The comparative study on the digital economy and trade between China, the U. S. and the EU

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Abstract: The development of digital economy and expansion of digital trade has become an inherent requirement for China to seize the high ground of digital industry revolution, and to build a new development pattern in which the domestic circulation is the mainstay and the domestic and international double circulation promote each other. Clarifying China's position, especially its advantages and disadvantages relative to the U.S. and the EU in the international competition of digital economy and trade, is crucial to judge and guide the future development of China's digital economy in both domestic and international double circulation. At present, there are various methods to define and measure the digital economy and digital trade, but there is a lack of connection and comparison between different methods as well as between different countries from a global perspective. Based on the solid statistical measurements and comparative analysis of relevant data, we make in-depth research on scale pattern, structural pattern, dynamic pattern, competition pattern, dependency pattern, etc. between China, the U.S. and the EU, and find that China's digital economy and trade is "big but not excellent, fast but not first, surplus but not winning". Therefore, we propose policy suggestions for the sustainable development of China's digital economy and trade, such as

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comprehensively optimizing the digital economic structure, promoting strengths and avoiding weaknesses in the electronic equipment manufacturing industry, cultivating a new pillar of the information service industry, and reversing the disadvantages in the digital media industry.

Keywords : digital economy; digital trade; digital industry; international comparison; economic structure; competition pattern

1. Introduction

Countries around the world view the development of the digital economy as a crucial means to achieve high-quality economic development, improve international competitiveness and seize the initiative of global development. From the perspective of the global pattern, China, the U.S. and the EU have each occupied essential positions, becoming the mainstay of the international digital economy and trade development. In the 21st century, China, the U.S. and the EU have elevated the development of the digital economy to a national strategic level, and introduced a series of incentives. Chinese President Xi Jinping has repeatedly stressed the importance of the digital economy at important events, such as the World Economic Forum, the "Belt and Road" International Cooperation Summit, the Central Economic Work Conference, and the Collective Study Sessions of the Central Political Bureau, proposing to make China′s digital economy stronger, better and bigger. As a new economic form of new-generation information technology and its deep integration with traditional industries, the digital economy is becoming a key force in restructuring global factor resources, reshaping the global economic structure and transforming the global competitive landscape with its rapid development, wide radiation and unprecedented influence. Therefore, China strongly advocates the development of the digital economy and extension of digital trade, in an effort to build a new development pattern in which domestic circulation plays a leading role while domestic and international dual circulation promote each other (Jiang and Meng, 2021).

To further promote the digital economy and trade of our country, the international competitive landscape of China′s digital economy and trade and their strengths and weaknesses should be taken into full consideration. In addition, the targeted development proposals can be made. In such cases, the

academic community has been considering the scientific and objective measurement of the digital economy and digital trade scales as a frontier issue. The Organization for Economic Cooperation and Development (OECD), the International Monetary Fund (IMF), U.S. Bureau of Economic Analysis (BEA), China Academy of Information and Communications Technology and other domestic and foreign institutions have conducted useful explorations on the definition scopes and measurement methods of the digital economy and trade from different perspectives. At the same time, many scholars have also calculated the added value scales along different lines (Herrero and Xu, 2018; Xu and Zhang, 2020; Liu et al., 2021). However, as the new research objects, the digital economy and trade are characterized by unclear definitions and inconclusive coverage of industries, which causes large deviations in the results of the digital economy and trade measured by different institutions at present. Therefore, the only way to objectively assess China′s international competitive position on a comparable basis is to first study the statistical measurement of the digital economy and trade.

On the basis of clarifying the definition and measurement of the digital economy and digital trade in the literature, this paper constructs an internationally comparable analysis framework of the digital economy from three scopes, i.e., core definition, narrow definition, and broad definition, and also constructs an analysis framework of digital trade in the sense of core digital economy, with in-depth judgments on the scale pattern, structural pattern, dynamic pattern, competition pattern, and dependency pattern of the digital economy between China, the U.S. and the EU. The objective data results reflect that China′s digital economy is in the state of "big but not excellent, fast but not first, and surplus but not win" compared with the EU and U.S. in multiple aspects, and accordingly, we put forward countermeasures and suggestions for future development.

2. Concept definitions and measurement methods of the digital economy and trade

2.1. Concept definitions of the digital economy

The concept definitions of the digital economy have been gradually

changing with technological progress and social development. In summary, there are three scopes of definitions for the digital economy at present: core definition, narrow definition and broad definition (Bukht and Heeks, 2017). Among them, the core definition of the digital economy refers to the information and communication technology (ICT) industry. The OECD pioneered the study of the digital economy, and has always defined the connotation and extension of the digital economy scientifically with the ICT industry as the core. The ICT industry refers to manufacturing and service industries that acquire, transmit, and display data and information electronically, including basic innovation sectors such as semiconductors and processors, key technology production sectors such as computers and telecommunications equipment, and infrastructure production sectors such as the Internet and telecommunications networks (OECD, 2014).

The digital economy is narrowly defined as digital products and digital services built on the foundation of the ICT industry①, whose business models rely entirely or mainly on digital technologies, digital goods or digital services, including platform economy, mobile applications, payment services, sharing economy and gig economy (Bukht and Heeks, 2017). The U.S. Bureau of Economic Analysis adopts this definition (Barefoot et al., 2018), and suggests three components that the digital economy includes: the first is the digitally enabled infrastructure which allows computers and networks to exist, the second is e-commerce achieved by network systems, and the third is digital media created and applied by the users of the digital economy.

The broad definition of the digital economy includes the digital transformation adopting digital technologies and services in traditional industries. And its representative definition proposed by the Group of Twenty (G20) at the 2016 Hangzhou Summit is "a series of economic activities that use digital knowledge and information as key factors of production, modern information networks as important carriers, and the effective use of information and communication technologies as an important driving force for efficiency

① United Nations Conference on Trade and Development (UNCTAD). Digital economy report 2019 value creation and capture: implications for developing countries [EB/OL]. (2019-09-04) [2022-02-20]. https://unctad.org/webflyer/digitaleco-nomy-report-2019.

improvement and economic structural optimization"②. China Academy of Information and Communications Technology adopts this definition, and refers to the broad digital economy as "industrial digitization", which represents the production quantity and production efficiency improvement in traditional industries generated by the application of digital technology (Kang, 2008). The Digital Economy and its Core Industries Statistical Classification③ published by the National Bureau of Statistics in 2021 refers to the broad digital economy industry as the digital efficiency improvement industry, which represents the increase in output and efficiency improvement brought by the application of digital technology and data resources for traditional industries. As a result, the broad digital economy is an advanced economic form based on the information industry, the information economy and the Internet economy, which is a comprehensive manifestation of the gradual generalization and integration of information technology into other traditional industries. It means that it can reflect the degree and effect of digital transformation of traditional industries to some extent.

2. 2. Measurement methods of the digital economy

It is a tough but urgent problem to measure scientifically and assess effectively the digital economy of each country. Largely, the accounting framework for gross domestic product (GDP) largely does not calculate the value of digital goods and services, including open-source software, online media, online platforms, etc. Many digital products and digital services are free, such as search engines, email and online maps, which makes the price index fail to reflect reality as well. However, a change in the current GDP accounting framework and rules not only fails to solve the above problems, but also brings more new challenges④ (Cai, 2018). In this connection, different research

② The Organizing Committee for the 2016 G20 Summit. G20 Initiative on Digital Economy Development and Cooperation [EB/OL]. (2016-09-20) [2022-01-04]. http://www.g20chn.org/hywj/dn-cgwj/201609/t20160920_3474.html.

③ National Bureau of Statistics. Statistical Classification of the Digital Economy and its Core Industries (2021) [EB/OL]. (2021-06-03) [2021-12-04]. http://www.stats.gov.cn/tjsj/tjbz/202106/t20210603_1818134.html.

④ International Monetary Fund (IMF). Measuring the digital economy [EB/OL]. (2018-04-03) [2022-02-20]. https://www.imf.org/en/Publications/Policy-Papers/Issues/2018/04/03/022818-measuring-the-digital-economy.

institutions around the world are striving to explore various digital economy measurement methods.

The OECD is the pioneer focusing on core digital economy measurement research. In *Measuring the Digital Economy: A New Perspective*, the OECD proposes a method that measures the added value of the ICT sector instead of the added value of the digital economy (OECD, 2014). The items to be measured include those in part 26 (computer, electronic and optical products manufacturing) of the ISIC 4th edition, and categories 58 to 60 (publishing and broadcasting), 61 (telecommunications) and 62 to 63 (computer programming and information services) in Section J (information and communication services). At the same time, although the OECD proposes to include ICT trade and maintenance activities (categories 465 and 951) in the scope of measurement, it also acknowledges that this proposal can be ignored due to the unavailability of such data in most cases. Herrero et al. (2018) summed up and calculated both digital manufacturing products and digital services in China according to the OECD operation manual and *Input-output Table of China in* 2012 published by the National Bureau of Statistics.

The U.S. Bureau of Economic Analysis (BEA) is the pioneer organization in the statistical measurement of the narrow digital economy. With the publication of Defining and Measuring of the Digital Economy⑤ in 2018, the BEA provides a comprehensive introduction and measurement of the US digital economy and its penetration into various economic sectors. Specifically, the BEA categorizes ICT-related industries into three digital industries, namely, digitally-enabled infrastructure, e-commerce and digital media according to the data of the input-output table, and sums their added value, then multiplies the added value of other industries by the ratio of intermediate inputs of digital industries to total inputs in that industry, and sums the above two to determine the scale of the digital economy. Kang (2008) measured China's digital economy in terms of the added value of the digital industry sector and the added value of digital auxiliary activities based on the digital economy measurement of

⑤ Available at: U.S. Bureau of Economic Analysis (BEA) . Defining and Measuring the Digital Economy [EB/OL]. (2018-03-15) [2022-02-19]. https://www.bea.gov/sites/default/files/papers/defining-and-measuring-the-digital-economy.pdf.

the U.S. Bureau of Economic Analysis Xu and Zhang (2020) categorized the digital economy into four parts: digitally-enabled infrastructure, digital media, digital transactions and digital economy transaction products, and measured the added value of China′s digital economy from 2007 to 2017 by drawing on the U.S. Department of Commerce′s methodology.

As a key to measuring the broad digital economy, it is crucial to decompose the part which is attributed to the digital economy in traditional industries. Cai (2018) argued that industrial digitization can be measured from the contribution of ICT capital growth to GDP growth. In this way, he measured the added value of China′s broad digital economy from 1993 to 2018 through the substitution and synergy effects of ICT (Cai and Niu, 2021). In White Paper on China′s Digital Economy Development and Employment (2019), China Academy of Information and Communications Technology measures the spillover value of the digital economy in other industries through the stock of ICT investment in the industry⑥. Specifically, China Academy of Information and Communications Technology firstly takes the total fixed asset formation of ICT, including computer, communications equipment and software in the input-output table as the base, and then calculates the actual stock of ICT investment in each industry across the country in that year, according to the perpetual inventory method with parameters, such as depreciation rate of 0.315, 5-year useful life and ICT investment price index (at constant 2,000 prices), and finally summed up to determine the digitization scale of industries in the broad digital economy.

Under the three definitions, only the scale of the core digital economy and the narrow digital economy can be measured directly within the GDP framework, which is used by the OECD, the U.S. Bureau of Economic Analysis and most scholars, with relatively close results. As the broad digital economy involves the integration part of the traditional industries, it is difficult to strip out the value belonging to the digital economy in the traditional industries, thus little exploration has been done in this regard. China Academy of Information and Communications Technology offers a viable method that introduces new ideas

⑥ Available at: China Academy of Information and Communications Technology (CAICT). China' s Digital Economy Development and Employment (2019) [EB/OL]. (2019-04-18) [2022-02-20]. https://mp.weixin.qq.com/s/dRiIPWE0Qah8dUvNhnbIRg.

for horizontal comparisons of the digital economy between different countries and regions, albeit the result is large and widely questioned.

2. 3. Concept definitions and measurement methods of digital trade

The rapid development of the digital economy has reshaped global trade, spawning digital trade as a new trade model, and gradually becoming an important indicator for assessing the international competitiveness of each country′s digital economy. With the extension of the definition and measurement of the digital economy, the connotation and extension of digital trade are also expanding (Lan and Dou, 2019). Early digital trade refers to commercial activities in which priced products or services are transmitted through electronic means, such as the Internet (Weber, 2010); however, the scope covered by digital trade has gradually expanded in practical measurements. For example, the United States International Trade Commission (USITC), in 2013, subdivided digital trade into four categories, namely digital content, social media, search engines and other digital products and services, while excluding physical products with digital characteristics⑦. In 2014, the USITC further included international trade based on Internet technologies that play a significant role in the ordering, production, or delivery of products and services⑧. By 2017, the USITC believed that digital trade includes not only final consumer goods sold and supplied on the Internet, but also data flows that enable global value chains and service flows that enable smart manufacturing, etc⑨.

The academic community has always had difficulties in measuring digital trade, mainly from the fact that digital technology has been integrated into all fields of the national economy, and it is not practical to measure digital trade with complete accuracy. In 2017, the OECD proposed that digital trade can be counted in three aspects: digital ordering, digital platforms and digital delivery (Ma et al., 2018; OECD, 2017). In 2020, the OECD further extended its statistics

⑦ The United States International Trade Commission (USITC). Digital trade in the U.S. and global economies, part 1 [EB/OL]. (2013-07) [2022-02-20]. https://www.usitc.gov/publications/332/pub4415.pdf.

⑧ The United States International Trade Commission (USITC). Digital trade in the U.S. and global economies, part2 [EB/OL]. (2014-08) [2022-02-20]. https://www.usitc.gov/publications/332/pub4485.pdf.

⑨ The United States International Trade Commission (USITC). Global digital trade 1: market opportunities and key foreign trade restrictions [EB/OL]. (2017-08) [2022-02-20]. https://www.usitc.gov/publications/332/pub4716.pdf.

from digital services to digital goods, and proposed 10 measurement recommendations for trade delivered digitally, without giving precise recommendations for measurement indicators (OECD et al., 2020). Some empirical studies tend to take a statistical approach to industries with typical characteristics of digital trade. For example, Liu et al. (2021) measured international trade data in three typical industries, namely "film, video and television production, sound recording and music publishing activities, and programming and broadcasting activities", "computer programming, consulting and other related activities and information service activities", and "telecommunications industry".

In summary, similar to the expansion of the measurement scope of the digital economy from the core to the narrow and the broad definition, the measurement scope of digital trade is also expanding from digital goods and services to ordinary transactions facilitated by digital means. However, international organizations, such as the World Trade Organization (WTO) do not yet conduct separate statistics on cross-border transactions through digital means, when publishing import and export data for each industry, therefore the import and export data of the core digital economy is still dominant in international comparative analysis.

3. The comparative analysis of the digital economy between China, the U. S. and the EU

The scale of a single digital market is particularly important for the development of the digital economy, as the strong penetration and wide coverage advantages of the digital economy need to be effectively exploited within a larger single digital market. That is why the EU has been sparing no efforts to create a single digital market and design the rules from a comprehensive view, which makes it qualified to compete with China and the U.S., the two natural digital single markets, forming a triple balance of power. Coupled with the inherent characteristics of the development of the digital economy, such as the network effect, Matthew effect and multiplier effect, the scale of the established digital economy will profoundly affect the future pattern.

3. 1. The comparison of the core digital economy between China, the U. S. and the EU

The European Commission has conducted statistics on the core digital economy for the EU 28 (pre-Brexit) as well as 12 major countries, including China and the U.S., with the full version of the data now updated to 2018. The European Commission′s operational definition of the ICT industry is categorized into two sectors, namely ICT and MC (media content), where the ICT sector includes ICT manufacturing and ICT services, and the MC sector includes book, periodical and other publishing activities, audiovisual and broadcasting activities and other information service activities. In this paper, ICT manufacturing, ICT services, and MC are referred to as the electronic equipment manufacturing industry, information service industry, and digital media industry, respectively. As shown in Fig. 1, in terms of the scale, the US led the world in digital economy in 2018 with EUR 1339.1 billion; the next place was the EU with EUR 801.8 billion; China followed closely behind with EUR 644.1 billion. In terms of the structure, China coordinated its digital economy driven by "two wheels", namely, electronic equipment manufacturing industry (41%) and information service industry (49%); the U.S. gave priority of information service industry (67%) while making digital media industry (23%) subsidiary; and the EU relied mainly on information service industry (75%).

3. 2. The comparison of narrow digital economy between China and the U. S.

The cross-country comparison of narrow digital economy is mainly for China and the U.S., as the European Commission does not measure and publish the data. The U.S. Bureau of Economic Analysis (BEA) has been publishing the data on narrow digital economy since 2016, with the most recent data published in June 2021. The scale of China′s narrow digital economy can be measured from the input-output table data from the National Bureau of Statistics. The input-output table can reflect the added value of sub-sectors in the national economy as well as the intermediate input relationship between every two sectors. For example, the latest input-output table published by the National Bureau of Statistics in 2018, lists a total of 159 sub-sectors. Among them, the narrow digital economy includes a total of 13 sub-sectors such aselectronic equipment manufacturing industry, information service industry, digital media

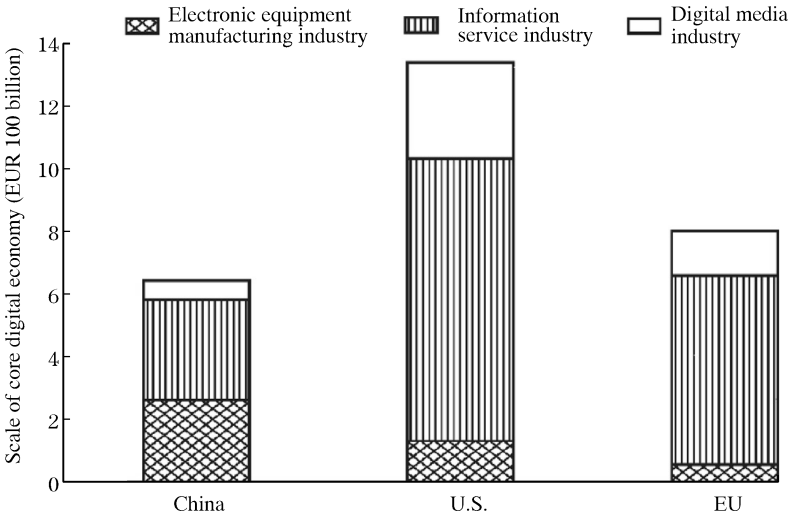

Fig. 1. The comparison of the scale and structure of the core digital economy between China, the U.S. and EU in 2018

Note: The data come from PREDICT project of the European Commission.

industry, etc⑩. In addition, the scale of the related digital economy is equal to the sum of the added value of these 13 sectors; The remaining 146 sub-sectors belong to traditional industries, and the scale of the related digital economy is equal to the added value of each sector multiplied by the coefficient of digital economy spillover value. By drawing on the U.S. Bureau of Economic Analysis′ measurement method, the coefficient of digital economy spillover value is the ratio of digital industries as intermediate inputs to total inputs, with the implicit assumption that "the proportion of intermediate consumption of digital economy in each industry to total digital economy output is the same as the proportion of intermediate consumption in the industry to which it belongs to total output" (Xu and Zhang, 2020). Therefore, the scale of China′s digital

⑩ Electronic equipment manufacturing industry includes 6 industries, such as computers, communications equipment, radio and television equipment, radar and supporting equipment, audio-visual equipment, electronic components and other electronic equipment; information service industry includes 5 industries, such as telecommunications, radio and television and satellite transmission services, Internet and related services, software services and information technology services; and digital media industry includes 2 industries, such as news and publishing industry, as well as radio, television, film and video recording production.

economy is the sum of the added value in digital industries and the spillover value of digital economy in traditional industries.

As shown in Table 1, this paper compares and analyzes the digital economy between China and the U.S. in terms of the scale of added value, the proportion of GDP, growth rate, and the number of people employed.

Table 1 The comparison of scale, proportion and employment in narrow digital economy between China and the U.S., from 2005 to 2018

Year	Scale of digital economy		Proportion of digital economy in GDP (%)		Proportion of China's digital economy in the U.S. digital economy (%)	Number of people employed in digital industry (10,000 people)	
	China (USD 100 million)	U.S. (USD 100 million)	China	U.S.		China	U.S.
2005	1,779	9,076	7.9	7.0	19.60	1,558	261
2007	2,253	10,989	6.6	7.6	20.50	1,467	253
2010	3,875	12,959	6.5	8.6	29.90	2,184	226
2012	5,081	13,958	6.0	8.6	36.40	2,026	228
2015	8,166	17,120	7.5	9.4	47.70	2,522	230
2017	9,204	19,666	7.5	10.1	46.80	2,401	233
2018	10,783	20,897	7.8	10.2	51.60	2,399	237

Note: China's data come from the National Bureau of Statistics of China, and the data of the U.S. comes from the U.S. Department of Commerce; since the input-output tables published by the National Bureau of Statistics of China are not continuous, the measurement years of digital economy are also not continuous; in the comparison of the digital economy between China and the U.S., the scale of China's digital economy is calculated by converting the annual average exchange rate between RMB and USD in that year.

(1) China's digital economy was larger than 50% of that of the U.S. China has witnessed an annual expansion of its digital economy from 2005 to 2018, growing from less than RMB 1.5 trillion in 2005 to more than RMB 7 trillion in 2018. We converted the scale of China's digital economy to the average exchange rate of that year, and then compared the results with the U.S. digital economy. In this way, we found that China's digital economy was only

19.6% of the U.S. digital economy in 2005, but this ratio has increased year by year, ultimately, surpassing 50% of the US digital economy (51.6%) in 2018.

(2) The proportion of China′s digital economy in GDP was slightly lower than that of the U.S. From 2005 to 2018, the proportion of China′s digital economy in GDP remained between 6% and 8%, with some decline during the period. In contrast, the digital economy in the US averaged 8.8% of GDP during the same period, and has risen to 10.2% in 2018 in particular, much higher than 7.8% in China. This shows that China′s digital economy has developed in tandem with the other economies, with no significant change in the economic structure, while the U.S. digital economy has been further strengthened.

(3) China′s digital economy has grown twice as fast as that of the U.S. From 2005 to 2018, China′s digital economy has grown at an average annual rate of 12.9%, compared to 6.6% in the U.S. In the same period, China′s GDP has grown at an average annual rate of 13.0%, while the GDP of the U.S. has grown at an average annual rate of 3.6%. It is clear that the U.S. digital economy has grown twice as fast as its GDP, but China′s digital economy has kept pace with its GDP growth.

(4) The number of people employed in the digital industry in China was 10 times higher than in the U.S. The scale of employment in the digital industry can be further measured by dividing the remuneration of workers in the electronic equipment manufacturing industry, information service industry and digital media industry by the average wage of each industry. The data show that the employment scale of China′s digital industry was about 24 million in 2018, compared to about 2.37 million in the U.S. However, the employment structure of the two countries was very different. In China′s digital economy, 60% of employment was concentrated in electronic equipment manufacturing industry, consisting mainly of industrial workers, while in the U.S. digital economy, about 70% of employment was concentrated in the information service industry, consisting mainly of technical engineers. Nevertheless, the number of people employed in information technology in China was much higher than the 1.6 million in the U.S. That means China enjoyed a scale advantage in terms of talent in enhancing the speed and quality of development in digital economy.

3.3. The comparison of broad digital economy between China, the U.S. and EU

China Academy of Information and Communications Technology adopts a broad definition to measure its digital economy, including both digital industrialization and industrial digitization. Digital industrialization measures the added value of industries, such as electronic information manufacturing industry, basic telecommunication industry, Internet industry and software service industry, while industrial digitization measures the added value brought by the application of digital technology in traditional industries. As the broad digital economy has wider connotations, the scale of digital economy measured by it differs significantly from the scale of digital economy in the core and narrow senses. According to The New Picture of Global Digital Economy (2020)[11] published by China Academy of Information and Communications Technology, in 2019, the scale of digital economy in China, the U.S. and Europe is about USD 5 trillion, USD 13 trillion and USD 7 trillion, respectively, almost all 10 times the European Commission's core digital economy measurement in 2018. As shown in Fig. 2, the U.S. and China are the largest countries in terms of the broad digital economy, and Germany, the UK, and the U.S. have the highest broad digital economy scale as a proportion of GDP.

In terms of structure, the scale of global industrial digitization was much higher than the scale of digital industrialization. In addition, the higher the level of economic development of countries, the higher the proportion of industrial digitization. Among them, China's industrial digitalization accounted for 80.2% of the digital economy, which was basically the same as the proportion of industrial digitalization in middle and high-income countries (80%), but lower than developed countries, such as the U.S. and the UK, and 10 percentage points lower than Germany (90.3%), which had the highest proportion.

In summary, the U.S. still had an absolute advantage in the global competitive landscape for the scale of broad digital economy, followed by the

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[11] Available at: China Academy of Information and Communications Technology (CAICT). The New Picture of Global Digital Economy (2020) [EB/OL]. (2020-10-14) [2022-02-20]. http://www.caict.ac.cn/kxyj/qwfb/bps/202010/P020201014373499777701.pdf.

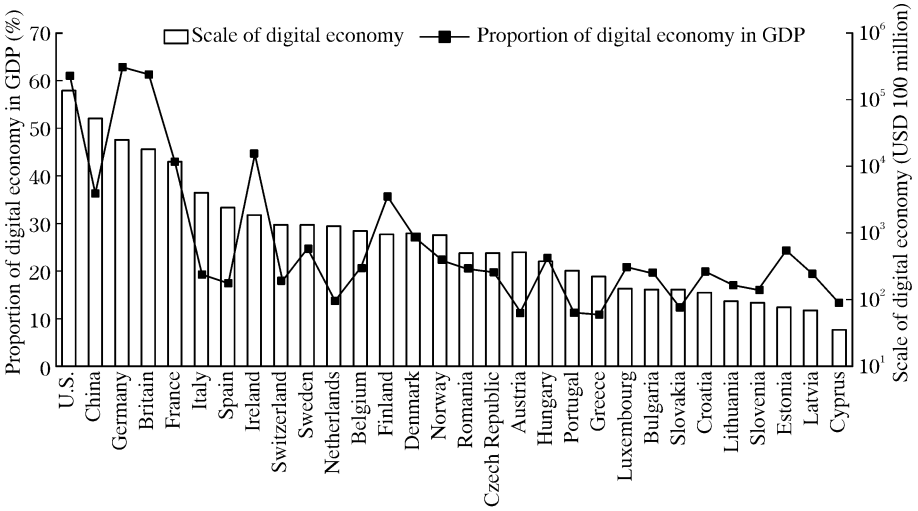

Fig. 2. The scale and proportion of broad digital economy in GDP between China, the U.S. and EU

Notes: 1. The data on scale of broad digital economy between China, the U.S. and EU come from The New Picture of Global Digital Economy (2020) published by China Academy of Information and Communications Technology;

2. The GDP data of each country come from the World Development Indicators of the World Bank.

EU and finally China, which was basically the same as the competitive landscape for the core digital economy and narrow digital economy. In terms of the internal structure of digital economy, although the U.S. and EU had slightly more digitalized industries than China, the gap was not significant.

4. The comparative analysis of digital trade between China, the U.S. and EU

The digital trade can reflect the competitive landscape of digital economies between China, the U.S. and EU, with a difference in the scale of these digital economies, i.e., the sizes of China, the U.S. and the EU in terms of the scale of digital economies do not always coincide with the superiority or inferiority pattern of digital trade. Therefore, on the basis of comparing the scale of digital economy in various countries, a further comparison of digital trade is needed. In

the international market of economic globalization, production, division of labor and trade in digital economy are the result of selection preferences based on differentiated products, and the result of free competition, consequently, comparative analysis can still be conducted in the framework of international trade analysis, and the international competitiveness of digital economy of each country can be judged through indicators, such as import and export volume and trade surplus. For example, an industry in digital economy has a trade surplus, which represents that the products or services under the industry are more popular with users in the international market. No matter whether this popularity stems from a low price of the product or from a uniqueness of the product itself, provided that it has won orders from the international market and achieved a trade surplus, it shows that it has an international competitive advantage.

4.1. The comparison of digital trade between China, the U.S. and EU

According to the data of sub-sectors published by WTO, the import and export of digital trade can be divided into two major parts: digital goods and digital services. Among them, ICT manufacturing-related items can be called digital goods, including electronic data processing and office equipment, telecommunications equipment as well as integrated circuits and electronic components and other three sub-sectors; and ICT services-related items can be called digital services, including telecommunications, computer and information services among other business services. The statistical results of the latest WTO trade data in 2019 are shown in Table 2.

Digital exports are the sum of exports of digital goods and exports of digital services, which can reflect the competitive strength of a country and region′s digital economy in the global market. The data shows that the three major economies namely China, the U.S. and EU together accounted for nearly 60% of global digital exports. Among them, China′s digital exports reached USD 706 billion, which accounted for 26% of global digital exports and ranked first, higher than USD 698.5 billion in the EU and much higher than USD 204.1 billion in the U.S. It is important to note that 55% of the EU′s digital exports are trade transactions between its internal countries. With the data on trade between the EU 28 countries stripped out from each other, the EU′s external digital exports stood at USD 312.5 billion, or 11.5% of the world.

Table 2 Statistical results of digital trade between China, the U. S. and EU in 2019

Rregion	Digital export						Digital trade					
	Digital goods		Digital services		Total export		Digital goods		Digital services		Total trade	
	Export volume (USD 100 million)	Proportion (%)	Export volume (USD 100 million)	Proportion (%)	Export volume (USD 100 million)	Proportion (%)	Trade volume (USD 100 million)	Proportion (%)	Trade volume (USD 100 million)	Proportion (%)	Trade volume (USD 100 million)	Proportion (%)
China	6,522	32.2	538	7.9	7,060	26.0	1,978	84.4	269	9.1	2,247	42.4
US	1,485	7.3	557	8.1	2041	7.5	−1,919	−81.9	119	4.0	−1,799	−34.0
EU (all)	3,638	18.0	3,347	48.9	6,985	25.8	−1,034	−44.1	1,808	61.2	774	14.6
EU (external)	1,176	5.8	1,949	28.5	3,125	11.5	−1,220	−52.1	1,120	37.9	−100	−1.9
Others	8,621	42.5	2,400	35.1	11,021	40.7	−1,369	−58.4	758	25.6	−611	−11.5
Total	20,266		6,841		27,107		−2,344		2,954		5,298	

Note: The data come from WTOStats. The data of the EU, UK and 27 other countries are included. "EU (all)" represents all trade situations of 28 countries, and "EU (external)" strips internal trade flows between 28 countries.

Digital trade refers to the scale of net exports of digital goods and digital services, that is, a country's digital exports minus its digital imports, which reflects the extent to which a country or region's digital economy is integrated into or dependent on global markets. The data shows that China had the largest digital trade surplus, with USD 224.7 billion. In contrast, the U.S. had the largest digital trade deficit, with a deficit of USD 179.9 billion. The EU had a deficit of USD 10 billion in external digital trade, which was relatively balanced.

In terms of the digital goods, China had an absolute competitive advantage. In 2019, China's digital goods exports amounted to USD 652.2 billion, which was more than four times that of the second-place U.S., a significantly higher figure than the overall EU's USD 363.8 billion. In terms of the trade surplus, China was the absolute first power, accounting for 42% of the world, while digital goods of the EU and the U.S. were in a serious trade deficit. That indicates that China was a major manufacturer of electronic equipment, and enjoyed a unique competitive advantage in the global market, where the electronic equipment produced was supplied to major global markets such as the EU and U.S.

In terms of the digital services, the EU was the top exporting economy for digital services, accounting for 49% of the global export market.After stripping trade between countries within the EU, it still held 28% of the global share. In terms of the digital services exports and imports, the EU had a larger proportion of the global trade surplus. However, from the perspective of the EU, except for Ireland, which has become Europe's "Silicon Valley" by virtue of its special policy positioning and location advantage, ranking first in the world in digital service exports all year round, the digital service exports of the rest of the EU countries were smaller than that of China. The U.S. exported USD 55.7 billion of digital services, slightly higher than USD 53.8 billion from China. However, in terms of the trade surplus, USD 26.9 billion from China was higher than USD 11.9 billion from the U.S.

4. 2. The analysis of destinations and origins of digital trade between China, the U. S. and EU

For the purpose of further exploring the digital trade pattern of China, the

U.S. and EU, and clarifying the interaction and dependence of each economy in the field of digital trade, it is necessary to further analyze the country or regional structure of import and export of digital trade. UN Comtrade Database has the advantage that it contains detailed import and export statistics reported by the statistical departments of 200 countries or regions worldwide, and covers the scale of trade between two countries or regions, which can reflect the intensity of trade between two countries or regions in specific industries (Qiao et al., 2022), but its data on digital services trade between China, the U.S. and EU were only updated to 2017. In contrast, while WTOStats lacks import and export data between countries in the field of trade in digital goods, it includes recent data on trade in digital services between economies. To make the research results both complete and current, this paper uses the UN Comtrade Database to analyze trade data of digital goods in 2020, and uses WTOStats to analyze trade data of digital services in 2019.

The top ten countries or regions in terms of the exports and imports in the field of digital goods trade from China, the U.S. and EU in 2020 are shown in Table 3. China was the most important origin of imports of digital goods for the U.S. and EU, accounting for 37% of the U.S. imports and 50% of EU imports; at the same time, China was also the second-largest destination of exports of digital goods for the EU, and the fourth-largest for the U.S. As a result, China, the U.S. and EU were dependent on each other in the field of digital goods trade.

The top ten countries or regions in terms of the exports and imports in the field of digital goods trade from China, the U.S. and EU in 2019 are shown in Table 4. Among them, the EU and U.S. were the most important destinations for China′s digital services exports, with 47% of China′s digital services exported to the US and EU; at the same time, China was also highly dependent on digital services trade exports from the U.S. and the EU to it, with the EU and U.S. together accounting for 56% of China′s digital services imports. The U.S. and EU were characterized by mutual dependence in the field of digital services trade. We can draw that conclusion from the following situations: 31% of digital services exported from the U.S. were destined for the EU, and the EU was the second-largest origin of digital services imports to the U.S.; for the EU, the U.S. was the most important destination of digital services exports and

Table 3 Top ten destinations of export and origins of import of digital goods trade between China, the U.S. and EU in 2020

Sort by	China				U.S.				EU			
	Destination of export	Percentage (%)	Origin of import	Percentage (%)	Destination of export	Percentage (%)	Origin of import	Percentage (%)	Destination of export	Percentage (%)	Origin of import	Percentage (%)
1	Hong Kong, China	20.6	Japan	15.5	Mexico	21.1	China	36.5	US	14.1	China	50.3
2	EU	17.6	Taiwan, China	13.0	EU	15.5	Mexico	14.9	China	13.3	Vietnam	7.5
3	U.S.	17.4	South Korea	12.9	Canada	12.6	Vietnam	9.1	Switzerland	6.0	U.S.	6.0
4	Japan	5.1	Vietnam	12.0	China	8.6	Taiwan, China	6.6	Taiwan, China	5.1	Japan	4.1
5	Netherlands	5.0	EU	8.0	South Korea	5.9	EU	6.4	South Korea	5.0	Malaysia	3.3
6	Vietnam	4.7	U.S.	3.0	Hong Kong, China	4.7	South Korea	5.7	Russia	3.5	Taiwan, China	3.3
7	South Korea	3.4	Malaysia	2.9	Japan	4.7	Japan	5.2	Norway	3.1	South Korea	2.6
8	India	2.9	Germany	2.7	Taiwan, China	4.5	Malaysia	4.5	Japan	2.9	Thailand	1.9
9	Mexico	2.8	Thailand	2.2	Netherlands	4.0	Thailand	3.1	Türkiye	2.8	Mexico	1.5
10	Germany	2.6	Singapore	1.9	Germany	3.2	Germany	1.8	Hong Kong, China	2.0	Morocco	1.5

Notes: The data come from the UN Comtrade Database, and the latest disclosed data are used in the paper; the EU data include the UK and 27 other countries and regions, and the statistics on the destination and origin of EU digital goods trade strip the internal trade data between the 28 countries and regions.

Table 4 Top ten destinations of export and origins of import of digital services trade between China, the U. S. and EU in 2019

Sort by	China				U.S.				EU			
	Destination of export	Percentage (%)	Origin of import	Percentage (%)	Destination of export	Percentage (%)	Origin of import	Percentage (%)	Destination of export	Percentage (%)	Origin of import	Percentage (%)
1	EU	24.4	EU	38.4	EU	31.4	India	35.0	US	71.8	US	34.4
2	U.S.	22.9	Britain	18.5	Canada	10.3	EU	31.1	Switzerland	18.6	India	7.4
3	Hong Kong, China	16.2	U.S.	17.9	Britain	8.8	Ireland	14.4	Australia	7.0	Switzerland	7.3
4	Japan	5.5	Hong Kong, China	14.5	Japan	7.0	Canada	10.7	Norway	5.8	Bermuda	2.6
5	Britain	4.5	Singapore	6.1	Ireland	6.0	Britain	7.0	Japan	4.9	China	2.5
6	Singapore	4.0	Ireland	4.5	Brazil	5.8	Philippines	3.1	Singapore	4.8	Canada	2.1
7	Australia	3.1	Germany	4.5	Switzerland	5.4	Norway	2.1	China	4.7	Norway	1.9
8	Germany	3.0	South Korea	3.6	Australia	4.2	Mexico	1.9	UAE	3.6	Morocco	1.9
9	Netherlands	2.7	Australia	2.8	Germany	4.0	Germany	1.8	Russia	3.2	Singapore	1.8
10	Italy	2.0	Japan	2.1	Mexico	3.6	Switzerland	1.5	India	3.0	Israel	1.4

Note: The data come from the World Trade Organization, the EU data include the UK and 27 other countries and regions, and the statistics on the destination and origin of EU trade in digital services strip the trade data between the 28 countries and regions.

origin of imports, resulting in a greater dependence on the U.S. market. However, China was not listed among the top ten destinations of exports and origins of imports for the U.S. digital services trade (ranked 13th for both exports and imports), while it was the seventh-largest destination of external exports and the fifth-largest origin of imports for the EU.

4.3. The analysis of China's digital trade structure

To further analyze the changes in the trade status of the three major digital industries, namely, electronic equipment manufacturing industry, information service industry and digital media industry, in China's digital economy, as well as the import and export of more sub-sectors, such as electronic components, this paper analyzes the data from the input-output table of the National Bureau of Statistics from 2002 to 2018, and the results are shown in Table 5. China's digital trade experienced a faster growth trend from 2002 to 2017, with net exports growing from RMB −65 billion in 2002 to RMB 762 billion in 2017, increasing by 235% per year on average, but starting to decline in 2018. From the perspective of trade structure, net exports of electronic equipment manufacturing industry reached a peak of RMB 772.2 billion in 2017, accounting for 101% of total net exports, and more than 95% in other years, which indicates that China's digital goods trade is mainly driven by electronic equipment manufacturing industry. However, electronic components in the electronic equipment manufacturing industry has been in a state of trade deficit, and the deficit scale increases year by year, making it the weakest part of international competition. The overall trade of information service industry showed a growth trend, which peaked at RMB 42.9 billion in 2010, and then declined year by year, emerging with a trade deficit for the first time in 2018. The digital media industry, on the other hand, suffers mainly from a trade deficit (except in 2005), with a peak deficit of RMB 146 billion in 2015 in particular, which indicates that the disadvantaged position of China's digital media industry in terms of the international competition has not yet fundamentally changed.

Table 5 China's digital trade and its net exports for industrial structure from 2002 to 2018 (RMB 100 million)

Year	Electronic equipment manufacturing industry	Electronic components	Information service industry	Digital media industry	Digital trade
2002	−599.4	−2,644.1	16.0	−66.7	−650.1
2005	2,113.6		63.9	49.7	2,227.2
2007	5,078.8	−7,414.6	47.5	−37.2	5,089.2
2010	6,464.0		429.1	−107.5	6,785.5
2012	6,079.2	−9,804.2	258.8	−350.6	5,987.5
2015	5,230.8		160.0	−1,460.5	3,930.2
2017	7,722.3	−13,447.0	286.1	−387.9	7,620.5
2018	6,315.3	−15,594.7	−213.9	−887.1	5,214.4

Note: The data come from the National Bureau of Statistics. The empty part of the data means it is missing. The larger fluctuation of the data on digital media industry is related to the facts that the data of sub-sectors are not disclosed in some years, and the data on the whole industry of "culture, sports and entertainment" is used instead.

5. The pattern study and related countermeasures of digital economy and trade between China, the U.S. and EU

With the rapid development of digital technology and its common application in many industries, the concept connotation and measurement scope of digital economy and digital trade are also expanding. Many studies have carried out different measurements according to different levels of understanding and different methods, which resulted in inconsistent measurement results, ultimately, causing difficulties in scientific and objective research on the digital economy and trade patterns between China, the U.S. and EU. However, these diverse definition ranges and measurement methods provide multiple data sources and multiple comparison methods for judging the global digital economy and trade patterns. Through a comparative analysis of core digital economy, narrow digital economy and broad digital economy, this paper explores the digital economy patterns between China, the U.S. and EU from multiple

perspectives. In this way, the following basic conclusions are drawn:

First, from the perspective of scale pattern, the world has formed a triple balance of power between the U.S., EU and China in digital economy pattern. Specifically, the scale of China's core digital economy in 2018 was 48% of the U.S. and 80% of the EU, the scale of China's narrow digital economy in 2018 was 52% of the U.S., and the scale of China's broad digital economy in 2019 was about 40% of the U.S. and 73% of the EU. The data from all three statistical calibers show that the U.S. is the world's biggest digital economy, followed by the EU in second and China in third. Despite the advantage of its huge market scale, China still has a significant gap compared to the U.S. and EU in the digital economy.

Second, from the perspective of the structural pattern, the U.S. and EU have more advantages than China's digital economy, while China is in the state of "big but not excellent". In terms of the core digital economy, the proportion of electronic equipment manufacturing industry in the U.S. and EU was less than 10%, while China amounted to 41%, resulting in the unrealized potential of information service industry and digital media industry with highly innovative and high value. In terms of the broad digital economy, China's industrial digitization also accounts for a lower proportion of the digital economy than major developed countries such as the U.S., UK and Germany, especially Germany was up to 90%, higher than China's 80%, which indicates that China's digital economy is not yet integrated enough into the real economy,and has not yet been able to create a new growth space in the wider real economy. This disadvantage is also reflected in the employment structure, with China's digital economy workforce dominated by industrial workers in electronic equipment manufacturing industry, while the U.S. and EU are dominated by IT engineers. Therefore, too much of China's digital economy is accounted for by the electronic equipment manufacturing industry as the "hardware segment", while the information service industry and digital media industry as the "software segment" still have much room for improvement.

Third, from the perspective of the dynamic pattern, the gap between China and the U.S. in terms of the scale of their digital economies has gradually narrowed, but China's digital economy has not grown faster than the traditional economy as the U.S. has, being in a state of "fast but not first". In recent years,

China′s digital economy has benefited from the overall growth of the national economy, but its growth momentum has not significantly outpaced that of the traditional economy, resulting in no significant increase in the proportion of digital economy in GDP, which is very different from that of the U.S. where it has been steadily increasing. That indicates that China′s digital economy has not yet won greater development space from the domestic market, and instead of empowering real economic growth, it has become a potential factor inhibiting overall economic growth. In contrast, the U.S. digital economy has grown twice as fast as GDP growth, with the digital economy accounting for a growing proportion of GDP and an expanding domestic footprint. Certainly, it may also be related to the fact that the overall economy of the U.S. has been shifted from the real economy to the fictitions economy.

Fourth, from the perspective of the competition pattern, China and the EU occupied the dominant positions in digital goods trade and digital services trade, respectively. However, China has not yet occupied the dominant ecological niche in digital trade, and is in the "surplus but not win". state of trade surplus without victory in competition. In digital goods trade, China has a significant disadvantage in key industrial chains, despite being the world′s top surplus power. For example, China′s net exports of electronic equipment in 2018 were more than RMB 600 billion, but the electronic components industry saw a trade deficit of RMB 1.6 trillion, which indicates that less than 30% of the value of the RMB 2.2 trillion in exports of digital goods was created by China. China′s strong trade surplus position in electronic equipment manufacturing industry faces the risk of being constrained by other countries, due to significant international competitive disadvantages in electronic components such as chips. Meanwhile, the information service industry, which accounts for the largest share of China′s digital economy, exports less than 5% of the electronic equipment manufacturing industry, struggling to become the new core pillar of digital trade. Not to mention the digital media industry, which has been in a trade deficit. As a result, the future sustainable competitive advantage of China′s digital trade suffers from serious challenges.

Fifth, from the perspective of the dependency pattern, only the hardware products of electronic equipment manufacturing industry in China′s digital economy are fully integrated into industrial chains in the EU and U.S. While the

information service industry and digital media industry are at a competitive disadvantage in mainstream markets such as the U.S. and EU, which reflects the unoptimized state of China's industrial structure within the digital economy. In terms of the digital goods trade, the EU and U.S. are extremely dependent on imports of electronic equipment products from China. While China contributes 50% and 36% of the imports of the EU and U.S., respectively, only less than 10% of the imports come from the EU and U.S. That means China enjoys an absolute advantage over the EU and U.S. While in terms of the trade in digital services, China is highly dependent on the EU and U.S., with import shares reaching 38% and 18%, respectively in 2019. In contrast, the U.S. and EU are interdependent on each other, and have a very low dependence on China, with import shares from China all less than 3%.

In summary, China's digital economy has developed rapidly and achieved remarkable progress in recent years. But compared with the U.S. and EU, China's digital economy is "big but not good, fast but not first, surplus but not win" in terms of the scale pattern, structural pattern, dynamic pattern, competition pattern and dependency pattern. On one hand, the development pattern of digital economy is closely related to the traditional economy, and is even a continuation of the traditional economic pattern. For example, China is a major manufacturer, and electronic equipment manufacturing industry, and the core digital economy segment is the source of almost all of China's digital trade exports, while developed countries, such as the EU and the U.S. face huge trade deficits. On the other hand, China's digital economy also suffers from a mismatch of scale and advantage. Its information service industry and digital media industry lack competitive advantages in the international digital services market, but domestically they are 1.5 times larger than the electronic equipment manufacturing industry. Aiming to achieve China's strategic goals, such as increasing the scale of digital economy, optimizing the structure of digital economy and strengthening the competition in digital trade, this paper proposes the following countermeasures:

First, China should fully optimize the structure of digital economy. In terms of the core digital economy, China should optimize the proportion of electronic equipment manufacturing industry in the digital economy, such as reducing imports of electronic components, forcing the upgrade of domestic electronic

components, and expanding the share of electronic equipment in the domestic market; at the same time, China should accelerate the development of information service industry and digital media industry to further enhance the proportion of digital service industry in the core digital economy. In terms of the narrow digital economy, China should accelerate industrial innovation in new industries and new models based on new-generation information technologies, such as big data and artificial intelligence. As such industries feature high knowledge-intensive characteristics, it is essential that the innovation chain and industry chain of digital technology are concertedly developed and coordinately driven. In terms of the broad digital economy, China should increase the proportion of industrial digitization in the digital economy, boost the process of digital transformation in various industries, improve the integration and promotion of digital technology in the traditional economy, and vigorously promote the penetration and integration of digital technology in other traditional industries. Ultimately, it will achieve cost reduction and efficiency increase, quality improvement, etc., facilitating high-quality economic development. In terms of the national economy, China should accelerate the development of digital economy compared to the rest of the economy, with the aim of increasing the proportion of digital economy in GDP.

Second, China should build on its strengths and avoid its weaknesses in electronic equipment manufacturing industry. That means it is necessary to strengthen China′s scale advantage and trade advantage in electronic equipment manufacturing industry, and more importantly, to make up for the manufacturing disadvantage in electronic components. It all stems from the strict sanctions and restrictions imposed by the U.S. on Chinese chips and other key electronic components, which has greatly eroded the international competitive advantage of China′s electronic equipment manufacturing industry in recent years. In this connection, China needs to focus on key technologies, such as chips and other electronic components in a way to reduce the trade deficit in electronic components, and to reduce dependence on foreign imports, developing an independent and autonomous electronic equipment manufacturing industry. More importantly, China is able to seize a dominant ecological niche in the manufacturing sector of digital economy by compensating for the manufacturing disadvantage of electronic components, and thereby occupying a dominant

position in the most valuable industrial chain.

Third, China should cultivate new advantages in the information service industry. That means it is necessary to accelerate the penetration and synergy of information service industry in the traditional domestic industry, and also to actively explore the markets of European and American countries externally. The information service industry is a high-value segment of the digital economy, and the accelerated extension of the global industry chain in digital services also represents a major feature of the upgrade in global industry chains driven by new technologies today (Jiang et al., 2021). However, the development pace of the information service industry in China has declined in recent years, which may be related to the fact that the consumer Internet has hit a bottleneck in its development, and also to the fact that China has strengthened the protection of Internet monopoly control, personal information and data security. Therefore, it is recommended to accelerate the development of the digital economy and to encourage technological innovation, data innovation and institutional innovation. In this way, the potential value of the massive data generated by China′s huge market scale and population size can be released as soon as possible. It is particularly important to accelerate the advancement of China′s industrial Internet. It means that China should digitally empower its manufacturing industry, leveraging the significant role of digital services in consolidating China as a world manufacturing hub.

Fourth, China should reverse its disadvantage in the digital media industry. The perennial trade deficit in news and publishing industry, as well as in radio, television, film and video recording production industry, which mirrors China′s huge international disadvantage in digital content industry, such as film and television productions. In this connection, it is necessary to increase support for leading enterprises in the digital media industry. That means the government should remove a series of obstacles, such as technology, standards and systems for such enterprises to develop their international market. In this way, Chinese cultural and entertainment products can access the international market and enhance national influence through cultural export.

The purpose of this paper is to analyze the global landscape and future trends of China′s digital economy through data, and to propose corresponding countermeasures accordingly. Furthermore, we can further analyze the important

reasons for the formation of the digital economy and trade pattern between China, the U.S. and EU in future studies. In addition, what is the significance of developing digital trade for the sustainable development of China′s digital economy, and how to design more favorable digital trade policies, such as responses to the realities of cross-border data flows and overseas digital taxation, are also major issues that need to be studied.

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