# Evaluation of Digital Economy Development Level in Hunan Province Based on Entropy Weight -TOPSIS Method

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*Abstract: This paper constructs a comprehensive evaluation index system of Hunan's digital economy development from four dimensions: digital infrastructure construction, digital industrialization development, industrial digitization development and innovation ability. The entropy weight method was used to calculate the weights of 18 proposed secondary indicators, and TOPSIS method was used to comprehensively evaluate the digital economy development level of Hunan Province from 2017 to 2021. The results show that the development level of digital economy in Hunan Province is increasing year by year, and the growth rate is obvious, but the growth rate has slowed down in the later period. Finally, based on the comprehensive evaluation results, the paper proposes to lay out "new infrastructure" from three aspects: infrastructure construction, industrial digital development and innovation ability, accelerate the construction of digital economic infrastructure and promote industrial digital transformation, building digital industrial clusters, increasing digital talent reserves and other targeted development strategies to promote Hunan's digital economy development level to a new height.*

*Keywords: Digital economy; Entropy weight TOPSIS method; Hunan Province*

## 1. Introduction

Digital economy, as a new economic form following traditional economies such as agricultural economy and industrial economy, is the main engine and new driving force for sustained economic growth. China will comprehensively and efficiently promote the development of the digital economy as a national strategy, and in 2021, the state clearly stated that it will accelerate the development of the digital economy and create new advantages of the digital economy. At this point, the development of digital economy has been mentioned to an unprecedented height.

At present, Hunan Province attaches great importance to the development of digital economy. Since 2018, Hunan Province has successively issued more than ten documents related to the digital economy, in order to give strong policy support and guarantee for the development of the digital economy in Hunan Province. "Accelerate the development of the digital economy and strive to increase the added value of the digital economy by 15%" is clearly written into the "2020 Hunan Provincial Government Work Report". In the "China Digital Economy Development Index Report" published in 2022, the digital economy development of 31 provinces (municipalities and districts) was comprehensively evaluated, and the analysis results showed that the industrial digital development level of Hunan Province grew faster. Hunan Province's industrial digitalization index increased by 1.70 times from 2013 to 2021, benefiting from policy support and government attention. The strength of Hunan's digital economy has been greatly improved, the level of digital industrialization and industrial digitalization is in a leading position in China, and the capacity of digital infrastructure has been fully enhanced. In 2020, Hunan Province issued a digital economy development plan for the next five years, proposing that the scale of Hunan's digital economy should exceed 2.5 trillion yuan by 2025. Therefore, the evaluation and analysis of the development level of digital economy in Hunan Province can provide a basis for the development planning of Hunan Province.

In terms of the construction of the evaluation system for the development level of digital economy, the Shanghai Academy of Social Sciences has studied the development of digital economy from a global perspective, specifically from four aspects: digital facilities, digital industry, digital innovation and digital governance.[1] Xinhua News Agency Digital Economy Research Institute put forward the urban digital economy indicator system, from the four perspectives of infrastructure, industrial integration,

urban services and governance to study urban digital economy. The "China Digital Economy Development Index Report" released by the Ministry of Industry and Information Technology in 2022 selected five indicators that affect the development of digital economy, including digital industrialization, industrial digitalization, digital infrastructure, digital technology and talent, and carried out a comprehensive evaluation of the digital economy in 31 provinces (municipalities and districts) across the country.[2] The China Digital Economy Development Report released by the China Academy of Information and Communications Technology in 2022 proposes to build China's digital economy indicator system from four dimensions: industrial digitalization, digital industrialization, digital governance and data value, and constantly improve the digitalization, networking and intelligence level of the economy and society. Wenjing Zhai and Xuejun Xu[3] constructed an evaluation index system for the development level of Zhejiang's digital economy from four aspects: digital infrastructure level, digital development environment, digital industrialization level and digital innovation ability. Chong Yuan[4] constructed an evaluation index system for the development level of digital economy in Jiangsu Province from four aspects: Internet facilities, communication facilities, industrial development and creative ability. Li Yan and Huang Rui[5] selected 21 indicators from the five aspects of digital infrastructure construction, digital people's livelihood, digital government, industrial digitalization and digital industrialization to build an evaluation index system for the development of Qingdao's digital economy. As shown in Table 1.

On the whole, the existing digital economy evaluation index system is mainly used to evaluate the national or provincial digital economy development status. For example, Meiling Zhang and Jun Liu[6] analyzed the development level of digital economy in Anhui Province, Xinhuan Huang and Linan Chen[7] also made a comprehensive evaluation of the development level of digital economy in Fujian Province. Based on this, this paper takes Hunan Province as an example and draws on existing studies to build a reasonable evaluation index system for the development level of digital economy. 2017-2021 is selected as the sample interval of the study, and the entropy weight method is used to calculate the weights of the proposed 18 secondary indicators. TOPSIS method was used to comprehensively evaluate the development level of digital economy in Hunan Province from 2017 to 2021, and targeted strategies were proposed for the development of digital economy in Hunan Province according to the final evaluation results.

*Table 1: Construction of domestic digital economy index system*

| Indicator source | Primary index |
| --- | --- |
| Shanghai Academy of Social Sciences | Digital facility; Digital industry; Digital innovation; Digital governance |
| Xinhua Digital Economy Research Institute | Infrastructure; Industrial convergence; Urban services and governance |
| China Digital Economy Development Index Report | Digital industrialization; Industrial digitization; Digital infrastructure; Digital technology and talent |
| China Digital Economy Development Report | Digital industrialization; Industrial digitization; Digital governance; Data value |
| Xiaoyu Wang, Hua Xu[8] | Digital infrastructure; Digital industrialization level; Digital innovation ability |

## 2. Construction and Evaluation Method of Digital Economy Evaluation Index System

### 2.1. Determination of Digital Economy Indicators

Starting from the connotation of digital economy, this paper focuses on the research of digital economy development conditions, industrial application and innovation guarantee, comprehensively considers the existing digital economy research at home and abroad and other provinces in China, according to the principles of comprehensive index selection and data availability, and combined with the actual development of digital economy in Hunan Province. In this paper, an all-round digital economy development index system suitable for Hunan province is constructed. The digital economy evaluation index system of Hunan Province is mainly constructed from a total of 18 secondary indexes in four dimensions: digital infrastructure construction, digital industry development, industrial digital development and innovation ability. As shown in Table 2.

*Table 2: Hunan Province digital economy development level index system*

| Primary indicators | Secondary indicators | Unit | Indicators attribute |
|---|---|---|---|
| Digital infrastructure development (M1) | Mobile Internet users (X1) | Ten thousand | Positive |
| | Mobile phone base station (X2) | individual | Positive |
| | Number of 5G sites (X3) | Ten thousand | Positive |
| | Number of Internet broadband access users (X4) | Ten thousand | Positive |
| | Optical cable line length (X5) | kilometre | Positive |
| Digital industry development (M2) | Digital industrialization scal (X6) | Hundred million yuan | Positive |
| | Number of legal entities in information transport, software and information technology services (X7) | individual | Positive |
| | Total volume of telecommunication service (X8) | Hundred million yuan | Positive |
| | Software revenue (X9) | Hundred million yuan | Positive |
| | Output value scale of software mobile Internet industry in the park (X10) | Hundred million yuan | Positive |
| | Number of investment Internet projects (X11) | number | Positive |
| Industrial digital development (M3) | Number of investment Internet projects (X12) | Hundred million yuan | Positive |
| | E-commerce transaction volume (X13) | Hundred million yuan | Positive |
| | Proportion of e-commerce transactions in GDP (X14) | % | Positive |
| | Number of industrial Internet apps (X15) | individual | Positive |
| Innovation energy (M4) | Number of patent applications (R&D output) (X16) | individual | Positive |
| | Technical research and development personnel accounted for the proportion of employees (X17) | % | Positive |
| | The average salary in the information industry (X18) | yuan | Positive |

## 2.2. Indicator Data Source and Data Processing

According to the digital economy evaluation index system of Hunan Province established above, the official website of the National Bureau of Statistics, China Information Yearbook, Hunan Statistical Yearbook and Hunan mobile Internet industry development Report were extensively consulted. In this paper, Hunan Province from 2017 to 2021 was selected as the sample interval of the study.

After data collection, interpolation method is used to supplement individual missing data scientifically to ensure data integrity.

## 2.3. Measurement Method

### 2.3.1. Entropy Weight Method

The development level of digital economy in Hunan Province includes 18 indicators. In order to ensure more reliable and effective evaluation results of indicators, this paper uses entropy weight method to measure the weight of each indicator to evaluate the development level of digital economy in Hunan Province.

Entropy weight method belongs to the category of objective weighting methods. The specific steps are as follows:

Dimensionless processing is carried out for each original index in the index system, and its formula is as follows:

$$\text{Positive indicators:} X_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \tag{1}$$

$$\text{Negative indicator:} X_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)} \tag{2}$$

Among them, i represents the year, $i \in \{1,2,\dots,5\}$, j represents the number of indicators, $j \in \{1,2,\dots,18\}$.

After standardized treatment, calculate the weight of the index value in year i under the j index $P_{ij}$:

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} (j=1,2,\dots,m) \tag{3}$$

Getting the specific gravity $P_{ij}$, the information entropy of each index can be calculated. The information entropy $e_j$ of the j index is calculated by the following formula.

$$e_j = -k \sum_{i=1}^{n} P_{ij} \ln P_{ij} \tag{4}$$

Among them, $k = 1/\ln n$, It satisfies e>0.

The weight of the j index is obtained by normalizing the j index. Of which, the coefficient of difference is $g_i = 1 - e_j$, The weight of the j index is as follows:

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \tag{5}$$

### 2.3.2. TOPSIS Method

TOPSIS method is an approach to the ideal solution ranking method, its basic principle is to order the solution according to the distance between the solution to be selected and the positive ideal solution (the best solution) and the negative ideal solution (the worst solution).

The specific steps of TOPSIS method are as follows:

(1) The canonical decision matrix is obtained by using vector canonical method

Let the decision matrix of the multi-attribute decision problem is $Y = \{y_{ij}\}$, the normalized decision matrix is $Z = \{z_{ij}\}$, Then there is

$$z_{ij} = Y'_{ij} / \sqrt{\sum_{i=1}^{m} y_{ij}^2}, \text{ i=1,2,\dots,m, j=1,2,\dots n;} \tag{6}$$

(2) Create a weighted gauge matrix $X = \{x_{ij}\}$

$$\omega = (w_1, w_2 \dots, w_n)^T, \ x_{ij} = w_j * z_{ij}, \text{ i=1,2,\dots,m, j=1,2,\dots n;} \tag{7}$$

(3) Determine the ideal solution $x^*$ and the negative ideal solution $x^0$:

$$x^* = \{x_1^*, x_2^*, \dots, x_m^*\} = \{(\max(x_{\theta ij} | j \in J_1), \min(x_{\theta ij} | j \in J_2) | 1 \leq \theta \leq y, 1 \leq i \leq n,)\} \tag{8}$$

$$x^0 = \{x_1^0, x_2^0, \dots, x_m^0\} = \{(\min(x_{\theta ij} | j \in J_1), \max(x_{\theta ij} | j \in J_2) | 1 \leq \theta \leq y, 1 \leq i \leq n,)\} \tag{9}$$

(4) Calculate the distance $d_i^*$ of the evaluation object to the ideal solution $x^*$ and the distance $d_i^0$ of the negative ideal solution $x^0$:

$$d_i^* = \sqrt{\sum_{\theta=1}^{y} \sum_{j=1}^{m} \left(w_j (x_{\theta ij} - x^*)\right)^2}, \text{i=1,2,\dots,n} \tag{10}$$

$$d_i^0 = \sqrt{\sum_{\theta=1}^{y} \sum_{j=1}^{m} \left(w_j (x_{\theta ij} - x^0)\right)^2}, \text{i=1,2,\dots,n} \tag{11}$$

(5) Calculate the relative proximity of each evaluation object (i.e. comprehensive evaluation index) $C_i^*$;

$$C_i^* = \frac{d_i^0}{d_i^* + d_i^0}, \text{ i=1,2,\dots,n} \tag{12}$$

According to equations 6 to 12, the relative closeness of each evaluation object can be obtained, that is, the final evaluation result, which ranges from 0 to 1, and the larger the value, the higher the level of digital economy development.

## 3. Evaluation Results and Analysis of Digital Economy Development Level in Hunan Province

### 3.1. Weight Calculation Result

By using the entropy weight method to measure the weights of various indicators of the development level of digital economy, this paper can obtain the weight results of each first-level indicator and second-level indicator, as shown in Table 3.

*Table 3: Hunan Province digital economy development level index weight*

| Primary indicators | First-order indicator weight | Secondary indicators | Secondary indicator weight |
|---|---|---|---|
| Digital infrastructure development (M1) | 0.3970 | Mobile Internet users (X1) | 0.0012 |
| | | Mobile phone base station (X2) | 0.0108 |
| | | Number of 5G sites (X3) | 0.3798 |
| | | Number of Internet broadband access users (X4) | 0.0048 |
| | | Optical cable line length (X5) | 0.0004 |
| Digital industry development (M2) | 0.1850 | Digital industrialization scal (X6) | 0.05.2 |
| | | Number of legal entities in information transport, software and information technology services (X7) | 0.0139 |
| | | Total volume of telecommunication service (X8) | 0.0684 |
| | | Software revenue (X9) | 0.0103 |
| | | Output value scale of software mobile Internet industry in the park (X10) | 0.0042 |
| | | Number of investment Internet projects (X11) | 0.0380 |
| Industrial digital development (M3) | 0.2896 | Number of investment Internet projects (X12) | 0.0139 |
| | | E-commerce transaction volume (X13) | 0.0163 |
| | | Proportion of e-commerce transactions in GDP (X14) | 0.0063 |
| | | Number of industrial Internet apps (X15) | 0.2531 |
| Innovation energy (M4) | 0.1284 | Number of patent applications (R&D output) (X16) | 0.1105 |
| | | Technical research and development personnel accounted for the proportion of employees (X17) | 0.0146 |
| | | The average salary in the information industry (X18) | 0.0033 |

Comparing the weights of the four first-level indicators, it is found that the largest contribution to the development of digital economy in Hunan Province is the construction of digital infrastructure, which accounts for 39.70% of the weight, of which the number of 5G stations has the largest weight, accounting for 37.98%. In order to improve the level of digital economy development in Hunan Province, the key is to promote the construction and popularization of digital infrastructure in Hunan Province, such as the construction of 5G stations and mobile phone base stations.

Secondly, the weight of industrial digital development is 28.96%, of which the number of industrial Internet apps accounts for the largest weight. It can be seen that enterprises in Hunan Province should build and apply industrial Internet platforms, and use big data, Internet and other means to promote high-quality economic development in Hunan Province. This is the key to improve the level of digital economy development in Hunan Province.

In addition, the weight of innovation ability is 12.84%. Among them, the weight of the number of patent applications accounted for 11.05%. Therefore, Hunan Province should increase investment in R&D funds, cultivate and attract multi-level Internet composite talents, promote the implementation of Hunan Province's "three high and four new" strategic positioning and mission, and promote the development of Hunan Province's digital economy.

According to the comparative analysis of the weights of first-level indicators, it is found that the

efficiency weakness of Hunan Province in the development of digital economy is innovation ability. In recent years, although Hunan Province has made significant and outstanding achievements in the fields of advanced computing and supercomputers, its core competitiveness in scientific and technological innovation is insufficient, and it has not yet formed a business model that can be implemented on a large-scale, and its innovation ability is insufficient.

### 3.2. Development Level Evaluation Results

Through the above calculation, the weights of the first and second indexes are obtained. TOPSIS method was used to calculate the digital infrastructure construction index (S1), digital industry development index (S2), industrial digital development index (S3), innovation ability index (S4) and digital economy development level index (DE) of Hunan Province from 2017 to 2021. The evaluation results are shown in Table 4.

*Table 4: Evaluation results of digital economy development level in Hunan Province from 2017 to 2021*

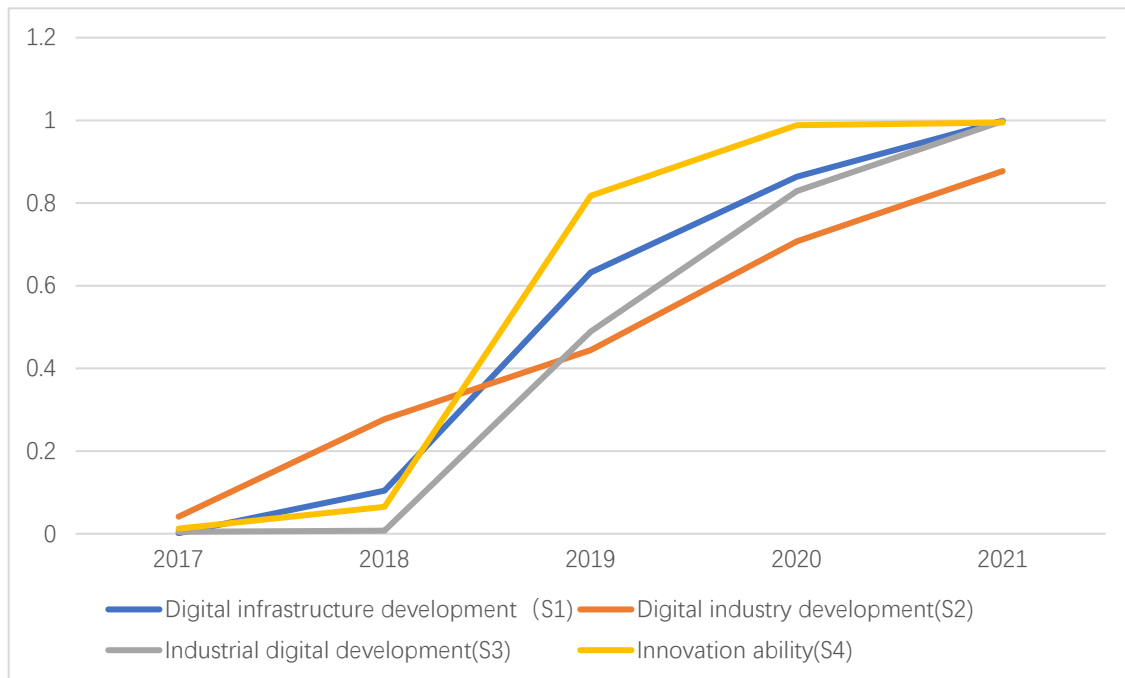| Year | Digital infrastructure development indicators (S1) | Digital industry development indicators (S2) | Industrial digital development indicators (S3) | Innovation ability indicators (S4) | Digital economy development level indicators (DE) | Sort result |
|------|------|------|------|------|------|------|
| 2017 | 0.0014 | 0.0412 | 0.0048 | 0.0124 | 0.0032 | 5 |
| 2018 | 0.1042 | 0.2774 | 0.0074 | 0.0652 | 0.0393 | 4 |
| 2019 | 0.6321 | 0.4442 | 0.4892 | 0.8174 | 0.5024 | 3 |
| 2020 | 0.8634 | 0.7071 | 0.8287 | 0.8983 | 0.8302 | 2 |
| 2021 | 0.9992 | 0.8772 | 0.9982 | 0.9946 | 0.9894 | 1 |



*Figure 1: Hunan Province digital economy development index trend chart*

Table 4 shows the comprehensive evaluation results of Hunan's digital economy development level from 2017 to 2021. As can be seen from Table 4, From 2017 to 2021, Hunan Digital Infrastructure Construction Index (S1), digital Industry Development index (S2), Industrial digital development index (S3), and innovation capability index (S4) are all in an increasing trend year by year, which also makes Hunan digital economy development level index (DE) also in an increasing level year by year. Among them, the sequential growth rate in 2019 was 118.16%, the fastest growth rate, and the sequential growth rate in 2021 was 19.18%, the growth rate slowed down.

As can be seen from Figure 1, the four evaluation indicators of digital infrastructure construction, digital industrialization development, industrial digitalization development and innovation capability of Hunan Province are all on the rise, but in the process of digitalization, the development speed of each

indicator is different. Among them, the growth trend of digital infrastructure construction is the most obvious, with a compound growth rate of 272.14%.

The compound growth rate of innovation capacity is 215.13%, and its weight ratio to the digital economy is 12.84%, and in 2018, the index grew at a rate of 125.37%. The rapid development of innovation ability has stimulated the state and government's economic investment in the development of digital economy in Hunan Province, promoted the rapid development of technological research, and thus promoted the development of digital economy in Hunan Province. The compound growth rate of the development of digital industrialization is only 84.35%, but its weight ratio in the digital economy is 28.96%, second only to the construction of digital infrastructure, to accelerate the digital transformation of the industry in order to better promote the development of digital economy.

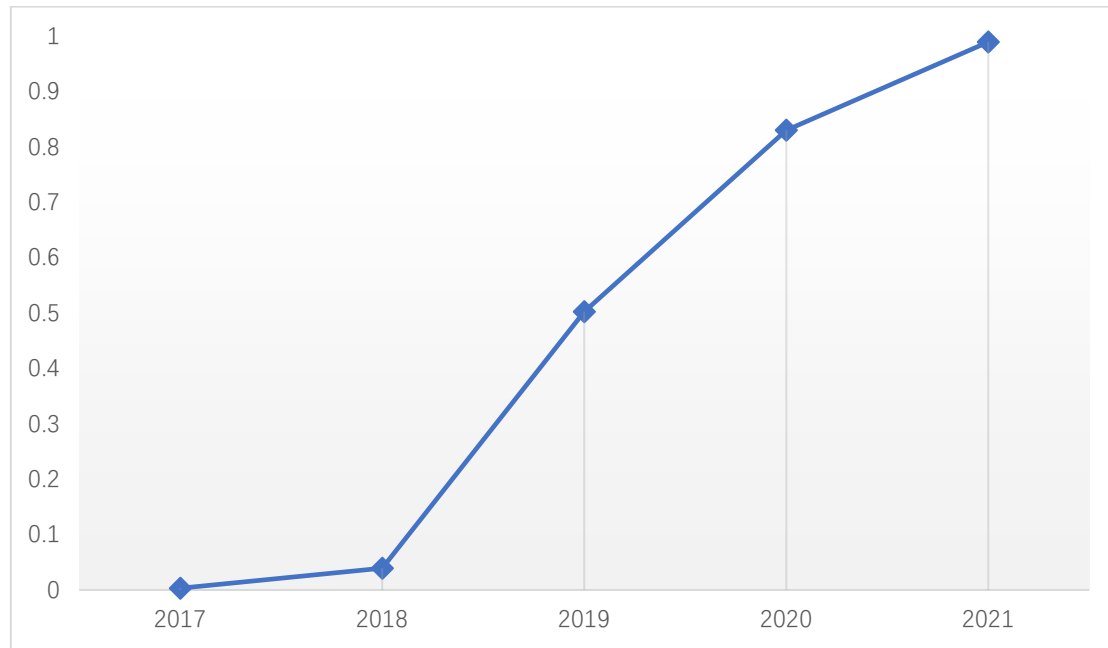### 3.3. Temporal Evolution Analysis of Digital Economy Development Level in Hunan Province



*Figure 2 Temporal evolution characteristics of digital economy development index in Hunan Province*

From the perspective of the evolution of time series, the development level of digital economy in Hunan Province presents the characteristics of increasing year by year (see Figure 2). The digital economy development level of Hunan Province was the lowest in 2017 (0.0032), and the highest in 2021 (0.9894). From 2018 to 2021, the development level of digital economy in Hunan Province has increased significantly, which is mainly related to China's policies and the high attention of the Hunan provincial government. Since 2018, Hunan Province has issued more than 10 documents related to the digital economy, providing strong policy support and guarantee for the development of the digital economy in Hunan Province. Therefore, since 2018, the digital economy construction in Hunan Province has begun to develop rapidly, and the development level of the digital economy has maintained double-digit high-speed growth for three consecutive years. Despite the greater impact of the epidemic, Hunan's digital economy still shows strong resilience and achieves "contrarian growth".

At present, the development of digital economy in Hunan Province is in an important window period, with good development momentum and outstanding potential advantages. Hunan Province is committed to the research of intelligent economy, promoting the research of big data, blockchain, digital twins, etc., and promoting the continuous rise of the level of digital economy. Hunan Province has national innovation platforms such as the National Supercomputing Changsha Center and the National Innovation Key Laboratory of High-Performance Computing. The newly established Xiangjiang Laboratory has created a super engine to enhance the computing power of Hunan Province. Based on this, it is expected that the development level of digital economy in Hunan Province will be steadily improved in the future, and the future development space of digital economy in Hunan Province is broad.

## 4. Summaries and Suggestions

Through the four dimensions of digital infrastructure construction, digital industry development, industrial digital development and innovation ability, and 18 secondary indexes, the digital economy evaluation index system of Hunan Province is constructed, and the entropy weight method and TOPSIS method are used to comprehensively evaluate the digital economy development level of Hunan Province from 2017 to 2021, and the evaluation results are analyzed. The following conclusions are drawn:

(1) On the whole, the development level of digital economy in Hunan Province shows an increasing trend year by year, and Hunan Province is actively promoting the development of digital economy. Especially in 2018, the growth rate of Hunan's digital economy is the most obvious, which is closely related to Hunan's digital economy development policy, but after 2020, the growth rate has slowed down.

(2) From the perspective of various evaluation indicators, the four evaluation indicators of digital infrastructure construction, digital industrialization development, industrial digitization development and innovation ability in Hunan Province have different weights in the digital economy. Although the development level of these four evaluation indicators is constantly improving, their development speed is different in the process of digitalization.

Based on the above analysis, based on the three aspects of digital infrastructure construction, industrial digital development and innovation ability, this paper puts forward the following three suggestions for improving the development level of digital economy in Hunan Province:

### 4.1. Lay out "New Infrastructure" and Speed up Infrastructure Construction

The digital "new infrastructure" has provided strong support for the development of the digital economy, and the new infrastructure has become an important engine for stable investment, promoting development and improving people's lives. The layout of the "new infrastructure" should focus on promoting the new generation of communication network infrastructure with 5G technology, industrial Internet and Internet of things as the core, expand the scope of optical cable laying, and promote the extension of 5G base stations in Hunan Province to rural and remote areas. Hunan Province should adhere to the "four computing in one" layout, promote the intelligent upgrading of computing facilities such as the National Supercomputing Changsha Center, build a new type of data center, and build a national advanced computing hub and an international leading algorithm innovation center. Efforts will be made to promote the construction of a number of national-level major innovation platforms in the field of artificial intelligence in Hunan Province, lay out the construction of national key laboratories, transform the municipal infrastructure of intelligent cities, promote industrial upgrading, improve people's livelihood and social governance, and vigorously promote the development and construction of blockchain industrial parks.

### 4.2. Promote Industrial Digital Transformation and Build Digital Industrial Clusters

Hunan Province needs to promote industrial digitalization, build and promote industrial Internet platforms, create industry-level and region-level industrial Internet platforms, introduce and cultivate a number of influential enterprises in the industry, comprehensively promote industrial digital transformation, guide the development of industrial "digital + network + intelligent", and accelerate the intelligent and digital transformation of industrial parks. We will promote the rapid development of new business forms such as smart transportation and digital finance, and improve high-quality and diversified digital life services. We will further promote the research and development and application of big data and artificial intelligence, foster a new generation of emerging industrial clusters focusing on electronic information, new materials and construction machinery, and develop and strengthen the digital economy.

### 4.3. Increase the Pool of Digital Talents and Enhance the Ability to Innovate

Scientific and technological talent is a new driving force for scientific and technological innovation, and a strong support for promoting high-quality development. Hunan Province, as a major education province, has 125 colleges and military colleges and universities, and rich supply of human resources. It is necessary to give full play to the talent advantages of Hunan Province, increase the discovery and cultivation of innovative talents, establish and improve the training system of scientific and technological talents, and increase the reserve of digital talents. At the same time, it is also necessary to guide students to conduct independent research and development and transformation of results through holding various

forms of college student entrepreneurship plan competitions and makerspace construction activities, and cultivate a group of young talents with innovative ability. Hunan Province should also actively organize and carry out various competitions such as new information consumption competition and industrial APP, encourage industry associations and leading enterprises to organize special technical training, and give full play to the advantages of technological innovation in universities and scientific research institutes.

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