Research on the Readiness Index System and Measurement of Urban Digital Economy Development in the Yangtze River Economic Belt

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Abstract: In this paper, the connotation and evaluation system of digital economy development are deeply analyzed. The related concepts and evaluation models of readiness theory are further studied. Based on this, a readiness index system of urban digital economy development is constructed. The entropy method is used to measure the readiness of digital economic development in 11 provincial capitals of the Yangtze River Economic Belt in 2017 from four dimensions: information base, economic development, human capital and development environment. The results show that the readiness level of digital economy in major cities in the Yangtze River Economic Belt generally shows a decreasing trend from east to west, and the readiness level of digital economy development in the developed cities in the eastern coastal areas is significantly higher than that of the inland areas.

1. Introduction

In November 2018, the 5th World Internet Conference released the blue paper of World Internet Development Report 2018 and China Internet Development Report 2018 [1]. In the paper, it pointed out that the world's digital economy reached USD 12.9 trillion in 2017, and the economic aggregate of US and China ranked Top 2 in the world respectively. In 2017, the economic aggregate of China reached USD 27.2 trillion, and the contribution rate of the digital economy to GDP growth reached 55%. Digital economy has now become an important engine to drive China's economic growth, as well as the major breakthrough in industrial transformation and upgrading[2]. At present, many provinces and cities in China have issued digital economic development plans for the purpose of taking digital economy as important support to accelerate economic transformation. Therefore, at a time when the country strongly advocates the development of digital economy, to understand the conditions and environmental maturity of the development of digital economy in the region is helpful to objectively understand the current situation and existing problems of the development of regional digital economy, and provide strong decision-making support for the policy makers to take effective measures and formulate strategies to accelerate the development of digital economy.

2. Literature Review

With regard to the measurement of digital economy, domestic and foreign government departments, high-end think tanks and research institutes have issued a digital economy index system or a digital economy index report from different angles. Since 2002, the World Economic Forum (WEF) began to release the Networked Readiness Index (NRI), which focused on analyzing the rankings, main experiences and practices of leading countries and regions in global informatization from four dimensions of environment, readiness, application and impact. In 2014, the EU released the Digital Economy & Society in the EU and the Digital Economy and Society Index (DESI). The Organization for Economic Co-operation and Development (OECD) has constructed an internationally comparable index system of digital economy covering 38 secondary indexes. Compared with foreign countries, China's research on the establishment and measurement of digital economy index system has developed rapidly in recent years. Since 2015, Tencent, together with JD.com, Didi and other institutions, has made a statistics of the whole sample data covering more than 10 core platforms, including Tencent's WeChat, payment and urban services, as well as the

industry data from companies such as JD.com, Didi and Ctrip, which has built China's "Internet + " digital index. In July 2017, the China Academy of Information and Communications Technology released the White Paper on the Development of China's Digital Economy (2017), put forward the Digital Economy Index (DEI), and built the leading index, consistent index and lagging index. Shanghai Academy of Social Sciences released the Global Digital Economy Competitiveness Index (2017) in December 2017, which divided the digital economy into the main industry part and the integrated application part. In November 2017, CCID Consulting released the 2017 China Digital Economy Development Index (DEDI), which divided the digital economy into four categories: basic type, resource type, technology type, integration type and service type. In May 2017, Caixin Insight and other institutions released China's Digital Economy Index (CDEI), which mainly focused on the ability of the digital economy to improve the efficiency of the whole society. The White Paper on China's Urban Digital Economy Index (2017), released by H3C Group in April 2017 was the first evaluation system for the development level of China's urban digital economy. It evaluated the development level of China's urban digital economy from the perspectives of urban information base, urban services, urban governance and industrial integration [3]. At the "Digital Economy Forum" in September 2018, AliResearch and KPMG jointly released the 2018 Global Digital Economy Development Index, discussed the driving factors and development path of the digital economy, and put forward the five-factor model of the digital economy[4]. In September 2019, AliResearch and the 21st Century Economic Research Institute jointly released the 2019 Yangtze River Delta Digital Economy Index to measure the digital economic level of 27 central cities in the Yangtze River Delta from infrastructure, business, industry, government affairs and people's livelihood.[5]

Many scholars and experts have also expounded the concept, connotation and characteristics of digital economy from various angles, providing good information to deepen our understanding of digital economy. The experts' understanding of digital economy has gradually changed from the relationship between digital economy, information technology and electronic commerce to the recognition that it is a new economic form. Elmasry pointed out that digital economy is not a concept, but a mode of behavior. It has three major contributions including creating value in the latest frontier of the economic world, optimizing processes from customer experience, and building basic capabilities to support the entire system [6]. House of Commons believed that digital economy refers to the digital access of goods and services and the promotion effect of digital technology on economic development [7]. Jian PANG et al. believed that the digital economy is an economic format based on information and communication technologies, which realizes digitalization of transactions, exchanges and cooperation through the Internet, mobile communication networks and the Internet of Things, and promotes economic and social progress and development [8]. Liangliang ZHANG et al. believed that digital economy refers to a new economic form with digital information as the core production factor, information technology as the support, modern information network as the main carrier, and using digital technology to provide products or services. It is a new economic form of technological integration, industrial integration and integration of producers and consumers[9]. Weiling WANG et al. believed that digital economy is a new economic form based on information and knowledge, with the new generation of information technology as the means, information industry as the backbone, information products and services as the main contents. The G20 believed that digital economy refers to a series of economic activities that use digital knowledge and information as key production factors, modern information networks as important carriers, and effective use of information and communication technologies as important driving forces for efficiency improvement and economic structure optimization [11].

We can see that at present a large number of think tanks have issued evaluation systems for the development level of China's urban digital economy, but domestic scholars mainly focus on the research on the concept, connotation and characteristics of digital economy or the analysis at the national and regional levels. For example, Xueling ZHANG et al. have established an evaluation index system for the development of digital economy from several dimensions such as information and communication infrastructure, ICT primary and advanced applications, enterprise digitalization, and the development of information and communication technology industry to measure the

development of China's digital economy [12]. From a macro perspective, Bochao ZHANG et al. took the countries along the "The Belt and Road" as the research subject and selected representative index data closely related to the development of digital economy to construct the readiness index system of digital economic development in the countries along "The Belt and Road"[13]. However, there are few studies on the measurement of the development level of digital economy in cities of China by scholars. In this paper, the evaluation research on the development level of digital economic development readiness has been carried out. Readiness is the degree of preparation, which mainly reflects the conditions and environmental maturity of a subject to carry out an activity [14]. With the continuous penetration of information technology in the fields of economy, education and service, it brings opportunities and capabilities for the development of these fields. Economic readiness index is an important index to measure the maturity of the economic development in a region, which is of great significance for studying the level of regional economic development. Readiness theory has been studied by relevant experts in the fields of technology development, capability development, network and informatization, e-commerce development, etc. Based on a deep understanding of the connotation of digital economic development readiness, we have constructed a readiness index system of urban digital economic development, thus measuring and analyzing the current situation of digital economic development readiness in 11 provincial capitals of the Yangtze River Economic Belt in 2017, aiming at providing support for grasping the actual situation of urban digital economic development and effectively promoting local governments in our country to formulate relevant policies for digital economic development.

3. Construction and Calculation of Readiness Index System for Urban Digital Economic Development

3.1 Construction of Index System

Based on the analysis and explanation of the connotation and measurement of digital economic development readiness in the previous section, following the principles of purposiveness, scientificalness, operability and dynamics, and taking into account the availability of data in quantitative analysis, a readiness index system of urban digital economic development including 4 primary indexes and 21 secondary indexes are constructed from the four dimensions of information base, economic development level, human capital and development environment [15], with specific indexes as shown in Table 1.

Table 1 Readiness index system of urban digital economic development

Objective layer	Criterion layer	Index layer	Variable	Unit
Region Digital economic development Readiness	Information base readiness	The number of internet broadband access users per 100 persons	F_1	Household / 100 people
		The number of fixed telephone calls owned per 100 persons	F_2	Number/ 100 people
		The number of mobile phone owned per 100 persons	F_3	Number/ 100 people
		The number of websites owned per 100 persons	F_4	Number/ 100 people
	Economic development readiness	Regional GDP	F_5	RMB 100 million
		GDP growth rate	F_6	%
		Contribution rate of tertiary industry	F_7	%
		The proportion of added value of knowledge-intensive service industry in GDP	F_8	%
		The proportion of added value of information transmission, software and	F_9	%

		information technology in GDP		
		The proportion of E-commerce turnover in GDP	F_{10}	%
	Human capital readiness	The proportion of talent in digital economy	F_{11}	%
		The proportion of employees in knowledge-intensive service industry	F_{12}	%
		The proportion of employees in information industry	F_{13}	%
		The proportion of R&D personnel	F_{14}	%
		The proportion of employees receiving higher education	F_{15}	%
	Development environment readiness	Number of patents granted	F_{16}	项
		The proportion of R&D expenditure in total fiscal expenditure	F_{17}	%
		The proportion of enterprises with R&D activities in the industrial enterprises	F_{18}	%
		The proportion of the fiscal expenditure on education in total fiscal expenditure	F_{19}	%
		The proportion of the high-tech enterprises in the industrial enterprises above the scale	F_{20}	%
		The proportion of online retail sales in total retail sales of social consumer goods	F_{21}	%

3.2 Selection, Processing and Calculation of Data

This study collected data from 11 provincial capitals and municipalities directly under the central government of the Yangtze River Economic Belt in 2017 for evaluation. The data came from China Population and Employment Statistics Yearbook, China City Statistical Yearbook, China Statistical Yearbook on Science and Technology, as well as Statistical Yearbook, Statistical Bulletin and EPS Data Platform of each city. In order to guarantee the objectivity of the evaluation, the author uses entropy method to calculate it.

The first step is to construct the original index matrix.

The index system includes m evaluation indexes and n cities. The original index matrix is as follows:
$$X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}$$

Wherein, x_{ij} is the index number of index i of city j, where i=1, 2,..., 20; j==1,2,...,11.

The second step is dimensionless data processing.

Due to the different dimensions of each index data, in order to make the data comparable, we conduct dimensionless treatment of the original data. Because the indexes used in this index system are all positive, the method is as follows:
$$y_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}}$$

Wherein, x_{ij} is the positive index, and y_{ij} is the dimensionless value of index i of city j.

The third step is to use entropy method for weighting

Calculate the proportion of features p_{ij}:
$$p_{ij} = \frac{y_{ij}}{\sum\limits_{i=1}^{m} y_{ij}} ;$$

Calculate the information entropy of index i of city j: Wherein: $e_i = -k \sum_{j=1}^{m} p_{ij} \ln p_{ij}$, $k = \dfrac{1}{\ln m}$ $\rangle$ 0, e_i $\rangle$ 0;

Calculate the weight of index i: $w_i = \dfrac{1 - e_i}{\sum_{i=1}^{n}(1 - e_i)}$

Calculate the comprehensive score of city j: $E_j = \sum_{i=1}^{n} w_i p_{ij}$

3.3 Calculation Results and Analysis

According to the readiness index system of urban digital economic development and the above measurement method, this paper calculates the total index of digital economic readiness of 11 provincial capitals and municipalities directly under the central government in the Yangtze River Economic Belt in 2017 and four sub-indexes including information base, economic development, human capital and development environment (see Table 2).

Table 2 Comprehensive evaluation value of digital economic development readiness in cities in the Yangtze River Economic Belt

Region	Comprehensive scores		Information base		Economic development		Human capital		Development environment	
	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking
Hangzhou	214.24	1	242.28	1	218.39	1	181.12	4	220.33	1
Shanghai	207.14	2	149.52	4	211.41	2	247.47	1	211.35	2
Nanjing	185.66	3	209.44	2	166.96	3	185.50	3	184.83	3
Chengdu	169.96	4	193.33	3	141.30	6	196.05	2	151.20	5
Wuhan	145.69	5	136.16	5	154.79	4	139.64	5	151.12	6
Changsha	137.14	6	134.51	6	123.39	9	137.68	6	155.02	4
Guiyang	129.56	7	119.11	8	138.94	7	117.58	9	142.31	8
Chongqing	126.73	8	109.58	10	144.44	5	118.35	8	132.07	9
Hefei	124.15	9	109.42	11	116.67	10	122.27	7	149.07	7
Kunming	121.21	10	119.49	7	129.58	8	106.81	11	129.54	10
Nanchang	113.31	11	111.87	9	113.68	11	111.90	10	115.87	11

Generally speaking, the digital economic development readiness of the cities in the Yangtze River Economic Belt was non-balanced and took on a declining trend from the east to the central and western regions. In the evaluation of the digital economic development readiness of cities in the Yangtze River Economic Belt in 2017, Hangzhou and Shanghai respectively ranked the first and second place with the index of digital economic readiness of 214.24 and 207.14, constituting the "first echelon" of the digital economic development readiness of the Yangtze River Economic Belt. The developed cities in eastern coastal region such as Nanjing, the central city in the central region such as Wuhan and Chengdu in the west region constitute the "second echelon" of the digital economic development readiness of the Yangtze River, while those from Changsha, Hefei and Nanchang in the central region and Chongqing, Guiyang and Kunming in the west region constitute the "third echelon".

In order to have a more comprehensive and profound understanding of the city's digital economic development readiness in the Yangtze River Economic Belt, this paper has compared and analyzed the information base readiness index, economic development readiness index, human capital readiness index and development environment readiness index of 11 cities in the Yangtze River Economic Belt based on the dimensionless results of secondary indexes (see Figure 1).

(a) Information base

The number of internet broadband access users per 100 persons
The number of fixed telephone calls owned per 100 persons
The number of mobile phone owned per 100 persons
The number of websites owned per 100 persons

(c) Human capital

The proportion of talent in digital economy
The proportion of employees in knowledge-intensive service industry
The proportion of employees in information industry
The proportion of R&D personnel
The proportion of employees receiving higher education

(b) Economic development

Regional GDP
GDP growth rate
Contribution rate of tertiary industry
The proportion of added value of knowledge-intensive service industry in GDP
The proportion of added value of information transmission, software and information technology in GDP
The proportion of E-commerce turnover in GDP

(d) Development environment

Number of patents granted
The proportion of R&D expenditure in total fiscal expenditure
The proportion of enterprises with R&D activities in the industrial enterprises
The proportion of the fiscal expenditure on education in total fiscal expenditure
The proportion of the high-tech enterprises in the industrial enterprises above the scale
The proportion of online retail sales in total retail sales of social consumer goods
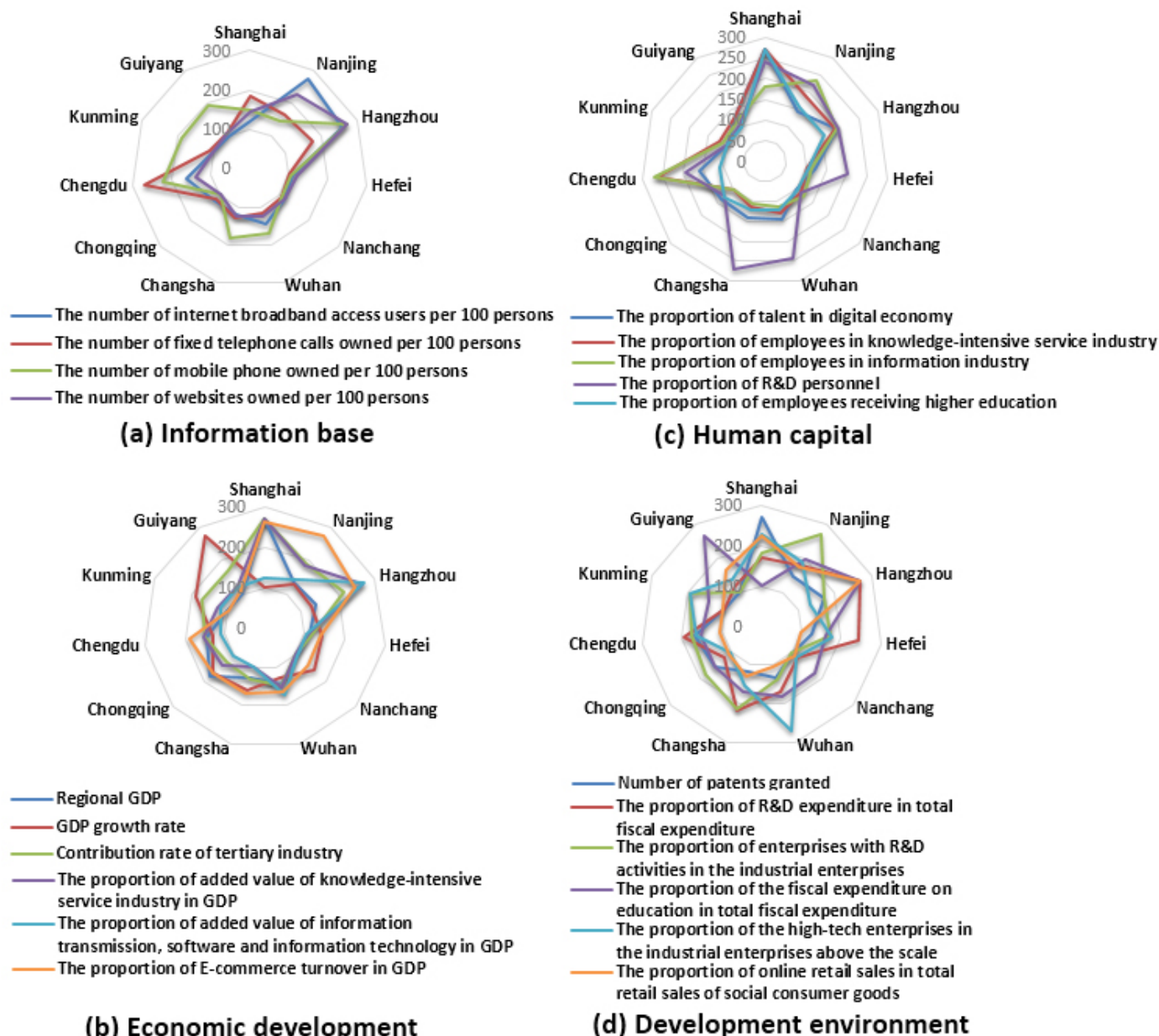
Figure 1 Secondary index of the city's digital economic development readiness in the Yangtze River Economic Belt

As the "first echelon", Hangzhou and Shanghai were the two cities with overall leading indexes of digital economic readiness than those of the inland cities in the central and western region, and the development conditions in all aspects were more balanced. Hangzhou, which ranked first in the level of digital economic readiness, has outstanding conditions on the whole, but the human capital for digital economy was obviously weaker than that of the other three aspects. As a digital economic innovation highland, Hangzhou's mobile phone coverage and website ownership coverage were in a relatively high level, which laid a good foundation for the development of the digital economy. Hangzhou's economic development level, especially the e-commerce, the Internet and the information technology industry, relied on the radiation effect of the Alibaba ecosystem, which has formed various forms of economic formats in Hangzhou, and was at a higher level in the whole country, specifically manifested in Hangzhou's software and information technology, e-commerce sales, network retail sales and other indexes. In terms of R&D, education and talent introduction, the Hangzhou municipal government has also invested a large amount of resources and support in its fiscal policy, and is committed to building Hangzhou into "the first city of the national digital economy". The digital economic readiness level in Shanghai is second only to that of Hangzhou, and

the readiness level of the two cities is very close to each other, with only seven points off in the overall score. Shanghai is China's largest economic center and trade port, as well as an important science and technology, economy, trade and finance, and information center in China. Its total economic output value, the contribution rate of the tertiary industry, and the added value of knowledge-intensive service industry are among the highest in the region. The proportion of digital talents and knowledge-intensive talents in Shanghai is also second to none in the whole region, and the proportion of employed personnel receiving higher education is much higher than that in other cities, which lays a good foundation for the development of digital economy. The high-tech enterprises are more densely distributed in Shanghai. The number of R & D patents is larger, and the development environment is better in high-end, precision and sophisticated industries.

The digital economic readiness of Nanjing, Chengdu and Wuhan, as the cities in the " second echelon", is at a higher level. As a city with more developed economy in the east, Nanjing's Internet broadband coverage, the proportion of e-commerce sales in GDP, and the proportion of enterprises with R&D activities in the industrial enterprises are the highest in the region. The level of website ownership, the proportion of employees in the information industry, and the proportion of R&D talents are also at a higher level. Its four aspects of digital economic development conditions are relatively balanced. Chengdu, as the core city for the development of digital economy in the central and western regions, relies mainly on its solid information base and digital talents bonus. As the first city in central China, Wuhan's pillar industries are mainly traditional industries such as automobiles, iron and steel, photoelectric communication and ships. Relying on related industries, its R&D talents and high-tech enterprises account for a relatively higher proportion, forming a unique regional advantage.

Among the several cities in the " third echelon", Changsha and Hefei are at a relatively higher level in terms of R&D talent and R&D expenditure. Both cities have high levels of human capital readiness and development environment readiness. Chongqing, as an important municipality directly under the Central Government in the west, has the second largest economic volume in the region. Its economic growth rate is fast and its level of economic development readiness is high. However, due to the general performance of the other three indexes, the overall level of digital economic readiness is lower than expected. Guiyang's digital economy has developed rapidly in recent years. The growth rate of the digital economy has been the highest in the country for three consecutive years. It has laid out big data industries in an all-round manner and made great efforts to build "China's Digital Valley". Its GDP growth rate is also the fastest in the region. The government also attaches great importance to the investment in education. Others can cultivate better digital talents. Although the current volume and development level are not at the forefront of the entire Yangtze River economic belt, its level of digital economic readiness has reached the mid-level of the region. In the four dimensions, some cities still have obvious short boards. Hefei, for example, has a weak information base and a weak level of economic development. Kunming is located in the southwest of China, and its human capital and development environment are ranked behind. Nanchang, as a city in central China, has four indexes at a relatively low level, which seriously restricts the development of the city's digital economy.

4. Countermeasures and Suggestions

In this paper, based on the understanding of the connotation of the readiness of digital economy and the measurement of the readiness of digital economy in the cities of the Yangtze River Economic Belt, the following suggestions are put forward for promoting the level of regional digital economic readiness: Firstly, it is to attach importance to the construction of digital economic infrastructure. On the basis of optimizing network infrastructure, we will lay out big data and cloud computing centers, deepen the construction of smart cities, use innovative technologies and the Internet to open up public services in cities, and optimize urban management and services. Secondly, it is to innovate the talent introduction and training mechanism, integrate various resources, solve the shortage of talents in the digital economy, combine production with education, accelerate the training of talents in digital economy, and innovate the strategy and mechanism of talents. Thirdly, the government should

innovate and open its mechanism, formulate policies to encourage innovation, form a good atmosphere for innovation, and guarantee a good environment for the development of digital economy. Fourthly, it is to take data as the core production factor for the development of the city's digital economy, lay out world-class digital industrial clusters, focus on the new ecology of the digital economy, strengthen inter-regional industrial collaboration and city collaboration, promote the digital upgrading of traditional industries and upgrade the level of digital governance.

Acknowledgements

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