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Assessing the Development Level of Wuhan's Digital Economy: Key Indicators and Insights

Weixue Han*
Faculty of Materials Science and Technology
Technical University of Ostrava
Ostrava, Czech Republic
weixue.han.st@vsb.cz

Kamila Janovska
Faculty of Materials Science and Technology
Technical University of Ostrava
Ostrava, Czech Republic
kamila.janovska@vsb.cz

Wenlong Yao
Hubei Circular Economy Development Research Center
Wuhan, Hubei Province, China
marcoe@163.com

Abstract

The purpose of this study is to measure the development level of digital economy in Wuhan China from 2013 to 2022 by using entropy value method. The indicator system is constructed from three aspects: infrastructure construction, science and technology innovation level and digital industry development. The following conclusions are drawn from the study: firstly, the digital economy of Wuhan has developed rapidly, scores growing from 14.273 to 79.955 in ten years. Especially in 2016 and 2017, the growth rate reached the highest level. Secondly, infrastructure construction, the level of scientific and technological innovation and the development of digital industry all have a positive effect on the development of regional digital economy. The weights reached 20.501%, 51.599% and 27.9% respectively. It can be seen that the level of science and technology innovation has the greatest influence. Finally, the number of students enrolled in general higher education institutions, telecommunication business revenue, the number of patents granted and the number of high-tech enterprises are the top four secondary indicators affecting the level of digital economy development in Wuhan. It is possible to promote the continued healthy and rapid development of Wuhan's digital economy level by strengthening higher education and talent cultivation, upgrading communication infrastructure, incentivizing scientific and technological innovation and patent output as well as supporting the development of high-tech enterprises.

CCS Concepts

• **Applied computing** → Law, social and behavioral sciences; Economics.

Keywords

Digital economy, Technological innovation, High-Tech industry, Infrastructure construction, Entropy value method

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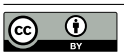
*Corresponding author.



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1 Introduction

The digital economy has emerged as a critical global topic, driving high-quality economic development by integrating digital technologies with traditional industries. In recent years, China has made significant advancements in technologies such as big data, artificial intelligence, and cloud computing, positioning itself as a leader in the digital economy. According to the China Academy of Information and Communication Research, the scale of China's digital economy expanded from approximately 30 trillion yuan in 2018 to 50.2 trillion yuan in 2022, ranking second globally. This growth has been marked by rapid development, extensive influence, and a transformative impact on economic structures, establishing the digital economy as a new engine and competitive frontier for development.

The COVID-19 pandemic further underscored the role of the digital economy in sustaining and transforming the real economy. E-commerce platforms like Taobao and JD.com ensured essential goods supply during lockdowns, while cloud-based platforms such as DingTalk, Tencent Meeting, and Xueersi facilitated remote work and education. Digital formats, including live streaming and online entertainment via platforms like TikTok, Weibo, and Bilibili, addressed disruptions in offline activities and generated new revenue streams. These innovations not only mitigated the economic challenges of the pandemic but also accelerated the digital transformation of traditional industries.

In response, Wuhan has introduced policies to advance digital connectivity across economic, governmental, and societal domains. By prioritizing digital industrialization, industrial digitization, and innovative economic models, the city aims to strengthen the integration of digital technologies into its development trajectory.

2 LITERATURE REVIEW

The concept of the digital economy was first introduced by Don Tapscott and subsequently promoted by the U.S. Department of Commerce, establishing it as a significant driver of global economic development [1]. The earliest academic discussion of the development of digital economy in China first analysed the role of information technology in promoting economic growth [2]. Later the main features of the digital economy were summarised at the G20 Hangzhou Summit such as virtuality, and many scholars have discussed the digital economy as a series of financial activities that

Table 1: Evaluation System of Indicators for the Development Level of Digital Economy in Wuhan.

objectives	Primary Indicators	Secondary Indicators
Development Level of Digital Economy	infrastructure construction	Passenger traffic(ten thousand persons)
		Volume of cargo transported (ten thousand tonnes)
		Total optical fibre cable production (ten thousand core kilometres)
		Internet broadband subscribers (ten thousand)
	scientific innovation level	Patent grants (cases)
		Number of Students Enrolled in Regular Higher Education Institutions (ten thousand persons)
		Number of High-Tech Enterprises
		Number of R&D Personnel (ten thousand persons)
		Percentage of Total Social R&D Expenditure in GDP (%)
	digital industry development	Total Output Value of High-Tech Industries (billion yuan)
		Telecommunications bbusiness rrevenue (billion yuan)
		Software business revenue (billion yuan)

rely on information and communication technologies (ICTs) as an important driving force for frequency enhancement and optimisation of economic structure [3].

From a macro perspective. The impact of the Internet on regional economic development is gradually expanding and going to be the main element of economic development [4]. Therefore, the development of the digital economy has important positive effects on the economic development of each region, total factor productivity, and regional innovation capacity [5–7]. Promoting the growth of digital economy is the core strategy of China's current economic transformation and high-quality development, aiming at optimising and upgrading the economic structure. On top of that, the integration of digital economy and industrial development develops and pushes China's economy forward. The development of digital economy is positively correlated with the development level of industrial structure, which can not only curb the imbalance of industrial structure but also promote the development of the level of industrial structure [8].

From the perspective of micro-analysis, the impact of the digital economy on enterprise development is more obvious. From the perspective of business risk, some scholars believe that with the increase in the level of development of the digital economy, the level of enterprise risk-taking can be improved [9]. From the structural level, the digital economy can promote the innovation of enterprise management mode, the adjustment of enterprise goals and the innovation of governance structure [10], which in turn stimulates the enthusiasm of enterprise's innovation [11]. And examined from a cost perspective, the rise of the digital economy has brought about massive amounts of data and information, which will motivate enterprises to pursue higher product quality. At the same time, the reduction of search costs also enhances this effect, making it easier for enterprises to obtain the information they need, thus enhancing product quality and market competitiveness [12].

Based on the strategic position and contemporary significance of the development of digital economy. Wuhan, China is selected as a sample city. An indicator system is constructed to measure the level of digital economy development in Wuhan. Try to discover the factors affecting the level of regional digital economy development and propose countermeasures accordingly.

3 Methodology

3.1 Construction of Indicator System

The evaluation indicators of digital economy should be as comprehensive, scientific and reasonable as possible. Therefore, when constructing the evaluation index system of Wuhan's digital economy development level, it draws on the existing research results of scholars in China and abroad, combines with the actual situation of Wuhan's economic development, and takes into account the availability and continuity of data. Measurement is carried out at three levels: infrastructure construction, scientific innovation level and digital industry development. Twelve secondary indicator levels are subdivided as shown in Table 1.

Infrastructure construction is the technological foundation of the digital economy, supporting large-scale data processing and innovative applications and enhancing economic efficiency. Robust networks and data centres ensure reliable and fast data transmission and storage, fostering the adoption of technologies such as big data and artificial intelligence while lowering the costs of digital transformation. By leveraging the asset allocation benefits of the digital economy, regions with high passenger and cargo traffic levels experience increased local economic activity, driving demand for advanced digital infrastructure and technical services. The expanded production of fiber optic cables and the growing number of internet broadband subscribers have provided a solid foundation for the digital economy, facilitating efficient information flow, enhanced data sharing, and improved information processing capabilities.

The level of scientific innovation is a critical measure of a city's ability to conduct technological research, develop digital solutions, and advance the digital economy. As the digital economy fundamentally represents progress in science and technology, scientific innovation serves as a core driver of productivity and a key factor in assessing digital economic development. Indicators such as the number of students enrolled in higher education institutions reflect the current and future talent pool, highlighting the region's

Table 2: Atribute and code of indicators in the evaluation system. Source: own research

Primary Indicators	Secondary Indicators	attribute	code
infrastructure construction	Passenger traffic (ten thousand persons)	positive	X1
	Volume of cargo transported (ten thousand tonnes)	positive	X2
	Total optical fibre cable production (ten thousand core kilometres)	positive	X3
	Internet broadband subscribers (ten thousand)	positive	X4
scientific innovation level	Patent grants (cases)	positive	X5
	Number of Students Enrolled in Regular Higher Education Institutions (ten thousand persons)	positive	X6
	Number of High-Tech Enterprises	positive	X7
	Number of R&D Personnel (ten thousand persons)	positive	X8
	Percentage of Total Social R&D Expenditure in GDP (%)	positive	X9
digital industry development	Total Output Value of High-Tech Industries (billion yuan)	positive	X10
	Telecommunications bbusiness rrevenue (billion yuan)	positive	X11
	Software business revenue (billion yuan)	positive	X12

long-term potential for digital economy growth. The proportion of R&D personnel and R&D expenditure relative to GDP indicates the region's overall investment in scientific research and talent development across enterprises. Meanwhile, output indicators such as the number of patents granted and the count of high-tech enterprises provide a direct measure of the region's scientific and technological innovation capacity, offering a clear picture of its current innovation level.

Digital economy-related industries have become an integral part of the current economy. The development of digital industries under new economic formats reflects the practical application and impact of these technologies in regional economies. Digital industries leverage technologies such as big data and digitization to create value from data resources, encompassing both emerging industries directly based on digital technologies and traditional industries innovatively utilizing digital technologies for development. The current status of digital economy-related industries can significantly reflect the current level of digital economic development. By selecting the total output value of high-tech industries, total telecommunications services, and software product revenue as indicators, it comprehensively assesses the development of digital industries from various aspects including industry scale, degree of digitization, and technological innovation.

3.2 Sample selection and data sources

The data used in this study comes from the China Economic Information Network Database, the Wuhan Municipal Bureau of Statistics, and the "China Urban Statistical Yearbook." Data from Wuhan for the period 2013-2022 were selected, and missing data was supplemented using the mean value method. Using the entropy method, Excel was employed to measure the development level of Wuhan's digital economy, ultimately obtaining the weight of each indicator and providing suggestions based on the analysis.

In order to maintain the information content and completeness of the data, differences in units of measurement and direction of measurement between indicators were eliminated. The indicator data in 1 were standardised.

The entropy value method can determine the weight of each indicator by calculating its information entropy, and then synthesise multiple indicators into one comprehensive indicator, so that indicators of different scales can be comprehensively evaluated in the same evaluation system. Upon analysis, all data responded positively to the results. Subsequently, a levelling process was carried out and 0.1 was added to all data. Pij was then calculated using equation 1.

$$P\text{ij} = \frac{yij}{\sum_{i=1}^{m} yij} \tag{1}$$

note:

- y_{ij}—The standardized value of indicator j at time i.
- m—The amount of samples.

Secondly, calculate the entropy value using equation

$$S_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{2}$$

note:

- k = 1/ln(m)

After calculation, the value of the adjustment coefficient k in this study is 0.434294482.

Thirdly, calculating the variance factor.

$$E_j = 1 - S_j \tag{3}$$

Fourthly, calculating the weight of indicator j.

$$W_j = E_j / \sum_{i=1}^{m} E_j \tag{4}$$

Finally, the weights of the indicators are used to calculate a comprehensive score for the level of digital economy development in Wuhan over the years.

4 Results and DISCUSSION

According to the above entropy method process, the weights of the indicators of the digital economy development level are calculated as shown in Table 3 below.

Based on the impact of primary indicators on the level of digital economy development, the weight of infrastructure construction is 20.501%, technological innovation is 51.509%, and digital industry is 27.9%, resulting in an overall ratio of approximately 2:5:3. This

Table 3: Weights of Evaluation Indicators for Digital Economy Development. Source: own research

Primary Indicators	Secondary Indicators	code	Weighting
infrastructure construction (20.5%)	Passenger traffic (ten thousand persons)	X1	0.04154124
	Volume of cargo transported (ten thousand tonnes)	X2	0.06387865
	Total optical fibre cable production (ten thousand core kilometres)	X3	0.04937605
	Internet broadband subscribers (ten thousand)	X4	0.05020935
scientific innovation level (51.6%)	Patent grants (cases)	X5	0.13091278
	Number of Students Enrolled in Regular Higher Education Institutions (ten thousand persons)	X6	0.14892517
	Number of High-Tech Enterprises	X7	0.11731171
	Number of R&D Personnel (ten thousand persons)	X8	0.07317074
	Percentage of Total Social R&D Expenditure in GDP (%)	X9	0.04567049
digital industry development (27.9%)	Total Output Value of High-Tech Industries (billion yuan)	X10	0.07921559
	Telecommunications business revenue (billion yuan)	X11	0.13823397
	Software business revenue (billion yuan)	X12	0.06155421

Table 4: Digital Economy Development Comprehensive Score Ranking in Wuhan (2013-2022) .

Year	Comprehensive Score	Ranking	Growth	Growth Ranking
2013	14.273	10	/	/
2014	18.257	8	28%	3
2015	16.012	9	-12%	9
2016	22.633	7	41%	2
2017	40.266	6	78%	1
2018	41.362	5	2.7%	8
2019	49.605	4	20%	5
2020	52.691	3	6.2%	7
2021	63.116	2	19.8%	6
2022	79.955	1	26.7%	4

distribution highlights the critical role of technological innovation in driving the digital economy, which is consistent with the modern trend where innovation acts as the primary catalyst for economic growth. The substantial weight assigned to technological innovation reflects its significance in enhancing productivity, fostering new business models, and improving competitiveness. The balanced weight of the digital industry indicates its essential support function, while the weight of infrastructure, though smaller, underscores its foundational role. This analysis appears reasonable and scientifically sound, aligning with the understanding that a robust digital economy relies on a synergistic interplay between infrastructure, innovation, and industry.

In terms of the weights of the secondary indicators, there are four indicators with weights higher than 10%. They are the number of students enrolled in general higher education institutions, telecommunications business revenue, the number of patents granted and the number of high-tech enterprises. These indicators represent the core roles of talent cultivation, infrastructure, innovation capacity and industrial application in the development of digital economy respectively. Higher education provides an adequate talent pool. Revenue from telecommunications business reflects a good communications infrastructure. The number of patents shows strong innovation capability. And the number of high-tech enterprises signals the ability to transform innovation into economic growth. The high weighting of these factors is in line with the actual needs of digital economy development. It also finds the direction and focus of efforts to promote the level of digital economy development in Wuhan.

After comprehensively measuring the data of each indicator with the corresponding weights, a comprehensive score of the level of digital economy development in Wuhan from 2013 to 2022 is derived. The results are also ranked by year, and shown in Table 4.

5 conclusion

Firstly, the result shows that the score of Wuhan's digital economy development level has achieved significant growth in ten years, from 14.273 points in 2013 to 79.955 points in 2022, with a growth rate of more than four times. During the period from 2016 to 2027 is a blowout trend, annual growth of nearly 60%, and exceeded 40 points. This marks the rapid development stage of Wuhan's digital economy. This can be attributed to the fact that in 2016, the Chinese government successively issued the '13th Five-Year Plan for National Informatization', the 'Outline of Action for Promoting the Development of Big Data' and other documents, which provided

strong policy support and technical support for the development of the digital economy.

Secondly, the infrastructure construction, the level of science and technology innovation and digital industry development in the indicator system all have a positive role in promoting the development of regional digital economy. Among them, the level of science and technology innovation has the most significant impact, reaching 51.6 percent.

Thirdly, according to the weighting analysis of the evaluation indexes of digital economy development, the scale of students enrolled in general colleges and universities, telecommunication business revenue, patent authorization and the number of high-tech enterprises are the four core indexes affecting the level of development of Wuhan's digital economy, which are also the key points of focus for promoting the high-quality development of Wuhan's digital economy.

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