The scale measurement and spatial differences of digital economy in China

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Abstract. Based on the calculation of the added value of three major digital economy industries in 30 provinces in China from 2017 to 2020, this paper uses the Gini coefficient and its decomposition method to explore the spatial differences of the scale of digital economy in China's provinces and its development dynamics over time. The analysis shows that the scale of digital economy in China's provinces continues to grow rapidly, and the proportion of provincial GDP is also increasing. On the other hand, there are large differences in the size of the digital economy between provinces, and inter-regional differences make the highest contribution to the overall differences. However, the size of the digital economy in all regions continues to grow, and the inter-regional Gini coefficient shows a downward trend during the observation period, which is expected to continue in the next few years. This paper clarifies the development status of major industries of China's digital economy, as well as the development trend of regional differences and scales, which is of great significance to the formulation of China's digital economy policy and the coordinated development of digital economy in the region.

Keywords: digital economy, big data, digital industry, new technology, data analysis.

1. Introduction

With the advancement of globalization and informatization, the digital economy has become a new engine of economic growth in the 21st century, playing an indispensable role in promoting social progress and improving people's living standards. Among them, China, as the world's second largest economy, is accelerating its digital transformation and comprehensively promoting the process of economic modernization. However, China's huge geographical area and complex geographical environment make the speed and development degree of digital economy in different regions differ significantly. Therefore, in-depth analysis and understanding of the scale measurement and spatial differences of China's provincial digital economy have become an important topic of current research, which is of great significance for exploring new growth drivers and growth points of China's economy [1].

As a new economic form, digital economy integrates information technology, data resources and modern industries. The calculation and analysis of its scale and structure can not only reflect the innovation ability and economic vitality of a region, but also reveal the direction of industrial transformation and upgrading [2]. Due to the significant differences in economic development level, educational resources, infrastructure and other aspects among different regions in China, the development of digital economy also presents complex spatial distribution characteristics. How to accurately grasp these differences, identify the bottlenecks and advantages of provincial digital economy development, and comprehensively study the scale and spatial differences of China's provincial digital economy can understand the development trend and challenges of Chinese society from a deeper level [3].

Through detailed statistical analysis, in-depth data calculation and comprehensive spatial comparative evaluation, this paper aims to conduct an all-round discussion on the scale measurement and spatial differences of the digital economy in China's provinces, and analyze the development status, influencing factors and future trends of the digital economy in each region. Through this in-depth research, we hope to provide valuable insights and guidance for government decision-making,

enterprise strategy and academic research, and jointly promote the healthy, orderly and sustainable development of China's digital economy [4].

2. Literature review

Research to measure the size and macro statistics of the digital economy has attracted a lot of attention from government agencies and academia around the world. The G20 Toolkit for Measuring the Digital Economy (2018) identifies four "themes" for key aspects of the digital economy. BEA (2020) expands the scope of business digitization in its latest estimates to include B2C and B2B e-commerce value in the U.S. economy, using survey data from the U.S. Census Bureau.

Although domestic and foreign institutions and scholars have different views on the digital economy, the debate on the scope of the digital economy can be divided into two aspects: one is to define the digital economy from the main digital sector, that is, ICT; The second is to explore the significance of the digital economy from the broader technology convergence and innovation behavior. In terms of value added accounting, scholars from different countries have formulated a variety of calculation schemes of value added of digital economy for different research purposes [5]. WB constructed the Knowledge Economy Index (KEI), and 146 countries have participated in KEI research (WB, 2010), which constructed a Digital Knowledge Economy Index (DKEI) based on data and KEI evaluation method to study the digital economy [6]. However, the construction method of the index has drawbacks such as strict requirements on innovation and efficiency of the index system, incomplete theoretical basis, and unstable data sources. By constructing auxiliary coefficients such as the structural coefficient of industrial added value and the adjustment coefficient of industrial digital economy according to the calculation method of BEA to estimate the inter-provincial added value of China's digital economy, studied the imbalance and regional differences, and innovatively introduced the interpretation method of the added value of the inter-provincial digital economy [7].

After a comprehensive analysis of literature and a summary of domestic and foreign research results, it can be concluded that there are still many shortcomings to be solved in the existing research. In order to solve the shortcomings of the existing research, this paper studies the products of the digital economy, separates the industrial framework of the digital economy on the basis of the clear concept of the digital economy, builds an independent industrial structure of the digital economy, combines the input-output model and the statistical data of the national economy, measures the scale of the digital economy, develops methods to measure industrial spillover effects, and helps improve the accounting system of the digital economy.

3. Research design

3.1. Definition of the scope of core industries of digital economy

The China Academy of Information and Communications Technology (CAICT) released the Industrial Classification of the Digital Economy in 2021 to fulfill the government's important decision and commitment to actively develop information technology and digital machines. The Digital Economy Industry Classification provides a scientific definition of the digital economy, describes the main industries, sectors and sub-industries of the digital economy in detail, and explains the specific meaning and practical value of each category, the first four categories are the key industries of the digital economy. Table1 shows the names of categories and middle categories, and clarifies the calculation range of digital economy added value in this paper.

Table 1. Digital economy industry classification

Broad category	Subdivision category
Digital Product Manufacturing	Manufacture of Computer parts and components, Manufacture of computer control systems, Manufacture of communication system equipment, Broadcast Social Media Manufacturing, Artificial Intelligence Product Manufacturing, ...
Digital product Service	Wholesale, retail and repair of digital products and other services for digital products n.e.c.
Digital technology application	Software development and implementation, Digital product information transmission services, Internet-related technical services,...
Digital elements driven industry	Internet activities providing third-party service platforms, Online financial services, Supply chain management services, Digital content and media,...

3.2. Research Methods

3.2.1 Methods for calculating the scale of digital economy in China's provinces

Based on the "Classification of Core Industries of Digital Economy", this paper calculates the added value of China's digital economy and related industries by using the government input calculation report and the China Economic Survey Yearbook. Xu Xianchun and Zhang Meihui (2020) calculated the scale of digital economy using BEA data, assumed that the proportion of digital economy input in the total output was the same as that of relevant industry input in the total output. This paper uses this estimation method to estimate the new basic industries of China's digital economy, but since China's current statistics do not cover all parts of China's digital economy, the industry-specific "digital economy correction coefficient" is used in the calculation process to estimate this part of the data. The calculation formula is as follows:

$$\text{Industry digital economy adjustment coefficien t} = \frac{\text{Industry digital economy added value}}{\text{Total value added of the industry}} \tag{1}$$

In all the industries covered by the digital economy, we can consider the ratio of the intermediate consumption of the digital economy to the total output of the digital economy is equivalent to the ratio of the intermediate consumption to the total output of all its industries. Therefore, the added value of the digital economy of a certain industry can be equal to the product of its corresponding total output value of the industry and the added value rate of the industry, so the combination can be obtained:

$$\frac{\text{Total output of industry digital economy}}{\text{Total industry output}} = \frac{\text{Industry digital economy added value}}{\text{Total value added of the industry}} \tag{2}$$

(1) Measurement of added value of digital product manufacturing industry. It is known that the added value of "communications equipment, computers and other electronic equipment" is calculated as a percentage of the total added value of the "manufacturing industry" to obtain the structural ratio of the added value. Assuming that the adjustment factor of the digital economy does not change in a short period of time, combining it with the annual value added of manufacturing in each region can obtain the value added of "communication equipment, computers and other electronic equipment" in the gap year.

(2) Calculation of added value of digital product service industry. Digital economy products and services include three aspects: network trading agency, Internet wholesale and retail. Based on the data of China Economic Survey Yearbook, the ratio of the total core business income of Internet wholesale, Internet retail and online trading agency to the core business income of wholesale industry is taken as the added value of digital economy, and combined with the added value of digital economy, the adjustment coefficient of digital economy is obtained.

(3) Calculation of added value of digital technology application industry. The scope of accounting includes software development, telecommunications, radio and television and satellite transmission services, Internet-related services, information technology services and other digital technology application industries. This part of the added value can be obtained directly from the provincial

statistical yearbook, and the remaining missing data is treated in line with the treatment of other industries added value.

(4) Calculation of industrial added value driven by digital elements. By the China Economic Census Yearbook, the ratio of the main business income of "radio, film and record industry" to that of "culture, sports and entertainment industry" is taken as the adjustment coefficient of digital economy. The proportion of "Wholesale of audiovisual products, electronic and digital publications" to "wholesale of cultural, sporting goods and equipment" is used as the digital economy adjustment coefficient of R-86 industry, and the calculation method of added value is the same as above.

3.2.2 Dagum Gini coefficient and its decomposition method

Traditional indicators and methods used to describe regional disequilibrium are not sufficient to decompose regional differences. In this case, the Gini coefficient proposed by Dagum in 1997 and its subgroup decomposition method are adopted in this paper to decompose the overall difference G into three parts, namely G_w contributed by intra-regional difference, G_{nb} contributed by inter-regional difference and G_t contributed by super-variable density. The relationship between them is $G = G_w + G_{nb} + G_t$. This method can not only realize the decomposition of the scale gap of digital economy development in different regions, but also avoid the problem of reduced measurement accuracy caused by regional overlap.

$$G = \sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{nj}\sum_{r=1}^{nh} | yji - yhr | / 2n^2\bar{y} \tag{3}$$

$$Gw = \sum_{j=1}^{k} Gjpjsj \tag{4}$$

$$Gnb = \sum_{j=2}^{k}\sum_{h=1}^{j-1} Gjh(pjsh + phsj)Djh \tag{5}$$

$$Gnb = \sum_{j=2}^{k}\sum_{h=1}^{j-1} Gjh(pjsh + phsj)(1 - Djh) \tag{6}$$

$$Djh = djh - pjh \Big/ djh + pjh \tag{7}$$

Equation (1) is the calculation formula of the overall Gini coefficient. Where, yji (yhr) is the value added of digital economy of any province in j(h) region, and is the average value of digital economy scale of each province, n is the number of provinces and cities, and k is the number of regions. In this paper, the whole country is divided into three major economic zones, so k is 3.nj (nh) is the number of provinces and cities in j(h) region. Equation (2) represents the contribution of intra-regional differences. Where,Gj is the Gini coefficient of region j,pj = nj /n ， sj = nj $\bar{Y}_j/$n $\bar{Y}$ ， and Djh is the relative influence of digital economy scale between regions j and h. Equation (3) is the contribution of inter-regional differences. Where,Gjh is the Gini coefficient between j and h regions. Equation (4) is the contribution of super-variable density. In Equation (5), djh is the difference of added value of digital economy between regions.

3.3. Data Sources

Data are derived from the China and provincial Statistical Yearbook, Economic Census Yearbook, input-output table and the 2021 White Paper on China's Digital Economy Development. The above data are used to estimate the added value of digital economy in China's provinces, but input-output tables for some years in the Tibet Autonomous Region are not available, so relevant data cannot be calculated. The entire input-output table is updated every 2 years and every 7 years, and a new

expansion table is provided every 5 years and every 10 years, so that the data for the remaining years are presented at the average annual growth rate of the available data.

(1) Digital product manufacturing. Based on all the input-output tables of China as of 2017 and the extended new table, and using the new extended table of the Statistical Bulletin of National Economic and Social Development in 2018-2020, the three-year growth rate of value added is calculated to evaluate the overall value added of the digital product manufacturing industry in 2017-2020.

(2) Digital product service industry. In calculating the adjustment coefficient of digital service industry, the sum of the inverse ratio between the main business income of digital product service industry and industry income obtained from the data of China Economic Survey Yearbook is used as the proportion of the total output value of digital product service industry in the total output value of industry. Similarly, an overall assessment of the value added of the digital goods services sector for 2017-2020 will be made based on the input-output tables for all Chinese provinces as of 2017 and the three-year value added growth rates calculated using the new tables expanded by the Statistical Bulletin of National Economic and Social Development for 2018-2020.

(3) Digital technology application industry. Directly corresponding to the "information transmission, software and information technology service industry" in the input-output table, combined with the value added of information transmission, software and information technology industry to calculate the adjustment coefficient of digital technology application industry, using the same method to calculate the growth rate of value added in the next three years.

(4) Digital factors drive industry. Data on "Internet platforms, Internet wholesale and retail, etc." can be found in the China Economic Census Yearbook. "Digital content and media" can be calculated by the penetration rate of the digital economy in the third largest industry published by the National Bureau of Statistics. The "culture, sports and entertainment industry" can be directly driven by business input and the proportion of industry revenue.

4. Result analysis

4.1. Analysis of digital economy scale measurement results

Table 2. Scale and components of China's provincial digital economy (unit: 100 million yuan, %)

	Digital Product Manufacturing	Digital Product Services	Digital technology applications industry	Digital elements drive industry	Total digital economy	Growth rate of the digital economy	Percentage of GDP	Growth rate of GDP
BJ	1610.35	1037.24	12766.00	2595.00	18008.59	10.87	55.50	9.00
TJ	2119.00	646.00	2884.00	728.00	6377.00	9.96	38.89	-8.00
LN	1267.00	361.00	2326.00	521.00	4475.00	3.45	18.03	1.65
HB	950.00	425.00	3288.00	661.00	5324.00	12.13	14.86	0.22
JL	52.00	75.00	329.00	217.00	673.00	4.33	4.95	-6.21
HL	40.29	206.00	2090.00	326.00	2662.29	2.97	17.79	-5.06
SD	4145.00	938.00	3442.00	1494.00	10019.00	7.67	13.66	0.35
SN	1332.00	254.00	2481.00	396.00	4463.00	14.19	18.16	6.22
QH	14.98	30.39	378.00	80.00	503.37	8.36	17.54	4.43

GS	120.00	63.00	546.00	83.00	812.00	0.37	9.65	5.52
XJ	12.31	243.00	664.00	346.00	1265.31	4.82	10.22	5.76
IM	137.00	119.00	1166.00	228.00	1650.00	7.54	9.29	-3.20
NX	5.72	26.90	447.00	59.90	539.52	6.69	14.55	4.34
AH	4196.00	769.00	2435.00	1043.00	8443.00	18.84	25.33	12.32
HN	2813.00	536.00	4107.00	957.00	8413.00	8.68	22.06	6.52
HB	1659.00	528.00	5655.00	1476.00	9318.00	7.32	22.57	6.33
JX	1787.00	220.00	2661.00	757.00	5425.00	16.47	23.25	7.16
SX	923.00	200.00	2733.00	526.00	4382.00	19.71	8.71	-27.95
HN	556.33	132.33	1097.33	105.33	1891.33	8.57	3.74	7.03
FJ	4604.00	362.00	3458.00	1431.00	9855.00	13.44	25.53	10.94
GD	34032.00	1912.00	15546.00	2869.00	54359.00	9.79	53.62	7.25
JS	20129.00	704.00	11867.00	3127.00	35827.00	8.92	37.63	6.16
SH	797.00	137.00	1771.00	892.00	3597.00	9.47	10.30	8.88
HN	7.44	77.80	555.00	137.00	777.24	7.59	15.32	6.20
ZJ	3912.00	695.00	6815.00	3204.00	14626.00	13.24	24.90	7.71
GX	1461.00	157.00	1647.00	312.00	3577.00	12.88	17.02	2.83
GZ	747.00	111.00	1623.00	265.00	2746.00	18.27	17.45	9.64
YN	185.00	218.00	2127.00	368.00	2898.00	20.44	14.11	14.54
CQ	3735.00	459.00	2672.00	563.00	7429.00	15.61	33.59	8.76
SC	4680.00	640.00	7080.00	1045.00	13445.00	14.78	31.11	9.62

(1) Analysis of the growth rate of digital economy in each province

Table 2 shows the size and structure of the digital economy for 30 provinces in China from 2017 to 2020, with each indicator being the average for the period from 2017 to 2020. As can be seen from the table, China's digital economy has a good development momentum, and the digital economy of all provinces in China has a positive growth trend during the observation period. The top five provinces with the fastest growth in digital economy are YN, SX, AH, GZ and JX, with growth rates of 20.44%, 19.71%, 18.84%, 18.27% and 16.41% respectively. However, the growth rate of digital economy in JL, LN and other provinces is less than 5%, which is far lower than the average growth rate, indicating that the cross-regional development of digital economy in each province is slightly different. In addition, 28 provinces and cities have a growth rate of digital economy that is much higher than their GDP growth rate, and only two provinces, XJ and GS, have a relatively slow

development of digital economy, and the growth rate of digital economy is lower than their own GDP growth rate. From a national perspective, the growth rate of the digital economy is 6.61% higher than the GDP growth rate on average, indicating that the digital economy has become a new driving force for the growth of provincial GDP and has played a strong role in promoting economic development.

(2) Analysis of the added value of digital economy in each province

During the survey period, all provinces and cities maintained a good development trend, and the digital economy flourished and reached a higher level of development. Table 2 shows that the provinces and cities with the highest level of development are GD, JS, ZJ, BJ and SC. In terms of added value, the digital economy added value of the above provinces exceeds 1 trillion yuan, and there are eight provinces and municipalities with digital economy added value of more than 500 billion yuan in turn. In terms of the proportion of digital economy in GDP, the scale of digital economy in BJ and GD accounts for more than 50% of regional GDP; FJ, HN, HB, AH and other provinces accounted for more than 30% of the total. The five provinces and cities with the lowest proportion of digital economy added value in local GDP are HN, JL, SX, IM and GS, with the proportion of 3.74%, 4.95%, 8.71%, 9.29% and 9.65% respectively, far lower than the average proportion of 21%, indicating that there is still room for further development of inter-provincial digital economy development level.

(3) According to the classification criteria, 30 provinces are divided into three major economic zones: eastern, central and western. It can be seen from the change trend of the digital economy scale and the proportion of digital economy in GDP of the three economic zones: (1) From the digital economy scale, the eastern region has the largest digital economy scale, followed by the central region, and the western region is the smallest. (2) In terms of the proportion of the scale of digital economy to GDP, the average scale of digital economy in the eastern region is 27.11%, much higher than the national average (20.97%), which contributes the most to economic growth. The proportion of digital economy size in GDP in central and western regions is lower than the national average, at 15.30% and 18.49% respectively.

4.2. Analysis of Gini coefficient results

Table 3. Results of Gini coefficient

		Intra-regional differences			Inter-regional difference			contribution rate %		
	Overall	Eastern	Central	Western	East-Middle	Middle-West	East-West	Intra-regional	Inter-regional	hypervariable density
2017	0.4345	0.3498	0.4094	0.3704	0.4042	0.5162	0.5276	29.8667	38.6892	31.4441
2018	0.3914	0.3559	0.2328	0.3725	0.3716	0.3573	0.5246	30.2293	53.2034	16.5673
2019	0.4022	0.3673	0.2824	0.3772	0.3867	0.3763	0.5136	31.0083	48.7051	20.2866
2020	0.4024	0.3686	0.2759	0.3808	0.3878	0.3744	0.5133	31.0183	48.6433	20.3384

As can be seen from the above, the development level of China's digital economy shows an unbalanced distribution in space. Therefore, this paper uses Gini coefficient to analyze the regional differences of China's digital economy from three regional perspectives: intra-regional differences, inter-regional differences and hypervariable density in the East, central and western regions.

(1) Overall difference

Table 3 shows the difference in the overall level of development of the digital economy from 2017 to 2020. During the study period, the proportion of inter-regional differences in the overall differences was much higher than that of intra-regional differences, and the average annual contribution accounted for 47.31%, indicating that the imbalance in the development of digital economy was mainly caused by inter-regional imbalance. The annual contribution rate of intra-regional differences

is 30.53%, indicating that intra-regional imbalance is also an important reason for the decline of the quality of digital economy development. The issue of interregional overlap in the development of the digital economy is reflected in hypervariable density, which contributes the least to overall inequality. The annual average of the overall Gini coefficient is 0.4077, and from the perspective of time, the overall difference mainly shows a downward trend, which indicates that there is a convergence of the disequilibrium in the development level of the digital economy. Due to their superior geographical location and developed economic infrastructure, eastern and central regions have been leading the country in the development level of digital economy, and the overall change amplitude and space are small. In short, regions with a lower level of development develop at a faster pace, while regions with a higher level of development develop at a slower pace, and the overall gap has narrowed and tended to balance during the study period.

(2) Intra-regional differences

During the study period, the average Gini coefficient of digital economy was in the western region, the eastern region and the central region in order from large to small, indicating that the western region had the largest difference in the development level of digital economy, and the central region had the smallest difference in the development level of digital economy. In terms of time, the Gini coefficient in the eastern and western regions increased slightly, while the difference in the development level of digital economy in the central region declined sharply in 2018 and has shown an upward trend since 2018. The main reason for the rise of the Gini coefficient in the western region is that QH, XJ and GS have weak digital foundation and limited growth rate of digital economy, while CQ, SC and NX have closely connected with the eastern region,under the influence of the diffusion effect in the eastern region, the digital economy has a higher development level and a faster growth rate.

(3) Inter-regional differences

During the study period, the highest Gini coefficient is in the east-west region, with an annual average of 0.520, and the lowest is in the east-central region, with an annual average of 0.388. From the time analysis, the Gini coefficient of the three regions mostly showed a relative downward trend. This shows that in recent years, with the support of various policies of the Chinese government, provinces have continuously carried out industrial restructuring and industrial upgrading, resulting in different degrees of improvement in the development of digital economy in various regions across the country, and the difference of digital in economic development between different regions has been relatively reduced.

5. Conclusions and Suggestions

This paper calculates the scale of the digital economy core industry in each province from 2017 to 2020, analyzes the spatial differences and dynamic changes of the digital economy scale in each region, and draws the following conclusions: (1) China's digital economy is developing rapidly, and the scale of the core industry of digital economy in all regions shows an overall increasing trend. However, the development difference between provinces is significant. The high-value area of digital economy development is mainly concentrated in the eastern coastal and developed regions, while the central and less-developed western regions are relatively lagging behind, showing obvious regional differences and non-equilibrium; (2) The dynamic evolution trend of the scale of the core industry of China's digital economy shows that the regional gap between the three regions is large in 2017, and has decreased significantly since 2018, and has maintained a relatively stable gap in the following three years. It shows that the scale of the core industries of digital economy in different regions of China is developing at the speed of synchronization and small difference, and the imbalance between regions may be further reduced. Based on this, I put forwards some suggestions:

(1)Attach importance to balanced development. Governments need to define the strategic positioning of each region to ensure that the development of the digital economy matches regional characteristics and strengths. For less developed areas, it is necessary to increase relevant support,

such as financial transfer payments, preferential policies, etc.. Developing digital skills training at the social level, build community support, and provide digital services and education through community centers, schools, etc., to reduce the digital divide between all sectors of society.

(2) Attach importance to the innovation-driven strategic direction. We will strengthen support for scientific and technological innovation, increase investment in research and development, encourage enterprises to make innovations, and build a sound scientific and technological innovation ecosystem. Focusing on education and personnel training, reform the education system, strengthen professional training related to the digital economy, and cultivate talents needed for the future digital economy.

(3) Attach importance to data security and ethics. We will strengthen relevant laws and regulations, formulate and improve relevant rules, and ensure data security and personal privacy. In terms of social order, to raise public awareness of data security and ethical issues, and to cultivate reasonable and responsible data use habits. At the same time, enterprises are the main force in the development of the digital economy, and it is necessary to cultivate corporate responsibility, emphasize the responsibility and obligation of enterprises in data management.

Through the above detailed discussion, we can more clearly understand the complexity and multi-dimensional characteristics of promoting the development of China's provincial digital economy. These Revelations and recommendations not only provide practical guidance for government decision-making, but also provide profound insights for corporate strategy and academic research, paving the way for the comprehensive and balanced development of China's digital economy in the future.

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