	0.01652	Fujian	-35.78723	0.01797	Sichuan	-34.98035	0.01751
Hebei	-16.37961	0.00830	Jiangxi	-31.50235	0.01581	Guizhou	-20.33080	0.01025
Shanxi	-16.82115	0.00850	Shandong	-27.74939	0.01397	Yunnan	-22.39650	0.01125
Inner Mongolia	-22.24441	0.01116	Henan	-35.75633	0.01791	Xizang	-22.39650	0.01125
Liaoning	-6.93968	0.00361	Hubei	-34.96263	0.01752	Shaanxi	-20.95527	0.01056
Jilin	-18.98911	0.00957	Hunan	-35.07310	0.01755	Gansu	-27.13337	0.01360
Heilongjiang	-14.97483	0.00756	Guangdong	-42.42186	0.02129	Qinghai	-25.75443	0.01289
Shang Hai	-18.39281	0.00936	Guangxi	-29.65493	0.01488	Ningxia	-44.08340	0.02201
Jiangsu	-27.73410	0.01401	Hainan	-58.38699	0.02912	Xinjiang	-30.40081	0.01524
Zhejiang	-31.86503	0.01608						

5.3 Visualization of Prediction Results

The scores of the comprehensive evaluation of digital economy development in the whole country from 2025 to 2029 calculated by linear regression model are shown in Table 7:

Table 7 Comprehensive Score Forecast of Digital Economy Development Nationwide from 2025 to 2029

Province and City	2025	2026	2027	2028	2029	2030

Beijing	0.66955	0.68141	0.69327	0.70513	0.71699	0.72885
Tianjin	0.5559	0.57242	0.58894	0.60546	0.62198	0.6385
Hebei	0.42789	0.43619	0.44449	0.45279	0.46109	0.46939
Shanxi	0.39135	0.39985	0.40835	0.41685	0.42535	0.43385
Inner Mongolia	0.35459	0.36575	0.37691	0.38807	0.39923	0.41039
Liaoning	0.37057	0.37418	0.37779	0.3814	0.38501	0.38862
Jilin	0.39014	0.39971	0.40928	0.41885	0.42842	0.43799
Heilongjiang	0.33417	0.34173	0.34929	0.35685	0.36441	0.37197
Shang Hai	0.56119	0.57055	0.57991	0.58927	0.59863	0.60799
Jiangsu	0.63615	0.65016	0.66417	0.67818	0.69219	0.7062
Zhejiang	0.69697	0.71305	0.72913	0.74521	0.76129	0.77737
Anhui	0.65235	0.67739	0.70243	0.72747	0.75251	0.77755
Fujian	0.60202	0.61999	0.63796	0.65593	0.6739	0.69187
Jiangxi	0.5129	0.52871	0.54452	0.56033	0.57614	0.59195
Shandong	0.53986	0.55383	0.5678	0.58177	0.59574	0.60971
Henan	0.51142	0.52933	0.54724	0.56515	0.58306	0.60097
Hubei	0.51537	0.53289	0.55041	0.56793	0.58545	0.60297
Hunan	0.46565	0.4832	0.50075	0.5183	0.53585	0.5534
Guangdong	0.69039	0.71168	0.73297	0.75426	0.77555	0.79684
Guangxi	0.47707	0.49195	0.50683	0.52171	0.53659	0.55147
Hainan	0.58101	0.61013	0.63925	0.66837	0.69749	0.72661
Chongqing	0.51823	0.54103	0.56383	0.58663	0.60943	0.63223
Sichuan	0.4774	0.49491	0.51242	0.52993	0.54744	0.56495
Guizhou	0.42545	0.4357	0.44595	0.4562	0.46645	0.4767
Yunnan	0.38475	0.396	0.40725	0.4185	0.42975	0.441
Xizang	0.38475	0.396	0.40725	0.4185	0.42975	0.441
Shaanxi	0.42873	0.43929	0.44985	0.46041	0.47097	0.48153
Gansu	0.40663	0.42023	0.43383	0.44743	0.46103	0.47463
Qinghai	0.34782	0.36071	0.3736	0.38649	0.39938	0.41227
Ningxia	0.48685	0.50886	0.53087	0.55288	0.57489	0.5969
Xinjiang	0.46019	0.47543	0.49067	0.50591	0.52115	0.53639

Through the prediction results of this model, the heat map of the national digital economy development in 2023 and 2030 is shown in the Figure2:

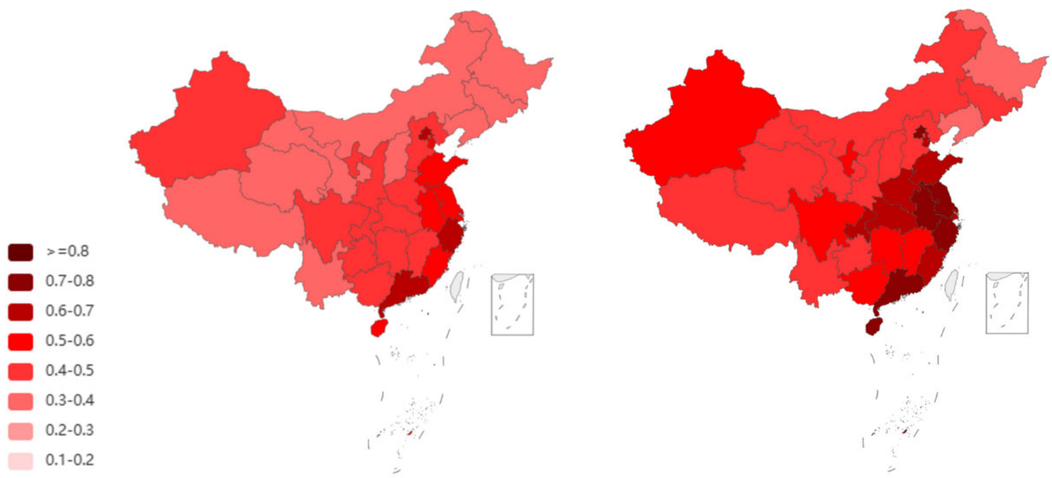

Fig2 2 Comparison of the Development of Digital Economy Nationwide Between 2023 and 2030

6. Conclusions

First of all, regions with better digital economy development include Guangdong, Zhejiang, Jiangsu, Beijing, Anhui and Hainan, with scores of 0.7968, 0.7776, 0.7774, 0.72885, 0.7266 and 0.7062 respectively.

Guangdong, Zhejiang, and Jiangsu are traditionally economically strong provinces. The digital economy has developed steadily for a long time. Relying on a strong industrial foundation and perfect policy support, the score has remained above 0.7, ranking among the top in the country. As the capital, Beijing has leading digital economy development capabilities with competent innovation resources, technology enterprises and government support.

The growth rate of the digital economy in Anhui and Hainan is particularly eye-catching. Although they are not traditional major provinces, their digital economy has developed by leaps and bounds thanks to the ultra-high GDP growth in recent years. Anhui Province grew from 0.5905 to 0.7776, which proves its great potential in digital industry and infrastructure construction. Hainan Province relies on the high growth rate of GDP, which has increased from 0.5312 to 0.7266, and the digital economy has risen rapidly.

Moreover, Fujian, Tianjin, Chongqing, Shandong, Shanghai, Hubei and Henan have “relatively better” digital economy development, with scores of 0.69187, 0.6385, 0.63223, 0.60971, 0.60799, 0.60297 and 0.60097 respectively.

Although these regions are not as good as the top digital economy provinces and cities (such as Guangdong, Zhejiang, etc.), they still present desirable growth in the next few years, especially Fujian Province, which is expected to score 0.69187 in 2030 with strong development potential. Shanghai’s digital economy score is 0.60799, an increase from 2023, but the growth rate is relatively slow, and the ranking is declining. The main reason for this phenomenon may be the saturation effect in the later stage of digital economic development. Shanghai achieved significant digital economic growth in the early stages. With the full rollout of infrastructure and digital technology, it entered the later stage of development, and the growth rate began to slow down. The rise of emerging regions represented by other provinces and cities such as Zhejiang and Guangdong has accelerated the development of the digital economy. Policy support and technological innovation have boosted their rapid progress, thus widening the gap with Shanghai.

The scores of Tianjin and Chongqing have also steadily improved, which are expected to be 0.6385 and 0.63223 respectively by 2030. The development of Tianjin’s digital economy relies on the Beijing-Tianjin-Hebei integration strategy, which promotes the deep integration of the digital industry. Chongqing has promoted economic transformation by accelerating the layout of digital manufacturing and smart city construction. Shandong, Hubei and Henan scored 0.60971, 0.60297 and 0.60097 respectively, which proves a stable performance. Especially in Shandong Province, under the guidance of policies, it has enhanced the digital transformation of enterprises and the construction of the new infrastructure, and the application of digital economy in manufacturing and agriculture has been expanded.

In addition, regions where digital economy development is “average” include Ningxia, Jiangxi, Sichuan, Hunan, Guangxi, and Xinjiang, with scores of 0.5969, 0.59195, 0.56495, 0.5534, 0.55147, and 0.53639 respectively.

The digital economy in these areas is also developing steadily, especially Ningxia scoring 0.5969. Focusing on the strategic goals of “China’s computing power capital” and “three bases and one center”, Ningxia promotes the deep integration of the digital economy and society, builds a digital industry base, a data security base, a digital infrastructure base, and constructs a digital economy development center, which will provide strong support for its future digital economic growth.

As a vital place in the northwest, Xinjiang has accelerated the layout of new infrastructure represented by 5G and cloud computing in recent years. Relying on regional advantages, it has explored energy digitalization and border governance informatization, and promoted the digital economy in a vast, sparsely populated and scattered structure. With a development breakthrough in the regional form, although it ranks low in 2023, it continues to maintain a high growth rate.

Other regions are steadily advancing the development of the digital economy, with a score of around 0.55. Through policy promotion and industrial transformation, various regions have accelerated digital construction, especially in the application of digital technology, smart city construction and digital transformation of traditional industries, which have made certain progress.

Finally, Liaoning and Heilongjiang are expected to score 0.38862 and 0.37197 respectively in 2030, which are significantly lower than the overall national level.

Their overall digital economic foundation is weak, and the industrial structure is dominated by traditional heavy industry, facing greater pressure of transformation. Besides, the profitability of enterprises is not strong with a lack of endogenous power to promote digital transformation. Meanwhile, there is a relative shortage of digital talents and advanced technologies in the region, resulting in lagging digital infrastructure construction. As economically underdeveloped regions, Liaoning and Heilongjiang have apparent disadvantages in attracting investment, promoting innovation, and strengthening supervision, which limits the potential for further development of the digital economy.

7. Suggestions

In the previous analysis and calculation, a variety of analyses are studied, and the development of China's digital economy and its regional differences are discussed. Based on the data analysis and the current development status of the digital economy in various provinces and cities, this paper puts forward a series of targeted development suggestions to boost the high-quality development of the digital economy:

7.1 Deepen Innovation-driven Efforts and Enhance Core Competencies

For areas where the digital economy is relatively mature, we should increase investment in scientific and technological research and development, promote industrial innovation and transformation, and enhance the core competitiveness of the digital economy. Moreover, it is necessary to strengthen cooperation between enterprises and international innovation platforms, promote more digital technologies and products with global influence to the world market, and grasp and improve the advantages of technological leadership.

7.2 Promote Industrial Integration and Promote Digital Transformation

For areas with good digital economic development, attention should be paid to the deep integration of traditional industries and digital technologies, especially the digital transformation potential in manufacturing and service industries. Through the wide application of intelligent manufacturing, big data and other technologies, we can improve industrial efficiency, enhance the comprehensive competitiveness of the digital economy, and promote the transformation and upgrading of the regional economy.

7.3 Improve Infrastructure and Narrow the Development Gap

For areas where the development of digital economy is relatively lagging behind, the construction of digital infrastructure should be strengthened, especially in key areas such as 5G networks and cloud computing platforms, so as to ensure the balanced development of infrastructure. By improving digital inclusive finance and digital education, we will further promote the digital development of areas with low development and narrow the digital divide between regions.

7.4 Optimize Policy Support and Strengthen Coordinated Development

For areas with great difficulties in the development of the digital economy, government policy support should be strengthened, financial subsidies, tax incentives and other measures should be provided, and enterprises should be encouraged to carry out digital transformation. Meanwhile, it is required to promote regional coordinated development, resource sharing and cooperation among different regions, and the coordinated development of the overall digital economy through policy guidance and cross-regional collaboration.

References

[1] Bogoviz A V, Lobova S V, Ragulina J V. Shift of the Global Investment Flows in the Conditions of Formation of Digital Economy// Popkova E. The Future of the Global Financial System: Downfall or Harmony. ISC 2018. Lecture Notes in Networks and Systems, vol 57. Springer, Cham, 2019.

[2] Azu N P, Jelivov G, Aras O N, Isik A. Influence of digital economy on youth unemployment in West Africa. Transnational Corporations Review, 2021, 13(1): 32–42.

[3] Suhendra I, Istikomah N, Anwar C J, Supriadi A, Wakhid A A, Purwanda E, Salim A. Influence of the digital economy on economic growth: empirical study of a region in Indonesia. Cogent Economics & Finance, 2025, 13(1).

[4] Jallouli R, ed. Digital Economy. Emerging Technologies and Business Innovation: 8th International Conference, ICDEc 2023, Braga, Portugal, May 2-4, 2023, Proceedings. Springer, 2023.

[5] Liu K, Lv S L, Liu W L, Huang W B. Analysis on measurement, spatiotemporal differences and influencing factors of digital economy development level in Chinese provinces. Journal of Huaqiao University (Natural Science), 2024(06): 789-799.

[6] Qu Y, Zhang S S. Research on the influencing factors of the integration development of digital economy and real economy based on Meta analysis. Journal of Hubei University of Science and Technology (Social Sciences), 2024(04): 33-42.

[7] Wang J W, Wang Q X, Lu D D. Spatio-temporal coupling pattern and its influencing factors of digital economy, tourism economy and new urbanization: A case study of Yangtze River Delta region. Geographical Research, 2024(12): 3301-3326.

[8] Cai W B, Zhou Z Q. Digital economy promotes high-quality development of higher education: Theoretical mechanisms and empirical tests. Heilongjiang Researches on Higher Education, 2025(02): 44-53.

[9] Marino A, Pariso P. Digital economy: technological, organizational and cultural contexts for the development of cooperation in Europe. Entrepreneurship and Sustainability Issues, 2021, 9(2): 363-383.

[10] Ragulina J V, ed. Sustainable development of modern digital economy: Perspectives from Russian experiences. Springer, 2021.

[11] Jiang Y, Yu Y. Evolution History of the Digital Economy// In Understanding the Digital Revolution and Its Influences. Springer, 2024: 15-37.

[12] Jiang X J, Jin J. The retrospect and prospect of the digital economic development in China. Journal of the Party School of the Central Committee of the CPC (Chinese Academy of Governance), 2022(01): 69-77.

[13] Bu L, Zhong H X, Liang D L, Wang W, Xia P, Xia C A. A glimpse of the future：Six major trends of Chinese innovation of digital economy [2025-02-11]. Retrieved from https://www.mckinsey.com.cn/%E6%B4%9E%E8%A7%81%E6%9C%AA%E6%9D%A5%EF%BC%9A%E4%B8%AD%E5%9B%BD%E6%95%B0%E5%AD%97%E7%BB%8F%E6%B5%8E%E5%88%9B%E6%96%B0%E5%85%AD%E5%A4%A7%E8%B6%8B%E5%8A%BF/.

[14] Saaty T L, Vargas L G. Models, methods, concepts & applications of the analytic hierarchy process. 2nd ed. Springer, 2012.