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Evaluation Index System of China's Digital Economy Development Level-Based on Factor Analysis

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Abstract: *In order to comply with the 14th Five-Year Plan for the development of digital economy, to better help China grasp new opportunities and challenges, and to seize the important node of the changing global competitive landscape, this paper applies factor analysis, based on three dimensions of infrastructure construction, scientific research and innovation capacity, and the current economic development, and selects the volume of goods turnover, domestic invention patent. The paper applies factor analysis to empirically analyze the level of digital economy development of 31 Chinese provinces in 2020 based on 3 dimensions: infrastructure construction, research and innovation capacity, and current economic development, and 11 secondary indicators such as the number of domestic invention patent applications granted. The research results show that regions with high overall scores generally have higher public factor scores in the three dimensions, and there is a decreasing level of China's digital economy development from the east to the west, with the northwestern region lagging behind in particular. Finally, this paper puts forward policy recommendations on ways to promote the development of digital economy according to the characteristics of different regions.*

Keywords: *digital economy, evaluation index, factor analysis method*

1. Introduction

With the new round of scientific and technological revolution and information revolution, the application of information technology has become more and more extensive, and the digital economy has gradually become active in the public eye and has become a new driving force to promote the high-quality development of the global economy. 2020 In the context of the new crown epidemic, the economy is constantly on the downside, the digital economy fully releases its potential and plays an important role in ensuring economic stability, showing great resilience. Ding Zhifan (2020)[1] believes that the digital economy can not only broaden factor sources, improve resource allocation efficiency, adjust industrial structure, and drive transformation and upgrading; but also rely on the positive external effects of scientific and technological progress, improve total factor productivity, expand output, and increase quality and speed for economic development. Zhang Hui et al. (2019)[2] believe that the digital economy will definitely become the most important engine to drive global economic development after the economic transformation in the new era, and countries all over the world are making efforts, and China needs to seize the opportunity to occupy the strategic high point.

The importance of the digital economy is growing in the course of China's economic development. However, due to the expanding influence of this emerging field and the high integration of production factors and their outputs with other fields, no consistent standard has been established worldwide today for evaluating the scope of accounting for the development level of the digital economy. Among the existing studies, Wenrui Yang et al. (2021)[3] combined the background of the pre- and post-epidemic era, used the entropy value method and TOPSIS method to conduct a cluster analysis of the current economic situation of each province in China, and then applied the PLS path model to study the relationship between each indicator and the development level of the digital economy, and concluded that the regional economic background and human capital accumulation greatly affect the digital economy in different regions from both direct and indirect aspects, respectively The development level of digital economy in different regions is greatly influenced by regional economic background and human capital accumulation, respectively. Wang Jun et al. (2021) [4] applied the panel data of each province in China from 2013-2018 and conducted empirical analysis by the natural discontinuity point grading method and the Thiel index, and found that there is a bottleneck of insufficient non-development of China's digital economy, which is mainly manifested by the fact that the economic development level of inland and western regions lags far behind that of coastal and eastern regions, and it is necessary to clarify regional heterogeneity and

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optimize resource allocation in the future In the future, we need to clarify regional heterogeneity and optimize resource allocation in order to promote the synergistic development of digital economy in various regions of China in the future.

Out of our government's intention to attach great importance to and vigorously promote the digital economy, this paper, based on the needs of China's economic development and realistic data indicators, analyzes three aspects of infrastructure construction, research and innovation capacity, and the current state of economic development based on factor analysis, and establishes a set of evaluation system dedicated to promoting a more scientific and objective study of the digital economy in the future and promoting the vigorous development of the digital economy.

2. The construction of digital economy evaluation index system

Considering that the establishment of evaluation index system should follow a series of principles such as systematic, modular, intuitive and quantifiable, on the basis of guaranteeing the accuracy and feasibility of the evaluation system, we try to retain all the main indicators of digital economy development, which can scientifically and objectively evaluate the current situation of digital economy development in various places.

In constructing the evaluation index system, this paper fully studied the published literature of many scholars at home and abroad, and summarized that the existing research generally extends around six dimensions: information construction, human resources, economic background, innovation capability, government support, and market supervision. Therefore, based on the objective reality and future goals of China's digital economy development, 3 primary indicators and 11 corresponding secondary indicators of infrastructure construction, research and innovation capability and current economic development are established, as shown in Table 1.

Infrastructure construction: Infrastructure construction is the basic condition for the development of digital economy. In recent years, China has vigorously developed a new type of infrastructure with information network construction as the core. Specifically, it includes promoting the synergistic development of the national backbone network and the network of towns and cities in various regions, improving the quality and speed of the gigabit optical network, building a national high-quality comprehensive three-dimensional transportation network, realizing the all-round coverage of the country's major cities, political centers, economic centers, major ports, important industrial and energy production bases and scenic spots, and meeting the country's economic, political, social, homeland and security needs. Promote the commercialization and large-scale application of the new generation of mobile communication networks. Develop a ubiquitous and collaborative Internet of things. Because only by widening the coverage and guaranteeing the stability of information network and comprehensive three-dimensional transportation network can we improve the operational efficiency of digital economy and promote integration and empowerment. In this paper, three indicators, cargo turnover (X1), cell phone penetration rate (X2), and mobile Internet access traffic (X3), are selected to quantify the hardware facilities supporting the development of China's digital economy.

Research and innovation capacity: insisting on innovation leading is the basic principle of digital economy development. Along with the demand for high-quality and sustainable development of China's economy, and the new crown epidemic has led to the continuous decline of China's economic growth rate and the economy has entered into recession, how to get through the recession and prompt an early economic rebound is a problem that must be overcome at this stage of China's economic development, so improving total factor productivity is the fundamental way to lead the transformation of the economic development mode [5]. And at this stage, the digital economy is rising in the global economic activities, and China, as one of the world's economic powerhouses, should keep developing new technologies and asking new questions, so that scientific research and innovation can become the source and driving force of economic growth. In this paper, we choose the number of domestic invention patent applications granted (X4), national financial education expenditure (X5), national financial education expenditure as an indicator (X6), and the number of people employed in urban units of scientific research, software, and information service industry (X7) to quantify the potential innovation capacity that can be brought about by the development results of national scientific research and innovation and the importance the country attaches to scientific research and education.

Current economic development: Removing infrastructure and research and innovation are important carriers and core elements for the development of the digital economy, and the external environment of the economy and society also plays a crucial role in the development of the digital economy. To a certain extent, the development trend of the digital economy can be inferred from the prosperity or decline of the external economic environment. Therefore, we should pay attention to its dynamics as well as not ignore the role of the external environment. In this paper, we describe the current economic development from the following perspectives: the proportion of enterprises with e-commerce transaction activities (X8), per capita GDP (X9), per capita consumption expenditure of all residents (X10), and total retail sales of consumer goods (X11), and analyze the current strengths and weaknesses of the digital economy in each province through the current state of society.

Table1: Digital economy evaluation index system

First level Indicators	Secondary indicators	Indicator Type
Infrastructure Development	Cargo turnover (X1)	Positive
	Cell phone penetration rate (X2)	Positive
	Mobile Internet access traffic (X3)	Positive
Research and Innovation Capability	Number of domestic invention patent applications granted (X4)	Positive
	National financial resources for education (X5)	Positive
	Local financial science and technology expenditure (X6)	Positive
	Research, software, and information services urban units employed (X7)	Positive
Current Economic Development	The proportion of the number of enterprises with e-commerce transaction activities (X8)	Positive
	GDP per capita (X9)	Positive
	Per capita consumption expenditure of all residents (X10)	Positive
	Total retail sales of social consumer goods (X11)	Positive

3. Empirical Analysis

3.1. Data pre-processing

3.1.1. Data source and sample selection

Based on the consideration of data authenticity and reliability of data sources, the data selected in this paper come from the official website of the National Bureau of Statistics and the database of the Ministry of Industry and Information Technology of China. Considering that the evaluation system needs to guarantee the timeliness of data, and the annual data statistics have a lag, and some provinces are still missing data in 2021, so this paper selects the cross-sectional data of 31 provinces in China in 2020 as the basis for the establishment of the evaluation index system.

3.1.2. Standardization of sample data

Because it is impossible to unify the units of each evaluation index, it is necessary to standardize the data. In this paper, we choose the MIN-MAX standardization method to linearly transform the original data to ensure that all data fall into the [0,1] interval. Since the indicators selected in this paper are all positive indicators, i.e., the larger the value of the indicators, the better the benefit, the higher the evaluation, so the positive indicator standardization formula is.

$$X_{ij}{}' = \frac{X_{ij}-\min(X_{ij}\cdots X_{ij})}{\max(X_{ij}\cdots X_{ij})-\min(X_{ij}\cdots X_{ij})} \tag{1}$$

where i denotes the province and j denotes the indicator.X_{ij} denotes the original data of the ith evaluation object and the jth indicator.$X_{ij}{}'$ denotes the value of the i-th evaluation object, j-th indicator data after standardization.$\max(X_{ij}\cdots X_{ij})$ and$\min(X_{ij}\cdots X_{ij})$ are the maximum and minimum values of each indicator, respectively.

3.2. Analysis of digital economy evaluation by provinces in China

3.2.1. KMO test and Bartlett's test

Because the basic idea of factor analysis is a multivariate statistical method to group some variables with complexity and repetitiveness and to study them by a few composite factors that can retain the vast

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majority of information. Therefore, before applying this method, KMO test and Bartlett's test need to be performed on the data. The KMO value is used to determine whether the group of data is suitable for the factor analysis method. For the KMO value y the following judgment should be followed.

$$= \begin{cases} Very\ suitable，KMO > 0.9 \\ Suitable，0.7 < KMO < 0.9 \\ Fair，0.6 < KMO < 0.7 \\ Poor，0.5 < KMO < 0.6 \\ Give\ up，KMO < 0.5 \end{cases} \quad (2)$$

By Bartlett's test, if P<0.05, the original hypothesis is not rejected, i.e., it is suitable for using factor analysis; if P>005, the original hypothesis cannot be rejected, i.e., it is not suitable for factor analysis. The results of this paper for the data of 31 provinces in China in 2020 are shown in Table 2: the KMO value is 0.776, Bartlett test P=0.000<0.05, which means that this group of data is suitable for using factor analysis method.

Table2: KMO test and Bartlett's test

KMO test and Bartlett's test			Test result determination basis	Results
KMO value		0.776	KAISER Inspection Standards	Apply factor analysis method
Bartlett's sphericity test	Approximate cardinality	502.493	Less than significant level 0.05	
	df	55		
	P	0.000***		

Note: ***, **, * represent 1%, 5%, 10% significance levels, respectively

3.2.2. Determination of the number of common factors

As shown in Table 3, the first three factors can cumulatively explain 91.857% of the total variance, which can fully explain the 11 original indicators with corresponding eigenvalues of 6.827, 2.352, and 0.925. In summary, the first 3 factors are selected as public factors in this paper, which can thus more adequately reflect the current stage of China's digital economy development level.

Table3: Total variance explained

Total variance explained						
Ingredients	Explanation of variance before rotation			Explanation of variance after rotation		
	Feature Root	Explanation of variance (%)	Cumulative variance explained (%)	Feature Root	Explanation of variance (%)	Cumulative variance explained (%)
1	6.827	62.062	62.062	484.308	44.028	44.028
2	2.352	21.386	83.448	395.033	35.912	79.94
3	0.925	8.409	91.857	131.085	11.917	91.857
4	0.339	3.085	94.942			
5	0.236	2.146	97.088			
6	0.147	1.338	98.426			
7	0.071	0.642	99.068			
8	0.050	0.456	99.524			
9	0.025	0.225	99.749			
10	0.017	0.155	99.904			
11	0.011	0.096	100			

3.2.3. Factor loading factor

The rotated factor loading coefficient table is shown in Table 4. It can be seen that the four indicators of the dimension of scientific research and innovation capability, national financial education expenditure, local financial science and technology expenditure, domestic invention patent applications granted, and the number of employed persons in urban units of scientific research, software and information service industries are well reflected in factor 1, so factor 1 is named scientific research and

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innovation factor; the information source of factor 2 is more focused on the The information of factor 2 is more focused on the infrastructure construction dimension, so factor 2 is named infrastructure factor; the information of factor 3 is mainly from the proportion of enterprises with e-commerce transaction activities, so factor 3 is named economic development factor.

Table4: Table of factor loading coefficients after rotation

Table of factor loading coefficients after rotation			
Name	Factor loading coefficients after rotation		
	Factor 1	Factor 2	Factor 3
National financial resources for education X5	0.98		
Mobile Internet access traffic X3	0.972		
Total retail sales of social consumer goods X11	0.938		
Local financial science and technology expenditure X6	0.86		
Number of domestic invention patent applications granted X4	0.711		
Cell phone penetration rate X2		0.941	
Per capita consumption expenditure of all residents X10		0.939	
GDP per capita X9		0.89	
Cargo turnover X1	0.621	0.563	
Research, software, information service industry urban units employed X7	0.551	0.667	
Share of the number of enterprises with e-commerce transaction activities X8			0.861

3.2.4. Public factor values by province

Using the common factor to replace the original variables, which are the original variables realized in linear combination form, the following factor score functions can be obtained for 2020.

F1=0.091*X1-0.007*X2+0.142*X3+0.104*X4+0.144*X5+0.126*X6+0.081*X7+0.023*X8+0.03*X9+0.034*X10+0.137*X11

F2=0.239*X1+0.4*X2-0.019*X3+0.228*X4+0.035*X5+0.179*X6+0.284*X7+0.149*X8+0.378*X9+0.399*X10+0.079*X11

F3=-0.427*X1+0.129*X2+0.051*X3+0.398*X4+0.076*X5+0.143*X6+0.403*X7+0.931*X8+0.277*X9+0.153*X10+0.127*X11

3.2.5. Establishment of comprehensive evaluation model

In order to quantify the contribution size of the three public factors, this paper establishes a comprehensive evaluation model of digital economy development level for each province by using the proportion of the variance contribution of the public factors to the cumulative variance contribution as weights.

$$F = \frac{\sum W_i F_i}{\sum W_i} \quad (3)$$

Where F is the comprehensive score of digital economy of each province, Fi is the ith public factor, and Wi is the variance contribution rate of the ith public factor. By substituting the variance contribution rate of the first three public factors in Table 3 into formula (3), we can obtain the predicted factor scores of the digital economy and the comprehensive score of the green economy of each province in China in 2020, and the final results are shown in Table 5.

$$F = \frac{44.028*F_1+35.912*F_2+11.917*F_3}{44.028+35.912+11.917} \quad (4)$$

From the final results, it can be seen that the three provinces with the highest overall scores in China's digital economy in 2020 based on the factor analysis method are Beijing, Guangdong Province, and Shanghai; the three provinces with the lowest overall scores are Ningxia Hui Autonomous Region, Gansu Province, and Tibet Autonomous Region. From the perspective of public factor scores, Beijing has the highest score in infrastructure factor and economic development factor among provinces; Guangdong Province has the highest score in research and innovation factor among provinces, and the infrastructure factor and economic development factor also rank in the top 3 in China; however, both

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Beijing and Shanghai have relatively low research and innovation factors, which means that the development of digital economy in Beijing and Shanghai mainly relies on physical foundation and economic environment. The three provinces with the lowest public factors are different, and a total of eight provinces have entered the last three scores, and most of them come from the northwest of China, which means that at this stage, China's digital economy development is not fully developed. This means that the problem of inadequate development of China's digital economy cannot be ignored, and the development of the national digital economy requires the concerted efforts of all provinces to form a development pattern of linkage between land and sea, and mutual assistance between east and west. In summary, regions with high digital economy scores perform better in all three dimensions, and the synergistic development of infrastructure, scientific research and environment can promote the maximum use of resources and drive the flourishing of digital economy.

Table5: Combined scores and rankings of digital economy by province based on factor analysis

Province	F_1	F_2	F_3	F	Ranking
Beijing	0.4206	1.8801	2.3651	1.2434	1
Guangdong	0.8286	1.4956	1.6742	1.1991	2
Shanghai	0.3944	1.7429	1.3124	1.0407	3
Jiangsu	0.5463	1.1254	1.2524	0.8643	4
Zhejiang	0.4761	1.1765	1.2829	0.8546	5
Shandong	0.4025	0.7160	0.9862	0.6008	6
Fujian	0.2335	0.7326	0.8049	0.5028	7
Anhui	0.2924	0.5585	0.8460	0.4683	8
Sichuan	0.2979	0.5333	0.8369	0.4599	9
Hubei	0.2559	0.5349	0.7470	0.4287	10
Henan	0.3213	0.4293	0.5010	0.3868	11
Chongqing	0.1583	0.5323	0.7572	0.3822	12
Hunan	0.2366	0.4564	0.6506	0.3762	13
Tianjin	0.1027	0.6607	0.4502	0.3659	14
Shaanxi	0.1651	0.4651	0.6577	0.3463	15
Hebei	0.2352	0.4397	0.4071	0.3375	16
Liaoning	0.1411	0.4248	0.3060	0.2734	17
Jiangxi	0.1679	0.3146	0.4751	0.2651	18
Yunnan	0.1635	0.2967	0.5323	0.2634	19
Inner Mongolia	0.0932	0.4294	0.3022	0.2518	20
Hainan	0.0525	0.3560	0.5824	0.2399	21
Guangxi	0.1488	0.2801	0.4288	0.2364	22
Guizhou	0.1440	0.2435	0.4404	0.2213	23
Shanxi	0.1087	0.3016	0.2326	0.2002	24
Jilin	0.0683	0.2930	0.1739	0.1698	25
Heilongjiang	0.0755	0.2816	0.1741	0.1689	26
Xinjiang	0.0845	0.2443	0.1886	0.1605	27
Qinghai	0.0221	0.2607	0.3562	0.1587	28
Ningxia	0.0234	0.2780	0.2964	0.1584	29
Gansu	0.0745	0.2021	0.2824	0.1514	30
Tibet	0.0121	0.0839	0.2573	0.0720	31

4. Conclusion

Through the scores of each public factor, it can be found that the scores of scientific research and innovation factor are generally lower than those of infrastructure factor and economic development factor, and our government needs to pay further attention to scientific research and innovation for the development of digital economy, increase the investment of scientific research funds, seek the well-being of science and innovation practitioners, attract talents to the software and information industry, drive the growth of the hard power of our scientific research and innovation through the rise of the number of employed people, and improve the total factor productivity, and achieve high-quality and sustainable development of the digital economy. At the same time, China's current geographical imbalance and inadequate development still exists, whether it is scientific research and innovation or infrastructure construction, which has led to a large gap in the development of the digital economy. In the face of the gap, China needs to strengthen cross-regional cooperation and promote the flow of resources from the

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eastern coastal areas to the western inland areas to narrow the development gap and achieve synergistic development. Therefore, provinces need to combine the actual development situation to identify problems, formulate policies to make up for shortcomings, optimize resource allocation, improve the development of the digital economy, and help China's digital economy to flourish.

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