

Study on the Impact of Digital Economy on the Export Trade in Yangtze River Delta

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Abstract. With the rapid development of the digital economy and its influence on the international trade pattern, it is important to study its impact on export trade in the Yangtze River Delta. Taking the three provinces and one municipality in the Yangtze River Delta as the research object, this study constructs an evaluation index system from four dimensions: digital infrastructure, digital industrialization, industrial digitalization and digital innovation. The entropy method is used to measure the comprehensive development level of the digital economy from 2013 to 2024. Based on provincial panel data, a two-way fixed effects model is further used to examine the impact of the digital economy on export trade and its transmission mechanism. The results show that the digital economy significantly promotes the development of export trade in the Yangtze River Delta, and industrial structure optimization plays an important mediating role. The promoting effect also shows regional heterogeneity, with a stronger marginal effect in regions with a higher level of digital economy development. Based on these findings, this study proposes policy recommendations including strengthening digital infrastructure, promoting the integration of the digital economy and the real economy, improving fiscal and financial support, deepening regional coordination, and improving trade governance, so as to enhance the role of the digital economy in supporting export trade development in the Yangtze River Delta.

Keywords: digital economy, Yangtze River Delta, export trade, two-way fixed effects model.

1. Introduction

At the global level, the digital economy, driven by frontier technologies such as artificial intelligence, big data and cloud computing, is becoming a new economic paradigm. It is deeply reshaping global value chains and the international trade pattern, and has become a core engine for global economic recovery and sustainable growth. General Secretary Xi Jinping pointed out that China should “accelerate the development of new drivers for foreign trade, and actively expand trade in intermediate goods, trade in services, digital trade, and cross-border e-commerce exports.” This strategic arrangement clarifies the role of the digital economy as a core new driver of China’s foreign trade development, and highlights its strategic value in building a new pattern of high-standard opening up.

At the first China International Import Expo held in November 2018, President Xi Jinping announced support for the integrated development of the Yangtze River Delta and elevated it to a national strategy. In December 2019, the Outline of the Yangtze River Delta Regional Integrated Development Plan was officially issued, covering the whole area of Jiangsu, Zhejiang, Anhui and Shanghai. Although the Yangtze River Delta accounts for only about 3.7% of China’s total land area and 16.9% of its total population, it contributed 24.6% of China’s GDP and 39.11% of its export trade volume in 2024. As one of the most dynamic, open and innovative regions in China, the Yangtze River Delta has long been a leading area of China’s export-oriented economy. However, under multiple external challenges, including the structural slowdown of global demand, rising geopolitical risks and the accelerated restructuring of global value chains, the traditional export growth model of the Yangtze River Delta is facing serious pressure. Therefore, how to effectively use its leading advantages in the digital economy to support the transformation and upgrading of export trade and respond to external uncertainty has become a core issue with both urgency and strategic significance.

This study aims to examine the impact of the digital economy on export trade development in the Yangtze River Delta by using literature review, the entropy method and a two-way fixed effects model. Compared with existing studies, the possible marginal contributions of this study are mainly reflected in two aspects. First, from the research perspective, this study regards the digital economy as a multidimensional development system rather than a single technology or a specific business form, and systematically examines its comprehensive impact on export trade development. Second, from the research object, this study focuses on the Yangtze River Delta, a world-class urban agglomeration with global influence. Compared with studies at the macro national level, its conclusions can provide more targeted policy reference for similar regions. At the same time, this study also recognizes some limitations. The statistical standards of the digital economy have not been fully unified, and the availability of high-quality data is still limited, which may affect the refinement of the index system and measurement results. In addition, the micro-level transmission mechanisms through which the digital economy affects export trade are relatively complex. Future research can be further extended by using firm-level or industrial-chain-level data.

The Yangtze River Delta is a core engine of China's economic development. Studying the impact of the digital economy on export trade development in the Yangtze River Delta has both theoretical and practical significance. At the theoretical level, this study incorporates the key variable of the digital economy into the analytical framework of regional trade development, enriching and extending the content of international trade theory in the digital era. Meanwhile, by constructing and measuring a comprehensive evaluation system for the development level of the digital economy in the Yangtze River Delta, this study provides a methodological reference for quantitative research in related fields. At the practical level, this study aims to identify the key paths through which the digital economy empowers export trade in the Yangtze River Delta, so as to provide empirical evidence and decision-making reference for formulating forward-looking digital economy policies, optimizing the path of industrial upgrading, and improving the international competitiveness of enterprises in this region.

The rest of this study is organized as follows. Section 2 reviews the literature and explains the theoretical basis. Section 3 describes the development status and characteristics of the digital economy and export trade in the Yangtze River Delta. Section 4 constructs and measures the comprehensive index system for the development level of the digital economy. Section 5 conducts an empirical analysis of the impact of the digital economy on export trade in the Yangtze River Delta. Section 6 presents the research conclusions and policy recommendations.

2. Literature Review and Theoretical Basis

2.1. Literature Review

Unlike export trade, which has a history of several hundred years, the digital economy is a new phenomenon, and its proposal and development have taken place within a relatively short period. In this study, the digital economy refers to a new economic development model that takes digital information as a basic factor of production, digital innovation as a key driving force, and modern information networks as the main support, so as to promote the digital transformation of traditional industries. Don Tapscott (1996) first proposed the term “digital economy” in his book *The Digital Economy: Promise and Peril in the Age of Networked Intelligence*. He argues that the Internet is an important force driving the development of the digital economy and will affect future economic development [1]. Since its emergence, the digital economy has attracted wide attention from scholars at home and abroad. Related studies have been carried out continuously, and the research scope has gradually expanded to many fields, including its impact on export trade. In general, existing studies on this topic mainly focus on the following issues:

2.1.1. Studies on the Digital Economy

Existing studies on the digital economy are mainly carried out from three aspects: the measurement of its development level, its influencing factors, and the digital economy in the specific region of the Yangtze River Delta.

(1) Studies on the Measurement of the Development Level of the Digital Economy

As the concept of the digital economy continues to expand, there is no unified standard for its measurement index system. Therefore, scholars at home and abroad have different views on how to measure the development level of the digital economy.

Itkoneil (2017) uses data on variables such as GDP to calculate the development level of the digital economy, and emphasizes the future impact of digitalization [2]. Brynjolfsson Erik et al. (2019) replace the GDP indicator widely used in previous studies with GDP-B, and measure the impact of different levels of digital economy development on residents' lives [3]. Su et al. (2021) quantify the level of information and communication technology in BRICS countries and link it with technological innovation and carbon emissions, which further enriches the ideas for constructing measurement indicators of the digital economy development level [4].

When measuring the development level of the digital economy at the provincial level in China, existing studies have adopted increasingly diverse methods. Among these methods, principal component analysis and the entropy method have been widely used and recognized by scholars. Scholars represented by Yu Tonghui (2023) [5] and Geng Zijian (2022) [6] adopt principal component analysis, while Ji Fujun (2023) [7], Zheng Yanjie (2023) [8] and Cheng Guangbin (2022) [9] choose the entropy method. Some scholars also use other methods to evaluate the provincial development level of the digital economy. For example, Yao Zhanqi (2022) takes the development of telecommunications services, informatization, e-commerce and the Internet as key indicators, and combines the entropy method with the TOPSIS method to measure the development level of the digital economy in different provinces and municipalities [10]. Chao Xiaojing (2023) constructs a comprehensive evaluation index system from four core dimensions, namely information economy, platform economy, sharing economy and intelligent economy, and then uses the vertical and horizontal scatter degree method to measure the development status of the digital economy [11]. Xie E (2022) designs an evaluation system from three key dimensions, namely digital infrastructure, digital application and digital industry development, and uses the fuzzy comprehensive evaluation method to analyze and evaluate the development level of the digital economy in different provinces from 2010 to 2019 [12]. Overall, although the specific methods are different, existing measurement systems increasingly tend to construct comprehensive evaluation indicators from multiple dimensions, such as digital infrastructure, industrial digitalization and digital governance, so as to reflect the connotation of digital economy development more comprehensively.

(2) Studies on the Influencing Factors of Digital Economy Development

There are many factors affecting the development of the digital economy, and scholars have used different research methods. In general, existing studies mainly include the following aspects.

Jiao Shuaitao and Sun Qiubi (2021) use a spatial autoregressive model to analyze the factors affecting the development level of China's provincial digital economy. They find that human resources, social and economic conditions, service quality and production mode all have a positive role in promoting the growth of China's digital economy [13]. Zhong Yexi and Mao Weisheng (2020) use the geographically weighted regression method and show that the level of information technology and industrial structure have a significant promoting effect on the development of the digital economy in the Yangtze River Economic Belt, while the effect of human capital is relatively weak [14]. Zhao Tao et al. (2020) use digital economy data of China's prefecture-level cities from 2011 to 2016, and propose an innovative view that stronger support for mass innovation and entrepreneurship can more significantly promote the development of the digital economy [15]. Li Yonghong et al. (2019) define China's digital economy according to the standards of the China Academy of Information and Communications Technology, and regard it as the result of the combination of industrialization and digitalization. Through empirical research, they find that the level of information technology, the

strength of government support and the intensity of market competition are all key factors affecting the sustainable development of the digital economy [16]. Yao Zhanqi (2021) finds that the level of informatization, the share of government expenditure on science and technology, import and export trade, and labor productivity affect the comprehensive competitiveness of the digital economy, while government expenditure on science and technology has the smallest impact on the comprehensive competitiveness of digital trade [17].

(3) Studies on the Digital Economy in the Yangtze River Delta

As a frontier region of China's economic development, the Yangtze River Delta has a leading level of digital economy development in China. Therefore, it has attracted wide attention from scholars and has produced the following research results.

Sun Yong et al. (2022) deeply explore the relationship between the digital economy and patent output. Their results show that the technology empowerment effect of the digital economy presents an obvious agglomeration trend in Shanghai, southern Jiangsu, northeastern Zhejiang and central Anhui [18]. Wang Juanjuan and She Ganjun (2021) conduct an in-depth evaluation of the development level of the digital economy in different regions of China by considering indicators related to digital foundation, digital industry and digital environment. Their results show that Shanghai, as the core city of the Yangtze River Delta, is in a leading position in the field of the digital economy and belongs to the first tier [19]. Yang Dong et al. (2021) use the fuzzy-set qualitative comparative analysis method to examine 27 core cities in the Yangtze River Delta, and find that the digital economy can promote the sustained economic growth of this region through five different paths, including a comprehensive path [20]. Chen Congbo and Ye Azhong (2021), based on data from the Yangtze River Delta and its core cities, study the impact of the digital economy on regional economic resilience. They find that the regional digital economy may put some pressure on the economic development of nearby provinces in the short term, but has a significant positive impact on economic development in the long term [21]. Xiong Li and Cai Xuelian (2020) use the Cobb-Douglas production function and an autoregressive model to quantitatively analyze the driving effect of the digital economy on technological innovation in the Yangtze River Delta from 2010 to 2018. Their results show that the development of the digital economy has a strong positive effect on the improvement of technological innovation [22].

2.1.2. Studies on Export Trade in the Yangtze River Delta

Academic studies on export trade in the Yangtze River Delta have produced relatively rich results, mainly focusing on three aspects: macro-level efficiency, policy-driven effects and internal structural characteristics.

First, at the macro-level efficiency, related studies affirm the overall performance of export trade in the Yangtze River Delta. Xie et al. (2021) use DEA and Tobit models and point out that the overall foreign trade efficiency of this region remains at a high and stable level, while industrial structure, foreign investment and infrastructure are key positive influencing variables [23]. Second, at the policy-driven level, scholars evaluate the positive effects of key opening-up policies through empirical analysis. Yang Yingqi and Liu Juan (2024), based on the trade gravity model, confirm that the establishment of the Shanghai Free Trade Zone significantly promotes export trade development in the whole Yangtze River Delta through a strong spillover effect [24]. Similarly, Huo Yunke and Wang Wuyi (2023) use a multi-period difference-in-differences model and find that the establishment of cross-border e-commerce comprehensive pilot zones has a significant promoting effect on export trade in the Yangtze River Delta [25]. Finally, at the internal structural level, related studies reveal more complex heterogeneous characteristics within the region. Tan Hua (2021) finds that financial agglomeration has significantly different effects on the export of different types of products. While it strongly promotes the export of technology-intensive and capital-intensive products, it has a crowding-out effect on the export of labor-intensive products. This heterogeneity is rooted in the differentiated export trade patterns among provinces and municipalities within the Yangtze River Delta [26]. Shen Xusheng et al. (2022), through an analysis of long-term trade data, point out that Shanghai and Jiangsu have advantages in processing trade and high-tech product exports, while

Zhejiang and Anhui have a higher share of general trade. In addition, the share of high-tech product exports in Zhejiang is relatively low, which directly shows the uneven development within the region [27].

2.1.3. Studies on the Impact of the Digital Economy on Export Trade Development

Studies at home and abroad show that the digital economy can promote export trade growth and improve trade efficiency. Yang Lindou et al. (2024), based on panel data of 262 prefecture-level cities in China, find that the digital economy promotes the growth of urban export trade in China, mainly through the price margin and the extensive margin [28]. Zhong Min and Wang Zengtao (2022) reach a similar conclusion and point out that mass entrepreneurship and innovation are important channels through which the digital economy releases export dividends [29]. In terms of trade efficiency, Fan Xin (2020) analyzes the impact of the development of the digital economy in importing countries on China's exports from the perspectives of international trade efficiency and trade uncertainty. The results show that the development of the digital economy in importing countries can significantly reduce the efficiency loss of China's exports and improve China's export trade efficiency [30]. He Shuquan et al. (2021) also find that the development of the digital economy in both exporting and importing countries has a significant promoting effect on value-added trade, and the effect is more significant for complex value chain exports [31]. Ahmedov (2020) discusses the role of digitalization and related technologies in today's international trade, and points out that the digital space is becoming a key field of global trade [32]. Mueller et al. (2019) find that exports of digital products grow faster and are more spatially concentrated [33]. These studies show that the digital economy effectively promotes the growth and efficiency improvement of export trade by reducing information collection costs, improving transaction efficiency and optimizing resource allocation.

Scholars have further explored the deeper transmission mechanisms behind this relationship, among which industrial structure optimization is regarded as a key path. Zhao Wei (2023) emphasizes that industrial structure upgrading is an important mechanism through which digital economy development affects the high-quality development of urban foreign trade [34]. Zhu (2024) also finds that the impact of the digital economy on export trade is mediated by industrial agglomeration. This indicates that the digital economy improves regional export capacity by promoting industrial agglomeration in specific regions and forming economies of scale and scope [35]. The digital economy promotes the digital transformation of traditional industries and gives rise to emerging digital industries, thereby optimizing the structure of export products and promoting their development toward higher added value and higher technological content.

2.1.4. Literature Review Summary

Through a systematic review of existing literature, it can be found that rich research results have been formed on the digital economy, export trade in the Yangtze River Delta, and the impact of the digital economy on export trade development. These studies provide a solid theoretical basis and methodological reference for this study. They also lay an important foundation for understanding the macro effects of the digital economy and the regional characteristics of export trade in the Yangtze River Delta.

However, although the academic community has widely recognized the macro background of the digital economy as a new engine of global economic growth, existing studies still have clear limitations in research topics. Most studies focus on the national or cross-national level. Although their conclusions are general, they cannot fully explain the heterogeneous characteristics of specific regions. For the Yangtze River Delta, although its importance as a core area of China's export trade has become a consensus, there are still relatively few specialized studies that take the digital economy as the core explanatory variable and systematically examine its impact on export trade in this region. This constitutes a research gap that needs to be filled.

To address the limitations of existing studies, this study takes the Yangtze River Delta as the empirical sample and incorporates the digital economy variable into the analytical framework of regional export trade. It aims to examine the overall effect of the digital economy on export trade in

the Yangtze River Delta and further clarify its internal transmission mechanism. On this basis, this study seeks to provide policy implications with both theoretical depth and practical value for optimizing the development path of the digital economy in the Yangtze River Delta and improving the quality of its export trade.

2.2. Theoretical Basis

2.2.1. Theory of Comparative Advantage

The theory of comparative advantage was first proposed by the classical economist David Ricardo in 1817 in *On the Principles of Political Economy and Taxation*. He argued that countries should participate in international trade based on their relative advantages in factors of production, so as to achieve complementary advantages and mutual benefits for both trading parties. In the era of the digital economy, the theory of comparative advantage still has important practical significance. The development of the digital economy has made emerging factors of production, such as data, technology, and innovation, increasingly important, while the Yangtze River Delta has relative advantages in these factors. Therefore, this region can further enhance its comparative advantage in export trade by vigorously developing the digital economy.

2.2.2. Theory of New Supply and New Demand

The theory of new supply and new demand is a macroeconomic theory proposed by Chinese economist Lin Yifu and other scholars in 2013. This theory points out that, with technological innovation and changes in market demand, new products, new production methods, new factors of production, and new consumer demand and habits are taking shape, becoming the core forces driving market changes. The Yangtze River Delta has strong technological innovation capacity and industrial foundations, and the development of the digital economy is expected to bring new supply and demand to the region, thereby promoting the growth of export trade.

2.2.3. Industrial Convergence Theory

In 1963, American scholar Rosenberg proposed the theory of industrial convergence, pointing out that technological innovation blurs industrial boundaries and promotes industrial convergence. In the development process of the digital economy, the innovation capacity of digital technology has also improved simultaneously, making the blurring of industrial boundaries among different industries faster. Against this background, industrial convergence has become increasingly common, such as the deep integration of digital technology with manufacturing, services, and other industries. The Yangtze River Delta has great potential and room for industrial convergence, and industrial convergence can bring new economic growth points and trade opportunities, thus exerting a positive promoting effect on the development of export trade.

3. Development Status and Characteristics of the Digital Economy and Export Trade in the Yangtze River Delta

3.1. Development Status and Characteristics of the Digital Economy in the Yangtze River Delta

3.1.1. The Scale of the Digital Economy Continues to Expand

In recent years, China's digital economy has maintained a strong momentum of development, with its scale continuing to expand. According to the *Research Report on China's Digital Economy Development* released by the China Academy of Information and Communications Technology, from 2016 to 2024, the scale of China's digital economy increased steadily from 22.6 trillion yuan to 59.2 trillion yuan, while its share of GDP rose from 30.3% to 43.8% (see Fig. 1). Overall, China's digital economy has continued to improve in terms of scale, proportion, and integrated application, and has become an important support for optimizing the economic structure and driving the development of the national economy.

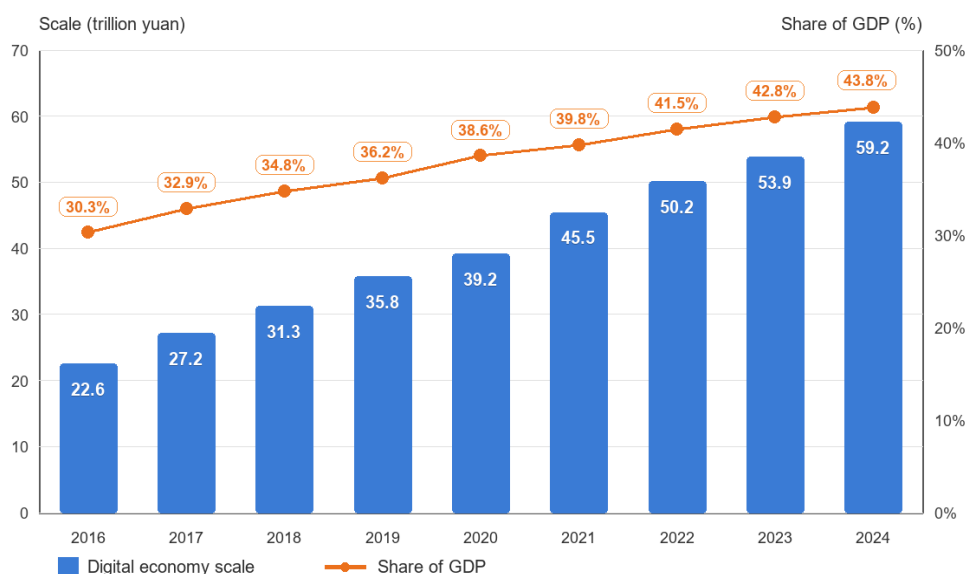


Fig. 1 Scale of China's Digital Economy and Its Share of GDP from 2016 to 2024

Data source: Compiled and drawn based on the *White Paper on China's Digital Economy Development* released by the China Academy of Information and Communications Technology over the years

The Yangtze River Delta has made an important contribution to the steady growth of China's digital economy and remains a leading region in terms of its total scale. In 2019, the total scale of the digital economy in the Yangtze River Delta reached 8.6 trillion yuan, increasing to 10.83 trillion yuan in 2020 and further to 12.7 trillion yuan in 2021. In 2022, the Yangtze River Delta accounted for nearly 30% of the national digital economy, and its total scale was higher than that of the Pearl River Delta and the Beijing-Tianjin-Hebei region. In 2023, the value added of the digital economy in the Yangtze River Delta exceeded 12 trillion yuan, accounting for about 30% of the national total. This indicates that the Yangtze River Delta has become one of the most active regions in China's digital economy development and will continue to serve as an important driving force for regional economic development.

3.1.2. The Structure of the Digital Economy Continues to Improve

The optimization of the digital economy structure lies mainly in the coordinated development of digital industrialization and industrial digitalization. At the national level, the *Research Report on China's Digital Economy Development (2024)* shows that the ratio of digital industrialization to industrial digitalization in China changed from about 3:7 in 2012 to about 2:8 in 2023. This indicates that the main driving force of digital economy growth is gradually shifting from the expansion of digital industries themselves, such as information and communication and software services, to the transformation and empowerment of real economy sectors, such as manufacturing, circulation, and services, through digital technology. As a result, the integration between the digital economy and the real economy has continued to deepen.

The optimization of the digital economy structure in the Yangtze River Delta reflects this trend. On the one hand, the region has a strong foundation in digital industries, such as software and information services, integrated circuits, artificial intelligence, and e-commerce. On the other hand, it has also gathered advanced manufacturing, commercial circulation, and export-oriented industrial chains, providing rich application scenarios for the integration of digital technology into the real economy. Specifically, Shanghai has clear advantages in digital services, integrated circuits, artificial intelligence, and the online new economy, and mainly plays a role in technology services and resource agglomeration. Jiangsu relies on its manufacturing base to promote the industrial Internet and intelligent transformation, thereby extending digital technology to the production process. Zhejiang developed e-commerce and the platform economy relatively early, and digital technology has been

widely applied in commercial circulation and business operations. Anhui is accelerating its catch-up in artificial intelligence, new display technologies, intelligent manufacturing, and other fields by relying on cities such as Hefei, and is integrating into regional division of labor by undertaking industrial transfer and building innovation platforms. Therefore, the essence of the structural optimization of the digital economy in the Yangtze River Delta lies in the combination of the foundation of digital industries, real economy application scenarios, and advantages in regional division of labor. This enables digital technology to gradually run through research and development, design, production and manufacturing, commercial circulation, and cross-border services, thus providing support for export enterprises to improve production efficiency, supply chain coordination, and responsiveness to the international market.

3.1.3. Policy Support for the Digital Economy Has Continued to Strengthen

The Yangtze River Delta is one of the regions in China where the policy layout for the digital economy started relatively early and policy tools have been relatively intensive. In recent years, the three provinces and one municipality have continuously issued policy documents on digital economy development, digital transformation of manufacturing, artificial intelligence, and other related fields (see Table 1). The policy focus has gradually extended from overall planning and industrial cultivation to specific industrial scenarios, breakthroughs in key technologies, and the integrated application of the digital economy and the real economy. These policies not only provide institutional support for the development of digital industrialization, but also create a favorable policy environment for industrial digitalization and the digital transformation of export trade.

Table 1. Selected Policy Documents Supporting the Development of the Digital Economy in the Yangtze River Delta

Region	Time	Policy Document
Shanghai Municipality	December 2024	Implementation Plan of Shanghai Municipality for Promoting the High-Quality Development of Digital Trade and Trade in Services
	April 2024	Action Plan of Shanghai Municipality for Promoting the Coordinated Digital and Green Transformation of Manufacturing (2024-2027)
	October 2023	Several Measures of Shanghai Municipality for Promoting the Innovative Development of Large AI Models (2023-2025)
	July 2022	Action Plan of Shanghai Municipality for Cultivating the New Metaverse Track (2022-2025)
	June 2022	14th Five-Year Plan of Shanghai Municipality for Digital Economy Development
Jiangsu Province	December 2024	Three-Year Action Plan of Jiangsu Province for Deepening the Intelligent Transformation, Digital Transformation, and Networked Connection of Manufacturing (2025-2027)
	December 2023	Several Policy Measures on Accelerating Independent Innovation in Industrial Software
	April 2022	Guiding Opinions on Comprehensively Improving the Development Level of Jiangsu's Digital Economy
	August 2021	14th Five-Year Plan of Jiangsu Province for Digital Economy Development
	October 2020	Opinions on Further Promoting the Development of the Digital Economy
Zhejiang Province	December 2023	Guiding Opinions on Accelerating the Development of the Artificial Intelligence Industry
	March 2023	Implementation Plan of Zhejiang Province for the "No. 1 Development Project" on Digital Economy Innovation and Quality Improvement
	July 2022	Action Plan for Promoting the Digital Transformation of Small and Medium-Sized Enterprises in Subdivided Industries
	June 2021	14th Five-Year Plan of Zhejiang Province for Digital Economy Development
	December 2020	Regulations of Zhejiang Province on Promoting the Digital Economy
Anhui Province	July 2024	Action Plan for Accelerating the High-Quality Development of the Digital Economy (2024-2026)
	July 2024	Several Policies for Supporting Digital Transformation to Promote the High-End, Intelligent, and Green Development of Manufacturing (2024 Edition)
	February 2023	Implementation Plan for Promoting the High-End, Intelligent, and Green Development of Manufacturing through Digital Transformation (2023-2025)
	August 2022	Action Plan for Accelerating the Development of the Digital Economy (2022-2024)
	March 2021	Regulations of Anhui Province on Big Data Development

Data source: Compiled based on materials from relevant government websites

3.2. Development Status and Characteristics of Export Trade in the Yangtze River Delta

3.2.1. Steady Expansion of Export Trade Scale

In recent years, with the continuous advancement of global economic integration and trade liberalization, the Yangtze River Delta has shown particularly strong performance in export trade, with its export trade scale increasing year by year. Table 2 presents the export scale of the Yangtze River Delta and China.

Table 2. Exports of the Yangtze River Delta and China from 2016 to 2024

Year	China	Yangtze River Delta	Shanghai Municipality	Jiangsu Province	Zhejiang Province	Anhui Province
2016	138419	52708	12098	21063	17667	1880
2017	153309	59237	13118	24607	19439	2073
2018	164129	63884	13665	26658	21175	2386
2019	172374	66795	13725	27209	23076	2785
2020	179279	69484	13721	27433	25169	3161
2021	214255	81882	15713	32078	30108	3983
2022	236337	90722	17102	34590	34331	4699
2023	237656	91981	17372	33716	35663	5230
2024	254545	99562	18176	36531	39057	5798

Data source: Compiled based on the *China Statistical Yearbook*

Overall, the Yangtze River Delta has maintained a relatively large export trade scale, and its growth rate was slightly higher than that of China as a whole during the same period. As shown in Table 2, from 2016 to 2024, China's export value increased from RMB 13,841.9 billion to RMB 25,454.5 billion, representing an increase of 83.9%; the export value of the Yangtze River Delta increased from RMB 5,270.8 billion to RMB 9,956.2 billion, representing an increase of 88.9%, while its share of China's total exports rose from 38.08% to 39.11%. In terms of export growth across provinces and municipality, Zhejiang Province and Anhui Province showed more prominent growth momentum. Specifically, the export value of Zhejiang Province increased from RMB 1,766.7 billion to RMB 3,905.7 billion, representing an increase of 121.1%, and Zhejiang Province became the province with the largest export scale in the region in 2024; the export value of Anhui Province increased from RMB 188.0 billion to RMB 579.8 billion, representing an increase of 208.4%. Although its overall export scale remained relatively small, it showed the fastest catch-up pace. By contrast, the export growth of Shanghai Municipality and Jiangsu Province was relatively stable. In 2024, their export values reached RMB 1,817.6 billion and RMB 3,653.1 billion, respectively, making them stable supports for regional exports. Overall, export growth in the Yangtze River Delta is characterized by scale support from Jiangsu Province and Zhejiang Province, stable driving effects from Shanghai Municipality, and accelerated catch-up by Anhui Province.

3.2.2. Increasing Diversification of Export Trade Modes

With continuous changes in the international trade environment and the intensification of market competition, the export trade modes in the Yangtze River Delta have continued to expand, gradually forming a development pattern in which general trade, processing trade, cross-border e-commerce, service trade, and other trade modes develop in parallel. Among them, general trade and processing trade remain an important foundation for goods exports, supporting the stable export of manufacturing products in the Yangtze River Delta. New trade modes such as cross-border e-commerce and service trade have enhanced enterprises' ability to directly connect with overseas markets, shorten transaction chains, and reduce transaction costs, making export activities more flexible and efficient and injecting new momentum into the growth of export trade in the Yangtze River Delta.

As an important form of integration between digital technology and international trade, cross-border e-commerce is characterized by convenient transactions, rapid response, diversified channels, and relatively low costs, and has become an important way for enterprises in the Yangtze River Delta to expand overseas markets. Relying on a relatively complete logistics system, industrial supporting facilities, and platform resources, enterprises in the Yangtze River Delta can use cross-border e-

commerce to conduct product display, order acquisition, payment settlement, after-sales services, and other processes online, thereby promoting the extension of export trade from single goods exports to the coordinated export of goods, services, and brands. At the same time, service trade in fields such as finance, education, and healthcare is also playing an increasingly important role in the export trade of the Yangtze River Delta. Overall, the expansion of trade modes has improved the ability of export enterprises in the Yangtze River Delta to adapt to changes in the international market, while also providing more channels for small and medium-sized enterprises to participate in global trade.

3.2.3. Steady Upgrading of Export Commodity Structure

The Yangtze River Delta has a relatively complete industrial foundation, and scientific and technological innovation as well as industrial upgrading have continued to advance. As a result, its export commodity structure has gradually shifted from labor-intensive products to capital- and technology-intensive products. With the accelerated development of industries such as electronic information, equipment manufacturing, biomedicine, and new energy, mechanical and electrical products and high-tech products have played an increasingly prominent supporting role in exports. This indicates that export growth in the Yangtze River Delta is gradually shifting from simple scale expansion to quality improvement and structural optimization.

From the perspective of specific commodity types, electronic information products, intelligent equipment, biomedicine products, and new energy-related products have played an increasingly important role in the exports of the Yangtze River Delta. This indicates that the region's export advantages are extending from traditional processing and manufacturing toward product fields with higher technological content and higher added value. Compared with traditional labor-intensive products, these commodities place higher requirements on research and development, design, supporting capacity for key components, quality standards, and brand capabilities, and they can better reflect the upgrading level of regional industrial chains. Meanwhile, with the rapid development of the digital economy, the export space for emerging products such as digital products and intelligent manufacturing equipment has continued to expand, further promoting the steady upgrading of the export commodity structure in the Yangtze River Delta.

4. Construction and Measurement of the Indicator System for the Development Level of Digital Economy

4.1. Construction of the Indicator System for the Development Level of Digital Economy

4.1.1. Principles for Constructing the Indicator System

A reasonable indicator system should be guided by scientific principles. Considering the characteristics of the research object in this paper, the design of the evaluation indicator system for the development level of digital economy should follow the following four principles:

(1) Principle of objectivity

This means that the construction of indicators should be based on objective facts and avoid the influence of subjective factors. Therefore, quantifiable indicators should be selected to ensure that they can objectively reflect the development level of digital economy.

(2) Principle of comprehensiveness

This means that the indicators should complement each other and reflect multiple aspects and the overall condition of digital economy in a comprehensive way.

(3) Principle of operability

This means that the definition of each indicator should be clear and specific, and the calculation method should be simple and easy to understand, so as to facilitate operation and interpretation. The data sources should be authentic and reliable, which is helpful for data collection and processing.

(4) Principle of dynamics

The development of digital economy is a dynamic process. Therefore, the construction of the indicator system should have a certain degree of flexibility and should be updated and improved over

time. By paying attention to the development trend of digital economy, this paper includes new indicators such as digital innovation into the evaluation system, so as to ensure that the system can reflect the latest situation of digital economy development in the Yangtze River Delta region.

4.1.2. Indicator Selection and Description

This paper mainly draws on the methods of Yao Zhanqi (2022) [10] and Xie E (2022) [12] to construct the indicator system for measuring the development level of digital economy. Following the principles of objectivity, comprehensiveness, operability, and dynamics, this paper constructs a comprehensive evaluation indicator system consisting of 4 primary indicators and 18 secondary indicators, as shown in Table 3, to evaluate the comprehensive development level of digital economy in the Yangtze River Delta region.

Table 3. Indicator System for the Development Level of Digital Economy

Primary Indicator	Secondary Indicator	Unit	Indicator Direction
Digital infrastructure construction	Switching capacity of mobile telephone exchanges	10,000 subscribers	Positive
	Number of mobile communication base stations	10,000 units	Positive
	Length of long-distance optical cable lines	km	Positive
	Number of Internet domain names	10,000 units	Positive
	Number of Internet webpages	10,000 pages	Positive
	Number of Internet broadband access ports	10,000 ports	Positive
	Mobile phone penetration rate	units per 100 persons	Positive
Digital industrialization	Total volume of telecommunications services	100 million yuan	Positive
	Software business revenue	10,000 yuan	Positive
	Number of employees in urban non-private units in the information transmission, software, and information technology service industry	10,000 persons	Positive
	Expenditure on new product development by industrial enterprises above designated size	10,000 yuan	Positive
Industrial digitalization	Number of websites owned by enterprises included in informatization statistics	unit	Positive
	Number of enterprises engaged in e-commerce transactions	unit	Positive
	E-commerce sales of enterprises	100 million yuan	Positive
	E-commerce purchases of enterprises	100 million yuan	Positive
Digital innovation	Number of valid invention patents held by industrial enterprises above designated size	item	Positive
	Full-time equivalent of R&D personnel in industrial enterprises above designated size	person-year	Positive
	Ratio of R&D expenditure to GDP	%	Positive

Digital infrastructure construction measures the basic conditions for the development of digital economy. The indicators selected in this dimension are used to evaluate the development of the Internet and telecommunications infrastructure. Among them, mobile phone penetration rate is used to measure the level of telecommunications services.

Digital industrialization refers to the cultivation and development of emerging industries related to digital economy, which provide various digital products and services. This dimension is used to measure the degree to which digital technologies are applied in industries. The indicators selected in this dimension reflect the operation and employment conditions of the telecommunications industry, the software and information technology service industry, as well as the investment in product development.

Industrial digitalization refers to the digital transformation of traditional production processes, business models, and management methods. This dimension can be used to evaluate the enabling role of digital technologies in industrial development and reflect the degree of deep integration between digital economy and the real economy. In this paper, the number of websites owned by enterprises included in informatization statistics is used to measure the utilization of Internet resources by enterprises, while the other indicators in this dimension are used to measure the development of e-commerce.

Digital innovation reflects the level of digital technology research and development, the transformation of innovation achievements, and the creation of an innovation environment. It is an

important criterion for measuring the development potential of digital economy. The indicators selected in this dimension are used to measure patents, enterprise scientific and technological activities, and R&D investment related to digital economy.

4.1.3. Data Sources and Sample Selection

The data used for constructing the indicators in this study are mainly obtained from the *China Statistical Yearbook* and the National Bureau of Statistics of China. Considering data availability, this study selects panel data of the Yangtze River Delta region from 2013 to 2024 as the research sample.

4.2. Measurement Method for the Development Level of Digital Economy

This study adopts the entropy method to measure the development level of digital economy. The specific steps are as follows:

(1) Data standardization

Since different indicators have different dimensions and value ranges, the data need to be standardized. Let the original matrix be $X = (X_{ij})_{m \times n}$, and let the standardized values be $Y_1, Y_2, \dots, Y_i$. Since all indicators in this study are positive indicators, the standardization formula is as follows:

$$Y_{ij} = \frac{X_{ij} - \min X_i}{\max X_i - \min X_i} \quad (1)$$

$$X_i = X_1, X_2, \dots, X_i$$

X_i represents the value of indicator i for province or municipality j in a certain year before standardization. $\min X_i$ and $\max X_i$ represent the minimum and maximum values of indicator i , respectively. Y_{ij} represents the standardized value. m represents the total number of samples, namely the number of sample observations of three provinces and one municipality in the Yangtze River Delta over 12 years. n represents the number of indicators.

(2) Calculation of indicator proportions

Based on the standardized data Y_{ij} of each indicator, the indicator proportion P_{ij} is calculated.

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^n Y_{ij}} \quad (2)$$

(3) Calculation of information entropy

Let E_i represent the information entropy of indicator i .

$$E_i = -\frac{1}{\ln n} \sum_{i=1}^n P_{ij} \ln P_{ij} \quad (3)$$

(4) Calculation of the difference coefficient

Let d_i represent the difference coefficient. The larger the difference coefficient, the more important the indicator.

$$d_i = 1 - E_i \quad (4)$$

(5) Calculation of indicator weights

Let W_i represent the weight coefficient. The sum of the weights of all indicators is 1.

$$W_i = \frac{d_i}{\sum_{i=1}^n d_i} \quad (5)$$

(6) Calculation of the comprehensive score

Based on the standardized indicator X_{ij} and the indicator weight W_i , the index level of digital economy development, denoted as DE , is calculated through weighted summation.

$$DE_j = \sum_{i=1}^n W_i \times P_{ij} \quad (6)$$

The calculation is conducted step by step using Stata software. DE_j represents the digital economy development level of province or municipality j . The value of DE_j ranges from 0 to 1. A larger value indicates a higher comprehensive development level of digital economy.

4.3. Measurement Results and Evaluation Analysis of the Development Level of Digital Economy

Based on the indicator system constructed above, this study calculates the comprehensive scores of digital economy development in the Yangtze River Delta region by using the entropy method, and draws a line chart accordingly.

Table 4. Comprehensive Scores of Digital Economy Development in the Yangtze River Delta Region

Year	Shanghai Municipality	Jiangsu Province	Anhui Province	Zhejiang Province
2013	0.0919	0.2932	0.0362	0.2038
2014	0.1307	0.3221	0.0561	0.2357
2015	0.1454	0.3528	0.0820	0.2764
2016	0.1693	0.3723	0.0943	0.2993
2017	0.1848	0.4036	0.1154	0.3299
2018	0.2102	0.4888	0.1423	0.3839
2019	0.2557	0.5740	0.1851	0.4634
2020	0.2933	0.6312	0.2163	0.5117
2021	0.3043	0.5544	0.1733	0.4471
2022	0.3456	0.6110	0.1864	0.4867
2023	0.4063	0.6766	0.2173	0.5522
2024	0.3931	0.7253	0.2284	0.5934
Overall ranking	3	1	4	2

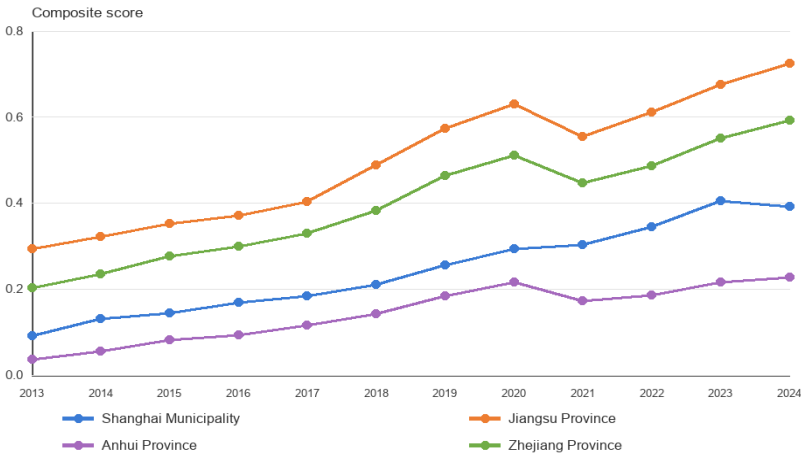


Fig. 2 Comprehensive Scores of Digital Economy Development in the Yangtze River Delta Region

As shown in Fig. 2 and Table 4, the development level of digital economy in the three provinces and one municipality of the Yangtze River Delta region showed an overall upward trend from 2013 to 2024, while significant regional differences still existed. In terms of overall ranking, Jiangsu Province remained in the leading position, followed by Zhejiang Province and Shanghai Municipality, while Anhui Province ranked last. Overall, the region showed a pattern in which Jiangsu Province took the lead, Zhejiang Province followed closely, Shanghai Municipality improved steadily, and Anhui Province continued to catch up.

From the perspective of temporal changes, the comprehensive scores of digital economy development in the three provinces and one municipality all increased overall. Specifically, the comprehensive score of Jiangsu Province rose from 0.2932 in 2013 to 0.7253 in 2024, maintaining the highest level in the Yangtze River Delta region throughout the sample period. This indicates that Jiangsu Province has strong comprehensive advantages in digital infrastructure, digital industrialization, and industrial digitalization. The comprehensive score of Zhejiang Province increased from 0.2038 to 0.5934, showing a clear growth trend and suggesting good prospects for its digital economy development. The comprehensive score of Shanghai Municipality rose from 0.0919 to 0.3931, with steady overall growth and relatively stable development. The comprehensive score of Anhui Province increased from 0.0362 to 0.2284. Although it remained lower than that of the other three provinces and municipality, it showed a continuous catching-up trend in the long run.

Further analysis shows that the development level of digital economy in the Yangtze River Delta region continued to improve from 2013 to 2020. In 2021, the comprehensive scores of Jiangsu Province, Zhejiang Province, and Anhui Province declined to different degrees, while the growth rate of Shanghai Municipality also slowed down. A possible reason is that the macroeconomic environment had a potential impact on the development level of digital economy. In 2021, the continued spread of the COVID-19 pandemic worldwide led to a significant slowdown in investment activities and a general decline in corporate profits, which had a negative impact on digital transformation and digital innovation. After 2022, the comprehensive scores of the three provinces and one municipality generally rebounded, especially in Jiangsu Province and Zhejiang Province, where the recovery was relatively fast. This indicates that the development of digital economy in the Yangtze River Delta region has strong resilience.

Overall, the development level of digital economy in the Yangtze River Delta region continued to improve from 2013 to 2024, but the internal imbalance among regions remained relatively obvious. Jiangsu Province and Zhejiang Province served as the main supporting forces for the development of digital economy in the Yangtze River Delta region. Shanghai Municipality developed steadily and had considerable potential, while Anhui Province remained in a relatively lagging position and still had large room for improvement. In the future, regional coordination should be further strengthened to promote the interconnection of digital infrastructure, cooperation in digital industries, and the diffusion of digital technologies, so as to narrow regional gaps and improve the overall development level of digital economy in the Yangtze River Delta region.

5. Empirical Study on the Impact of the Digital Economy on Export Trade Development in the Yangtze River Delta

5.1. Model Construction

To test the impact of the digital economy on export trade development in the Yangtze River Delta, and to consider differences across regions and years, this study uses a two-way fixed effects model. Since the core explanatory variable is measured by an index system, and taking collinearity into account, this study refers to the classic gravity model and builds the empirical model as follows:

$$EX_{it} = \beta_0 + \beta_1 DE_{it} + \beta_2 FL_{it} + \beta_3 GI_{it} + \beta_4 UR_{it} + \mu_i + v_t + u_{it} \quad (7)$$

In the model, EX denotes the development level of export trade, DE denotes the development level of the digital economy measured above, FL denotes the level of financial development, GI denotes the level of government input, and UR denotes the level of urbanization. i denotes the three provinces and one municipality, t denotes the year, μ_i denotes unobserved individual factors, v_t denotes unobserved time factors, and u_{it} denotes the random disturbance term. β_0 is the constant term, while β_1 , β_2 , β_3 , and β_4 are the parameters to be estimated.

5.2. Variable Selection and Data Sources

5.2.1. Variable Selection

(1) Dependent Variable

The dependent variable in the model of this study is the level of export trade development (EX), which is measured by total exports. Total exports directly reflect the scale of goods sold abroad by a region within a certain period, and it is the most direct and comprehensive indicator of the level of export trade. Therefore, this study selects the total exports of the three provinces and one municipality in the Yangtze River Delta region to measure the level of export trade development.

(2) Key Explanatory Variable

The key explanatory variable in the model is the level of digital economy development (DE). This study constructs an indicator system for the level of digital economy development, obtains a

comprehensive variable after assigning weights by the entropy method, and uses it as the key explanatory variable.

(3) Control Variables

To exclude the influence of other factors on the level of export trade development, this study refers to relevant literature and considers data availability. Financial development level, government input level, and urbanization level are selected as control variables.

① Financial Development Level (*FL*)

Financial development can improve the external financing capacity of enterprises through the borrowing and transfer of funds and credit, thereby affecting the development of export trade. This study uses the ratio of the balance of domestic and foreign currency loans of financial institutions to GDP to measure the level of financial development.

② Government Input Level (*GI*)

Government input plays an important role in the development of export trade. A higher level of government input is more favorable to local trade. This study uses general public budget expenditure to measure the level of government input. To reduce errors, the logarithmic form is used in the actual analysis.

③ Urbanization Level (*UR*)

With the improvement of urbanization, a large number of people gather in cities, which makes it more convenient to obtain labor factors and reduces human resource costs, thereby affecting the development of export trade. Therefore, this study uses the urbanization rate of the permanent resident population to measure the level of urbanization.

(4) Mediating Variable

The development of the digital economy promotes the upgrading and transformation of the industrial structure, improves the optimal allocation and efficient use of resources, and provides a more solid foundation for the development of export trade. Therefore, this study selects industrial structure (*IS*) as the mediating variable. Referring to relevant literature, this study uses the value added of the tertiary industry to measure industrial structure. A higher value added of the tertiary industry indicates a higher level of industrial structure optimization.

5.2.2. Data Sources

Considering data availability, this study selects panel data of the Yangtze River Delta region from 2013 to 2024 to examine the impact of the digital economy on the development of export trade in the Yangtze River Delta region. The data used in the empirical analysis are mainly from the statistical yearbooks of China and relevant provinces and municipalities, Shanghai Municipal Statistics Bureau, Jiangsu Statistical Bulletin, Zhejiang Provincial Bureau of Statistics, and CEInet Statistics Database. Among them, the provincial export totals in 2013 are calculated based on the growth rate of total exports. The level of digital economy development (*DE*) is the comprehensive score calculated by the entropy method in the previous section and retained to five decimal places, with a data range from 0 to 1.

Descriptive statistics are conducted for the variables in the empirical model, and the specific results are shown in Table 5.

Table 5. Descriptive Statistics

Variable Code	Variable Name	Mean	Standard Deviation	Minimum	Maximum
EX	Development Level of Export Trade	1.734	1.084	0.176	3.905
DE	Development Level of the Digital Economy	0.322	0.179	0.036	0.725
FL	Financial Development Level	1.714	0.457	0.956	2.640
GI	Government Input Level	9.034	0.341	8.378	9.635
UR	Urbanization Level	71.560	12.493	47.870	89.850
IS	Industrial Structure	3.132	1.552	0.818	7.258

5.3. Empirical Results and Analysis

5.3.1. Correlation Analysis

The correlations among the variables are tested, and the specific results are shown in Table 6. The results indicate that the development level of export trade has a strong positive correlation with the development level of the digital economy, financial development level, government input level, urbanization level, and industrial structure.

Table 6. Correlation Analysis

	EX	DE	FL	GI	UR	IS
EX	1					
DE	0.918***	1				
FL	0.467***	0.374***	1			
GI	0.789***	0.921***	0.319**	1		
UR	0.390***	0.280*	0.733***	0.278*	1	
IS	0.879***	0.964***	0.324**	0.942***	0.321**	1

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.3.2. Multicollinearity Test

This study tests multicollinearity by calculating the variance inflation factor. As shown in Table 7, the VIF values of all variables and the Mean VIF value of the model are less than 10. Therefore, the empirical model in this study passes the multicollinearity test.

Table 7. Multicollinearity Test

	VIF	1/VIF
DE	7.01	0.143
FL	2.37	0.421
GI	6.74	0.148
UR	2.21	0.453
Mean VIF	4.58	

5.3.3. Analysis of Baseline Regression Results

This study uses a two-way fixed effects model to control for individual effects and time effects, so as to examine the impact of the digital economy on the development of export trade in the Yangtze River Delta region. Columns (1) to (4) in Table 8 report the regression results after gradually adding control variables.

To ensure the reliability of the regression results, no control variables are added in Column (1) of Table 8. The coefficient of the core explanatory variable *DE* is positive and significant at the 1% level. The regression coefficient of *DE* is 5.599, indicating that each one-unit increase in the development level of the digital economy can, on average, increase the development level of export trade in the Yangtze River Delta region by 5.599 units. This shows that improving digital infrastructure construction, promoting digital industrialization and industrial digitalization, and encouraging digital innovation in the Yangtze River Delta region will be conducive to the development of export trade in this region.

With the gradual addition of control variables, the coefficient of the core explanatory variable *DE* remains positive and significant at the 1% level. The R^2 of the model is consistent with expectations, and the model shows a good overall fit. The results show that, after controlling for a series of factors, the development level of the digital economy (*DE*) has a significant promoting effect on the development level of export trade (*EX*) in the Yangtze River Delta region.

Among the control variables, the regression coefficient of financial development level (*FL*) is significantly positive, indicating that financial development can promote the development of export trade by improving enterprises' external financing capacity. The regression coefficient of government input level (*GI*) is also significantly positive, suggesting that stronger government input is more conducive to the development of local export trade. The regression coefficient of urbanization level

(*UR*) is positive but not significant, indicating that its direct impact on the development of export trade is relatively limited.

Table 8. Baseline Regression Results

	(1) EX	(2) EX	(3) EX	(4) EX
DE	5.599***	4.088***	4.083***	4.133***
	(1.112)	(0.752)	(0.684)	(0.732)
FL		2.043***	1.664***	1.618***
		(0.302)	(0.307)	(0.379)
GI			1.297**	1.313**
			(0.473)	(0.486)
UR				0.003
				(0.015)
N	48	48	48	48
R2	0.838	0.934	0.948	0.948
r2 a	0.762	0.901	0.918	0.915
ID	YES	YES	YES	YES
YEAR	YES	YES	YES	YES

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; standard errors are reported in parentheses

5.3.4. Mechanism Test

To further analyze the mechanism through which the digital economy affects the development of export trade in the Yangtze River Delta region, this study uses the stepwise regression approach to test the mediating effect of industrial structure (*IS*). The regression models for the mediating effect are as follows:

$$EX_{it} = \beta_0 + \beta_1 DE_{it} + \beta_2 FL_{it} + \beta_3 GI_{it} + \beta_4 UR_{it} + \mu_i + v_t + u_{it} \quad (8)$$

$$IS_{it} = \alpha_0 + \alpha_1 DE_{it} + \alpha_2 FL_{it} + \alpha_3 GI_{it} + \alpha_4 UR_{it} + \mu_i + v_t + u_{it} \quad (9)$$

$$EX_{it} = \gamma_0 + \gamma_1 DE_{it} + \gamma_2 IS_{it} + \gamma_3 FL_{it} + \gamma_4 GI_{it} + \gamma_5 UR_{it} + \mu_i + v_t + u_{it} \quad (10)$$

The results of the mediating effect test are shown in Table 9.

Table 9. Results of the Mediating Effect Test

	(1) IS	(2) EX	(3) EX
DE	7.741***	1.444	4.133***
	(0.960)	(1.194)	(0.732)
IS		0.347**	
		(0.128)	
FL	0.870*	1.315***	1.618***
	(0.497)	(0.361)	(0.379)
GI	-0.713	1.561***	1.313**
	(0.637)	(0.450)	(0.486)
UR	0.019	-0.003	0.003
	(0.020)	(0.014)	(0.015)
N	48	48	48
R2	0.979	0.959	0.948
r2 a	0.965	0.930	0.915
ID	YES	YES	YES
YEAR	YES	YES	YES

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; standard errors are reported in parentheses.

Column (1) of Table 9 verifies the relationship between the development level of the digital economy (*DE*) and industrial structure (*IS*). The results show that *DE* is significant at the 1% level. This indicates that the development of the digital economy has an important positive promoting effect on the optimization of industrial structure. The digital economy can promote the optimization and upgrading of industrial structure through the following channels. First, the digital economy promotes the digital transformation of traditional industries. Traditional industries can use digital technologies such as big data to achieve transformation and upgrading, improve production efficiency, and reduce operating costs. Second, the digital economy gives rise to new forms of business and new models, which provide new growth points for industrial development. Third, the digital economy breaks geographical boundaries, thereby promoting the optimal allocation of resources in a broader field. The Yangtze River Delta region can use the digital economy to realize efficient sharing and complementarity of resources within the region and improve the industrial competitiveness of the whole region.

Column (2) of Table 9 examines the impact of the digital economy on the development of export trade after adding the mediating variable to the baseline regression model. The results show that, after industrial structure (*IS*) is added, the regression coefficient of the development level of the digital economy (*DE*) on the development level of export trade (*EX*) becomes insignificant, while the regression coefficient of industrial structure (*IS*) is significantly positive at the 5% level. This indicates that industrial structure (*IS*) plays a mediating role in the impact of the digital economy on the development of export trade in the Yangtze River Delta region, showing that the digital economy promotes the development of export trade by optimizing industrial structure. On the one hand, the digital economy promotes the upgrading of industrial structure through information technology, data factors, and platform-based organizational forms, and supports the development of tertiary industry sectors such as modern logistics, financial services, information services, business services, cross-border e-commerce, and supply chain management. On the other hand, goods exports do not only depend on the manufacturing process itself, but also rely heavily on the support of producer services such as research and development design, digital marketing, payment and settlement, customs clearance and logistics, after-sales services, and supply chain coordination. The improvement of the development level of the tertiary industry can reduce trade search costs, transaction costs, and logistics costs, improve enterprises' order response capacity and export organization efficiency, and thus transform the technological advantages, platform advantages, and resource allocation advantages formed by the digital economy into the expansion of goods export scale. Against the background of the strong development of the digital economy, the Yangtze River Delta region can further optimize its industrial structure and thereby significantly improve the overall competitiveness of its export trade.

5.3.5. Robustness Test

(1) Lagged Variable Approach

Considering that the impact of the digital economy on the development of export trade in the Yangtze River Delta region may have a lagged effect, this study adopts the lagged variable approach. The one-period lag of the key explanatory variable, DE_{t-1} , is used to replace the original key explanatory variable *DE*, so as to examine the impact of the one-period lagged digital economy development level on current export trade development (*EX*). The regression results are shown in Table 10.

Table 10. Regression Results of the Lagged Variable Approach

	(1) EX	(2) EX	(3) EX	(4) EX
DE _{t-1}	5.700*** (1.301)	3.998*** (0.787)	3.912*** (0.800)	3.720*** (0.856)
FL		2.129*** (0.279)	1.991*** (0.331)	2.113*** (0.379)
GI			0.456 (0.576)	0.475 (0.583)
UR				-0.012 (0.018)
N	44	44	44	44
R2	0.828	0.944	0.945	0.946
r2 a	0.745	0.914	0.913	0.911
ID	YES	YES	YES	YES
YEAR	YES	YES	YES	YES

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; standard errors are reported in parentheses.

From Column (1) of Table 10, the coefficient of the key explanatory variable after being lagged by one period increases compared with that in Column (1) of the baseline regression in Table 8. Each one-unit increase in the one-period lagged digital economy development level can, on average, increase the development level of export trade in the Yangtze River Delta region by 5.700 units. From Columns (1) to (4) of Table 10, the impact of the one-period lagged digital economy development level (DE_{t-1}) on current export trade development (EX) is significant at the 1% level. In terms of control variables, the regression coefficients of financial development level all pass the significance test at the 1% level, and the signs of the regression coefficients of government input level also remain stable. This indicates that the impact of the digital economy on the development of export trade in the Yangtze River Delta region has a certain degree of continuity, and that the results of the baseline model test above are robust.

(2) Model Robustness Test

This study evaluates the robustness of the research conclusions by examining whether the empirical results of the model are sensitive to specific econometric methods or assumptions. Ordinary least squares (OLS) is a basic linear regression method, which assumes that explanatory variables are not correlated with the error term and that the error term satisfies conditions such as homoscedasticity and zero mean. Column (1) of Table 11 reports the regression results of ordinary least squares.

Table 11. Model Robustness Test

	(1) EX	(2) EX
DE	7.408*** (0.827)	4.133*** (0.732)
FL	0.100 (0.188)	1.618*** (0.379)
GI	-1.216*** (0.425)	1.313** (0.486)
UR	0.011 (0.007)	0.003 (0.015)
N	48	48
R2	0.886	0.948
r2 a	0.876	0.915
ID	NO	YES
YEAR	NO	YES

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; standard errors are reported in parentheses.

Compared with the regression results of the two-way fixed effects model in column (2) of Table 11, the coefficient sign and significance of the core explanatory variable in the OLS model are consistent. Therefore, the research conclusions can be considered robust.

5.3.6. Regional Heterogeneity Test

To further examine the impact of the digital economy on the development of export trade in different areas of the Yangtze River Delta, this study divides the three provinces and one municipality in the Yangtze River Delta into regions with a higher level of digital economy development and regions with a relatively lower level of digital economy development, based on the average level of the comprehensive scores of the digital economy from 2013 to 2024 calculated in Chapter 4. Among them, Jiangsu Province and Zhejiang Province have relatively high average comprehensive scores and are classified as regions with a higher level of digital economy development. Shanghai Municipality and Anhui Province have relatively low average comprehensive scores and are classified as regions with a relatively lower level of digital economy development. After grouping, regressions are conducted separately. Columns (1) and (2) of Table 12 report the regression results for regions with a relatively lower level of digital economy development and regions with a higher level of digital economy development, respectively.

Table 12. Results of Regional Heterogeneity Test

	(1) EX	(2) EX
DE	1.361*	8.225*
	(0.601)	(3.530)
FL	0.075	2.625***
	(0.265)	(0.572)
GI	-0.108	2.207***
	(0.233)	(0.514)
UR	-0.002	0.216*
	(0.006)	(0.092)
N	24	24
R2	0.990	0.997
r2 a	0.967	0.990
ID	YES	YES
YEAR	YES	YES

Note: *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively; standard errors are reported in parentheses.

The regression results show that the coefficients of the digital economy development level (*DE*) are positive and statistically significant at the 10% level in both subsamples. However, the estimated coefficients differ considerably across the two groups. Specifically, the *DE* coefficient is 1.361 in regions with a relatively lower level of digital economy development, while it reaches 8.225 in regions with a higher level of digital economy development. This indicates that the effect of the digital economy on export trade is more pronounced in regions with more advanced digital infrastructure, a stronger digital industry base, and a higher degree of industrial digitalization.

One possible explanation is that Jiangsu Province and Zhejiang Province have a stronger manufacturing base, a more active private economy, and a more developed export-oriented economy. In these regions, digital technologies can be more effectively integrated into production and manufacturing, supply chain coordination, cross-border e-commerce, logistics and distribution, and market expansion. As a result, the digital economy can be more fully transformed into growth in merchandise exports. By contrast, regions with a relatively lower level of digital economy development still have certain weaknesses in digital infrastructure connection and the application of industrial digitalization. Their export-oriented manufacturing agglomeration and industrial chain coordination are also relatively insufficient. Therefore, the conditions for transforming digital technologies into merchandise export growth are not yet fully developed. For this reason, the impact

of the digital economy on export trade in this group is positive, but its promoting effect is weaker than that in regions with a higher level of digital economy development.

In regions with a higher level of digital economy development, the coefficients of the control variables, including financial development level (*FL*), government input level (*GI*), and urbanization level (*UR*), are all significantly positive. This suggests that more developed financial services and public input can complement the digital economy and jointly strengthen the development of export trade. In contrast, in regions with a relatively lower level of digital economy development, the relevant control variables are not sufficiently significant. This indicates that relying only on financial support or fiscal input may not be immediately translated into export growth. Instead, digital infrastructure, enterprise digitalization, and other supporting conditions need to play a joint role. Overall, the regional heterogeneity test shows that the positive effect of the digital economy on export trade differs across regions and is jointly affected by factors such as the level of regional digital infrastructure and the degree of industrial digitalization. Regions with a higher level of digital economy development show a stronger marginal contribution of the digital economy to export trade.

6. Research Conclusions and Policy Recommendations

6.1. Research Conclusions

This study constructs an indicator system for measuring the development level of the digital economy, assigns weights using the entropy method, and obtains a composite variable to calculate the comprehensive score of the digital economy development level in the Yangtze River Delta. On this basis, according to the empirical analysis above, the following conclusions are drawn:

(1) The digital economy significantly promotes the development of export trade in the Yangtze River Delta. The baseline regression results show that, after controlling for relevant factors, the regression coefficient of the digital economy development level remains significantly positive, indicating that the digital economy has become an important factor driving the growth of export trade in the Yangtze River Delta.

(2) Industrial structure optimization is an important transmission mechanism through which the digital economy promotes the development of export trade in the Yangtze River Delta. The mechanism test results show that the digital economy can promote industrial structure optimization, while industrial structure has a significant positive impact on export trade development. This indicates that industrial structure plays a mediating role in the process through which the digital economy affects export trade development.

(3) There is regional heterogeneity in the impact of the digital economy on export trade development. The grouped regression results show that the improvement of the digital economy development level has a positive impact on export trade in both regions with a higher level of digital economy development and regions with a relatively lower level of digital economy development. However, its promoting effect is stronger in regions with a higher level of digital economy development.

(4) The effects of control variables on export trade development differ. The baseline regression results show that the level of financial development and the level of government input have a significant positive impact on export trade development, while the regression coefficient of the urbanization level is positive but not significant, indicating that its direct impact is relatively limited.

6.2. Policy Recommendations

Based on the theoretical and empirical analysis results above, this study puts forward the following policy recommendations, with the aim of further strengthening the promoting effect of the digital economy on export trade development in the Yangtze River Delta and enhancing the region's competitiveness and influence in the international market.

(1) Strengthen Digital Infrastructure and Consolidate the Foundation for Trade Development

Digital infrastructure provides essential support for export enterprises to carry out digital operations and cross-border trade activities, and it also constitutes a basic condition through which the digital economy affects export trade. The Yangtze River Delta should continue to promote the development of 5G networks, industrial Internet, computing power platforms, data centers, and public service platforms for cross-border trade, so as to improve its capabilities in information transmission, data processing, and market connectivity. At the same time, efforts should be made to strengthen the deep integration of digital infrastructure with manufacturing clusters, cross-border e-commerce platforms, international logistics, and supply chain management systems, enabling digital facilities to better support key trade processes such as order acquisition, production organization, customs clearance and settlement, and after-sales services. For areas with relatively weak digital foundations, greater support should be provided for enterprise cloud migration, the application of industrial Internet, and the digital transformation of small and medium-sized enterprises, so as to prevent the gap in digital infrastructure from further evolving into a gap in export capacity.

(2) Promote the Integration between the Digital Economy and the Real Economy and Enhance Export Quality and Efficiency

The role of the digital economy in export trade lies primarily in promoting the application of digital technology in real-economy industries and trade chains, thereby enhancing export competitiveness through industrial structure optimization. The Yangtze River Delta should guide enterprises to extend digital transformation from internal management to key links such as research and development, design, production and manufacturing, quality traceability, warehousing and logistics, order matching, customs clearance and settlement, and after-sales services, so as to increase the added value of export products and improve delivery efficiency. For advanced manufacturing and strategic emerging industries, support should be provided for leading enterprises to build industrial Internet platforms, thereby driving upstream and downstream enterprises to share information on orders, inventory, quality, and logistics. For traditional manufacturing industries, digital solutions that are cost-controllable and can produce relatively quick results should be promoted, so as to improve enterprises' ability to adjust to fluctuations in external demand and promote the transformation of export growth from scale expansion to quality improvement.

(3) Improve Fiscal and Financial Support and Reduce Transformation Costs

The digital transformation of export enterprises is characterized by long investment cycles, large funding needs, and uncertain returns. Therefore, it is difficult to sustain such transformation solely through enterprises' own accumulation, and financial services and fiscal policies need to work together. Financial institutions may design credit products that are better suited to small and medium-sized foreign trade enterprises around scenarios such as equipment renewal, software systems, cross-border e-commerce platforms, overseas warehouse construction, and supply chain management, so as to reduce the cost of digital transformation for enterprises. Government funds should be directed more toward public platforms, common technologies, data services, pilot demonstrations, and talent training, while avoiding low-level repetitive construction. Fiscal support should also place greater emphasis on precision and performance orientation, and should be more targeted at enterprises with export potential but insufficient digital capabilities, so as to improve the efficiency of policy resource allocation and guide social capital to participate in the digital transformation of export enterprises.

(4) Deepen Regional Coordination and Optimize the Pattern of Division of Labor

The three provinces and one municipality in the Yangtze River Delta have different industrial foundations and foreign trade functions. Therefore, regional coordination should be strengthened to enhance overall export competitiveness. On the one hand, efforts should be made to promote the integrated development of data standards, logistics and customs clearance, cross-border e-commerce platforms, industrial parks, and public services, so as to reduce institutional and platform barriers among regions and improve the efficiency of factor mobility and trade organization within the region. On the other hand, a differentiated pattern of division of labor should be formed. Shanghai Municipality should focus on institutional innovation, financial services, and the connection with digital trade rules; Jiangsu Province should focus on manufacturing clusters and supply chain

organization; Zhejiang Province should focus on the platform economy and private foreign trade networks; and Anhui Province should focus on undertaking industrial transfer and fostering emerging manufacturing industries. Through division of labor and collaboration, the Yangtze River Delta can further strengthen the overall resilience of its export trade and its responsiveness to external markets.

(5) Improve Trade Governance and Cultivate Interdisciplinary Talent

The development of digital trade depends not only on technology and platforms, but also on a stable and transparent institutional environment and professional talent support. The Yangtze River Delta should improve its regulatory framework in areas such as cross-border data flows, intellectual property protection, platform compliance, cybersecurity, and digital trade regulation, so as to strengthen enterprises' institutional expectations when engaging in cross-border e-commerce, digital service trade, and supply chain coordination. At the same time, universities, research institutions, platform enterprises, and foreign trade enterprises should be encouraged to jointly cultivate interdisciplinary talent, with a focus on improving capabilities in data compliance, cross-border operations, digital marketing, international settlement, and supply chain management. By advancing rule development and talent cultivation in a coordinated manner, the region can reduce the uncertainty faced by enterprises participating in international digital trade and enhance the long-term competitiveness of export trade in the Yangtze River Delta in the context of the digital economy.

Overall, the Yangtze River Delta needs to more closely integrate the development of the digital economy with the transformation of export trade. While improving the basic conditions for development, it should also enhance the level of industrial coordination and institutional supply, so that the digital economy can be more effectively transformed into a sustained driving force for export trade development.

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