

# Research on the Impact of Digital Economy Development on Industrial Green Total Factor Productivity in the Yangtze River Delta

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## Abstract

The Yangtze River Delta is the region with the most active economic development and the highest degree of openness in China. However, with the acceleration of economic development in the Yangtze River Delta, the problem of regional pollution has gradually become prominent, and the functions of the ecological resource system have been seriously degraded. The development of the digital economy can effectively improve industrial GTFP by changing industrial production methods, upgrading industrial structures, and optimizing human capital investment, which has a significant positive effect on green economy development. Therefore, the Yangtze River Delta should further vigorously develop the digital economy industry to improve industrial enterprises' green development level. This is of great significance to achieving high-quality development of the regional economy.

## Keywords

Digital Economy; Green Total Factor Productivity; Yangtze River Delta.

## 1. Introduction

The Yangtze River Delta region, including Shanghai, Jiangsu, Zhejiang, and Anhui, has a total of 41 cities with a population of 227 million with an area of 358,000 square kilometers. In 2020, the GDP of the Yangtze River Delta region will reach 24.5 trillion yuan, accounting for 24.17 % of the national GDP. It is one of the regions with the most active economic development, the highest degree of openness, and the most vital innovation ability in China. In 2019, the Chinese government promulgated the "Outline of the Yangtze River Delta Regional Integrated Development Plan," which elevated the integrated development of the Yangtze River Delta to a significant strategy for regional development. With the acceleration of the integration process of the Yangtze River Delta and the influence of the traditional economic development model, the problem of regional pollution has gradually become prominent. In 2020, the total discharge of chemical oxygen demand of industrial wastewater in the Yangtze River Delta region reached 2.999 million tons, the production of general industrial solid waste increased from 214 million tons in 2008 to 323 million tons in 2020, and the emission of sulfur dioxide reached 108,600 tons, the function of the regional ecological resource system is degraded, and the environmental pollution is severe. Therefore, the Chinese government proposes adhering to the principle of ecological priority, consolidating the ecological requirements for green development, and striving to build a beautiful Yangtze River Delta. By giving full play to the advantages of cutting-edge technologies such as artificial intelligence, quantum information, and digital economy, it will optimize and adjust the industrial structure, promote the green transformation of traditional industries, and build a development system in which the economy and ecology of the Yangtze River Delta are coordinated, to promote the green and sustainable development of the Yangtze River Delta.

In recent years, China's digital economy has developed rapidly. In 2020, the added value of China's digital economy development core industries will account for 7.8% of GDP. Among them, the scale of the digital economy in the Yangtze River Delta accounts for about 44% of the regional GDP, accounting for the total scale of the national digital economy by 28%. The Yangtze River Delta region has become a demonstrator and leader in developing digital industries. At present, the "14th Five-Year Plan for Digital Economy Development" issued by the China State Council pointed out that by 2025, the country will further expand the scale of the digital industry, significantly enhance the level of intelligence, and improve the governance system for the development of the digital economy; by 2035, The digital economy is entering a period of prosperity and maturity, and the development level of the digital technology foundation and the digital industrial system ranks among the top in the world. In this context, analyzing the impact mechanism of digital economy development on industrial GTFP can enrich research in the field of digital economy development and provide research ideas for improving industrial GTFP. It can provide reference ideas for the Yangtze River Delta to adhere to high-quality development and the integrated development of the Yangtze River Delta.

## 2. Literature Review

### 2.1. The Impact of Digital Economic Development on the Economy

The digital economy develops with the use of the Internet. Tapscott Don (1995) put forward the concept of the digital economy in "Digital Economy: Hope and Risk in the Age of Intellectual Interconnection." It is pointed out that the digital economy is an economic form in which human beings identify, select, filter, store, and use data (digital knowledge and information), guide and arrange the rapid optimal allocation and regeneration of resources, and achieve high-quality development. It includes computer, network communication, and digital payment services [1]. In 1998, Tapscott Don and others further pointed out that the digital economy has a driving role in future social development. The European Commission pointed out by defining the digital economy and society index that the connotation of the digital economy includes five aspects: digitization of public services, broadband connection, digital technology integration enterprises, Internet citizenship index, and digitization of human capital structure [2]. According to China's industrial classification definition, the digital economy is characterized by the ability to collect a large amount of data, to be used on a large scale through the popularization of the Internet, and to use digital communication technology as a communication medium. The development of the digital economy is considered a series of economic activities that can promote the improvement of economic efficiency and the optimization of industrial structure.

As scholars continue to deepen their research on the digital economy, on the one hand, some scholars believe that the digital economy is a new economy that has a specific positive effect on promoting economic development (Kling and Lamb, 1999; Carlsson B, 2004; He Xiaoyin, 2004, 2013) [3][4]. Some scholars believe that the digital economy is based on communication technology and takes the Internet as the carrier, which promotes the rapid development of information technology and provides the effective impetus for social and economic growth and technological innovation (Feng Jian and Zhu Xinming, 2013) [5]. On the other hand, some scholars believe that the development of the digital economy has a certain impact on the economic structure. Some scholars mainly focus on the research between the digital economy and industrial transformation and upgrading. Chen Xiaohong (2018) believes that only by constantly applying new technologies to the production process of enterprises To realize the structural upgrading of the industrial industry and then promote the green development of the Chinese economy, the development of the digital economy has been widely used in the fields of government public management, medical services, retail, manufacturing, and location services

involving individuals, and has produced Huge economic and social value [6]. In addition, Wu Xiaoting et al. (2021) believe that the development of the digital economy can optimize the manufacturing industry and promote the transformation and upgrading of the manufacturing industry. Enterprises can take advantage of the digital economy's connectivity, integration, and efficiency to promote industrial enterprises to reduce costs and improve the efficiency of market resource allocation. The research found that the development of the digital economy has a more significant indirect contribution to the production of traditional manufacturing. The development of the digital economy has played a role in promoting the development of traditional manufacturing, and the driving effect is stronger than the pulling effect [7]. A review of the literature on the development of the digital economy shows that the development of the digital economy is innovative and can improve economic efficiency and optimize the industrial structure. At the same time, the development of the digital economy can also play a positive role in promoting economic growth and enterprise transformation.

## **2.2. Research on the Influencing Factors of Digital Economy Development on Industrial GTFP**

The research on the relationship between digital economy development and industrial GTFP is mainly reflected in the following three aspects:

(1) From the perspective of the mechanism of Internet development on industrial GTFP. Lu Fucai et al. (2021) found that the Internet has a significant positive effect on improving industrial GTFP. The threshold model found that the relationship between the Internet and industrial GTFP is nonlinear. When the Internet is lower than a certain level, the effect of the Internet on industrial GTFP tends to weaken [8]. Similarly, Yue Lirong et al. (2020) believe that the industrial Internet has a driving effect on green innovation performance, and absorptive capacity has a positive role in promoting the online, intelligent, and service-oriented industrial Internet and green innovation performance and has a positive effect on customization. It has a negative effect on green innovation performance [9]. Based on the industrial data of 108 cities in the Yangtze River Economic Belt, Li Lin et al. (2018) found that the development of the Internet in the Yangtze River Economic Belt significantly promoted the progress of green industrial technology and the improvement of the endowment structure inhibited the growth of industrial GTFP. There were regional differences in this effect. The Internet development in the cities west of the Yangtze River Economic Belt at a low level of improving technical efficiency, and the high level of Internet development in the Pan-Chengdu and Yangtze River Deltas have a significant role in promoting technological progress [10].

(2) From the perspective of the relationship between the development of the digital economy and GTFP. Wu Jing et al. (2021) used the spatial Dubin model and the panel threshold model to find that the development of the digital economy has a significant positive effect on green development, and GTFP has significant spatial spillover and time dependence. The results of sub-regions show that the promotion of digital economy development in China's central and western regions is more vital than in the eastern region; the results of the threshold model show that scientific research funding plays a single threshold role. When the threshold value is crossed, the promotion effect of the digital economy on GTFP will show a decreasing law [11]. Similarly, Zhou Xiaohui et al. (2021) believe that the development of the digital economy can promote the growth of GTFP, and there are noticeable regional differences. The digital economy has significantly improved the GTFP of central cities and its "siphon effect." It hinders the improvement of GTFP in peripheral cities. In addition, the development of the digital economy also has a "structural" promotion effect on GTFP, and the development of digital industrialization and industrial digitization is the driving force for the long-term improvement of GTFP [12]. Chen Bing and Wang Weilong (2021) believe that both the Internet and the upgrading of the industrial structure significantly promote the improvement of GTFP,

and the synergy between the Internet and industrial structure upgrading also significantly promotes the growth of GTFP; under different fields, different innovation policies and different resource types, The impact of urban Internet and industrial structure upgrading on GTFP is significantly different [13].

(3) From the perspective of the digital economy's development mechanism on industrial GTFP. Xiao Yuanfei et al. (2021), based on the industrial data of various provinces in the country, the research believes that the development of the digital economy can improve the efficiency of China's industrial green production by promoting the degree of openness, upgrading the industrial structure and optimizing the investment of human capital. The development of the digital economy has a significant positive effect on the green development of the industry. China should develop digital economy technology to improve industrial GTFP [14]. Similarly, Cheng Wenxian et al. (2021) found by studying the nonlinear characteristics of the digital economy and GTFP that the digital economy can promote the growth of China's industrial GTFP as a whole. The threshold model test results show that regional industry scale and a single threshold effect in environmental regulation show an increasing trend. The results of regional heterogeneity show that there are differences in impact in different regions [15]. Zhou Yong et al. (2021) also concluded that the digital economy has a significant role in promoting the growth of China's industrial GTFP, and there are significant regional differences [16].

Based on the research situation at home and abroad, there have been abundant studies on the connotation of the digital economy at home and abroad. Based on the background of high-quality development in the Yangtze River Delta, this paper combines digital economy, green development, and industrial total factor productivity to study the path of digital economy development and the impact mechanism of the digital economy on industrial GTFP.

### **3. The Impact Mechanism of the Digital Economy on Industrial GTFP**

#### **3.1. The Direct Effect of Digital Economy Development on GTFP**

The development of the digital economy can empower traditional industries, not only promote technological innovation of enterprises but also optimize resource allocation and promote green development of enterprises. The development of the digital economy has a direct effect on the growth of industrial GTFP, which is mainly reflected in the following two aspects:

(1) The development of the digital economy can boost the total factor productivity of industrial enterprises. First of all, the application of big data, cloud computing, the Internet of Things, and other technologies can realize the transformation of traditional industrial enterprises to intelligent manufacturing, enhance the innovation ability of industrial enterprises through digital technology, and promote the technological progress of enterprises. Especially in the face of the epidemic's impact, the digital economy has acted as a catalyst for economic recovery and a vital force in promoting the rapid return of the Chinese economy to the right track. In the post-COVID-19 era, the digital economy will continue to play an essential role in promoting the process of supply-side structural reform. It will also be an important driving force for industrial enterprise growth of total factor productivity. Secondly, in the context of the development of the digital economy, on the one hand, the business model of the Internet has increased the distance between enterprises and consumers. Enterprises rely on digital technology, and modern consumers can participate in product production and value creation. Continuous digitization and intelligence to more effectively meet the individual needs of consumers. On the other hand, enterprises can obtain customer data and analyze data through big data, smart devices, and digital technology to achieve timely feedback on customer information and needs [17]. Therefore, customers' needs have become an important source of innovation for industrial enterprises through the amplification of digital technology, which accelerates the product

upgrading and technological improvement of industrial enterprises, and improves the total factor productivity of industrial enterprises.

(2) The development of the digital economy can promote enterprises to follow a green development path. On the one hand, digital technology development can help companies optimize resource allocation and save energy consumption. With the digital transformation of industrial enterprises, it is possible to reduce resource misallocation and improve resource use efficiency. In particular, the role of digital economy development in industrial pollutant control and resource optimization allocation can be considered. By optimizing production processes and production processes, resources can be effectively improved. The collection efficiency can be achieved to achieve the optimal allocation of resources. Therefore, the development of digital technology can improve resource use efficiency and reduce energy consumption by optimizing the industrial structure [18]. On the other hand, developing the digital economy can promote China's realization of the Dual Carbon goals. The government can use the Internet to conduct environmental information disclosure, automatic monitoring, environmental protection publicity, etc., build environmental information governance, and carry out external supervision platforms, especially using blockchain technology to take advantage of its decentralization characteristics to build a green infrastructure financing platform. The platform can include infrastructure such as photovoltaic power stations, shared transportation, urban greening, etc., to ensure that new industrial infrastructure is consistent with carbon emission reduction goals. In addition, it can collect relevant information through big data, provide professional identification, precise positioning and tracking services, urge enterprises to reduce carbon emissions in the production process, and effectively combine the carbon emissions of enterprises with national carbon emission reduction measures.

### **3.2. Indirect Effects of Digital Economy Development on Industrial GTFP**

The development of the digital economy will promote the growth of the GTFP of industrial enterprises and can also optimize the industrial structure, bring innovation effects, and improve the level of economic growth. The digital economy's development indirectly affects the growth of industrial enterprises' GTFP.

(1) The digital economy can optimize the industrial structure through infrastructures such as the Internet and cloud computing, break the spatial constraints of the industry, improve the production efficiency of enterprises, and then improve the total factor productivity. On the one hand, developing the digital economy can produce innovative effects. The development of the digital economy has a solid positive externality on the transformation of traditional industrial enterprises. In particular, the technological spillover effect brought by the development of the Internet can significantly promote the production efficiency and innovation performance of industrial enterprises. The innovation effect has transformed many aspects of traditional enterprise production, research, development, organization, management, etc., and has promoted industrial transformation and upgrading. On the other hand, developing the digital economy can synergistically integrate industrial resources. The development of the digital economy plays an essential role in the integration degree and connection form of the industrial chain's upper, middle, and lower reaches. The digital economy strengthens the connection between various industries and associations. The effect is conducive to promoting enterprises to accelerate their transformation. At the same time, to improve the competitiveness of the industry and enhance its position in the value chain, enterprises will use information technology and digital technology to optimize and reorganize and obtain a higher division of labor through industrial upgrading, thus occupying a dominant position in the industrial division of labor. Therefore, the development of the digital economy will promote the upgrading of the industrial structure of industrial enterprises, improve the production efficiency of enterprises, and then positively affect the growth of the GTFP of industrial enterprises.

(2) Developing the digital economy can promote local governments' economic growth and innovative behaviors. On the one hand, developing the digital economy can promote the tax revenue of local governments, which is conducive to expanding the scale of fiscal revenue and enables local governments to have more vital fiscal autonomy. At the same time, developing the digital economy can bring value dividends and increase local governments' income. Local governments will adopt more active financial and preferential tax policies related to the digital economy's development, expand related industries' financial expenditures, and strengthen the intervention in allocating local resources. Guiding the healthy development of the industry will increase the scale of investment in digital technologies such as the Internet, big data, blockchain, and artificial intelligence and attract more high-tech companies to invest locally through tax incentives, thereby driving local economic growth. On the other hand, the innovation effect generated by the digital economy has promoted the further development and broad application of digital technology, which is conducive to the improvement of labor level, the refinement of division of labor, the broadening of production links, and the improvement of enterprise productivity, thereby reducing the cost of each link, to achieve value-added. In addition, the increase in the scale and output value of local enterprises can enhance the competitiveness of local enterprises. By optimizing the efficiency of production, consumption, distribution, and other links, enterprises can attract more capital, promote the further expansion of industrial scale, and help expand the scale of fiscal revenue. Therefore, local governments will further increase investment in the digital economy and financial expenditures on science and technology, which will inevitably promote the technological progress of local enterprises and the total factor productivity of enterprises.

(3) Developing the digital economy can inject new momentum into enterprises, promote economic efficiency, and feed environmental governance. It is possible to collect and manage macroeconomic operations and microscopic production and operation management activities in real-time through digital technology; that is, it can improve the decision-making ability and level of the enterprise from the whole or the part and improve the operation efficiency of the enterprise. At the same time, enterprises can take advantage of the connectivity, integration, and efficiency of the digital economy to effectively overcome the irrationality of market allocation, promote industrial enterprises to reduce costs, and improve the efficiency of market resource allocation. Therefore, it is self-evident that the development of the digital economy can promote economic development. On the other hand, it can be known from the Kuznets curve that when the level of economic development reaches a certain level, economic development will bring about an environmental improvement. As the second largest economy in the world, China constantly attaches great importance to environmental protection, emphasizes green development, and actively advances carbon to peak carbon neutrality. Therefore, with the continuous improvement of China's economic level, China's industrial green development level may also show a gradual upward trend.

## **4. The Status of Digital Economy and its Impact on Industrial GTFP in the Yangtze River Delta Region**

### **4.1. Development Level of Digital Economy**

As a critical national planning area, the Yangtze River Delta region has a relatively high level of economic development. With the development of the Internet economy, digital technology has been applied on a large scale, the digital industry has developed rapidly, and the level of the digital economy is far ahead of other regions in China.

In 2021, the digital economy white paper released by the China Academy of Information and Communications Technology constructed an indicator of the development level of the digital economy from the three dimensions of the leading index, the consensus index, and the lagging

index, and calculated that the entire digital economy in the Yangtze River Delta region in 2020 will reach 10.83 trillion yuan, accounting for about 28% of the total scale of the national digital economy and 44.26% of the total GDP in the Yangtze River Delta region. The "three provinces and one city" in the Yangtze River Delta (Zhejiang Province, Jiangsu Province, Anhui Province, and Shanghai Municipality) saw the growth rate of the digital economy by more than five percentage points higher than the GDP growth rate over the same period. The penetration rate of the digital economy in the tertiary industry was higher than 40%. By using five indicators of digital foundation, digital industrialization, industrial digitization, digital innovation, and digital education to measure the development level of the digital economy in the Yangtze River Delta region, it can be found that the development level of the digital economy in the Yangtze River Delta region shows a rapid upward trend.

In terms of total volume, in 2020, the scale of Jiangsu's digital economy exceeded 4.4 trillion yuan, accounting for more than 43% of GDP, ranking second in the country. The entire digital economy in Zhejiang Province reached 3 trillion yuan, ranking fourth in the country, and the digital economy accounted for about 46.8% of GDP; the scale of Shanghai's digital economy was 2.1 trillion yuan, ranking first among all cities in the country. The scale of the digital economy in Anhui Province reached 1.1 trillion yuan, a year-on-year increase of about 11%.

In terms of growth rate, the average annual growth rate of Anhui Province is 49.15%, and the growth rate has remained above 10% for three consecutive years. The average annual growth rate is the highest among the "three provinces and one city" in the Yangtze River Delta. The average annual growth rate of the digital economy in Jiangsu Province has reached 39.42%, Zhejiang Province is 35.30%, and Shanghai is 28.01%. The development of the digital economy has become the main driving force for the high-quality integrated development of the Yangtze River Delta region.

#### **4.2. The Impact of Digital Economy on Industrial GTFP**

Industrial green development in the Yangtze River Delta region, driven by technological progress, is on the rise. Among them, the development of the digital economy has promoted technological innovation in the Yangtze River Delta region, promoted the optimization of industrial structure, and then promoted the growth of industrial GTFP. From 2008 to 2019, the overall level of green industrial development in the Yangtze River Delta region showed an upward trend.

The industrial GTFP experienced two "valleys" and two "peaks." From 2006 to 2008, with the dividends of China's accession to the WTO and the effects of related policies gradually appearing, the GDP of the Yangtze River Delta region grew rapidly, resulting in a significant increase in GTFP. From 2008 to 2009, affected by the financial crisis, the development of GTFP entered a trough. From 2014 to 2015, due to the adjustment of economic structure and the "new normal" of economic development, GTFP was hit to a certain extent.

With the passing of the painful period of economic transformation, GTFP reached its second peak. From 2008 to 2019, Zhejiang Province performed the best regarding the average annual growth rate of industrial GTFP in the "three provinces and one city" in the Yangtze River Delta. Among the 12 years, nine years of industrial GTFP. It is positive growth, with an average annual growth rate of 7.4%. Followed by Shanghai, there are eight years of positive growth. There have been six years of positive growth in Jiangsu Province. The improvement of industrial GTFP in Anhui Province did not perform well. In the eight years from 2008 to 2015, only the industrial GTFP in 2012 was positive, and the rest of the years were negative. However, from 2016 to 2019, Anhui's industrial GTFP was all positive growth, and the industrial GTFP has improved significantly in the last five years.

In general, Shanghai is leading in improving industrial GTFP in the Yangtze River Delta region. It acts as a "technical innovator" and "economic leader." Followed by Zhejiang, Jiangsu. Anhui

is in the third echelon of green economic development in the Yangtze River Delta region, and it acts more as an "industry undertaker" and "technology imitator." Jiangsu and Zhejiang provinces have similar GTFP levels, strong economic strength, advanced environmental technology, continuous optimization and upgrading of industrial structures, and rapid development of high-tech industries, achieving balanced economic and environmental development.

## **5. Countermeasures and Suggestions**

### **5.1. Strengthen the Investment of Digital Resources and Human Capital and Give Full Play to the Enabling Role of the Digital Economy**

The first is to give full play to the enabling role of digital economy development in traditional industries, promote the transformation of traditional industrial enterprises to automation and digitalization, and strengthen the positive role of digital transformation of traditional industrial enterprises in improving industrial GTFP. Especially in the post-epidemic era, the digital economy can be a catalyst for economic development; it can achieve high-quality economic development, accelerate the innovation and application scenarios of the digital economy, and continuously release the digital economy's inherent potential. The second is to improve the high-end talent training mechanism and increase human capital investment in the digital economy. Create many highly educated, high-quality talents to promote technical efficiency and technological progress. Increase financial investment in cutting-edge technologies, continue to increase tax incentives and talent subsidy policies for high-tech enterprises; on the other hand, improve the talent training model to provide talent support for the development of the digital economy.

### **5.2. Give Play to the Role of Digital Economy Development in Promoting the Upgrading of Industrial Structure**

The first is to promote the digital transformation of traditional industries and use digital economy technology to transform and optimize enterprises with full coverage, complete functions, and entire chains. At the same time, give full play to the positive role of Internet technology in seeking technological innovation in traditional industries, promote the comprehensive application of the digital economy, promote technological integration, industrial integration, and data integration, and give full play to the development potential of the digital economy. Second, enterprises can fully integrate Internet technology in the process of production and operation, use Internet thinking to transform and transform traditional industrial enterprise production methods, draw the distance between consumers and enterprises, and carry out R&D innovation and model innovation according to the individual needs of customers, production process innovation and positioning innovation, to optimize the product structure of the enterprise.

### **5.3. Optimize the Financial System and Mechanism, Improve Relevant Laws and Regulations, and Create a Good Innovation Environment for Enterprises**

The first is to promote the government to optimize the financial system and mechanism to create an external environment for the digital transformation of industrial enterprises. Local governments can increase policy support for transforming and upgrading traditional intensive industries and formulate active fiscal and tax policies to help enterprises carry out digitalization and intelligent transformation. At the same time, strengthen the construction of digital economy infrastructures, such as big data platforms and blockchain technology, to promote the connection between industrial enterprises and digital economy development platforms and improve the digital transformation of traditional labor-intensive enterprises through



production resource sharing, thereby improving the production efficiency of traditional industrial enterprises.

#### 5.4. Improve the Regional Coordinated Development Strategy

There is a large gap between the digital economy level and manufacturing upgrades in cities in the Yangtze River Delta region, and the problem of unbalanced regional development is more prominent. As the foundations and geographical factors of the development of the digital economy and manufacturing industry vary from place to place, relevant development policies should be introduced according to local conditions, fully consider the actual development situation of the region, explore a path to promote the joint development of the entire region, allocate resources rationally, and improve utilization efficiency, to give full play to the unique advantages of each region and achieve coordinated development. The geographical advantages of Shanghai, Jiangsu Province, and Zhejiang Province have an excellent foundation for developing the manufacturing industry. It is necessary to attach importance to the development of medium and high-end industries. The government provides specific policy support, actively learns and applies advanced technologies at home and abroad, and improves the upgrading and development level of the manufacturing industry. The digital economy development and manufacturing upgrading in Anhui Province are still relatively low. Local governments should actively provide talent and technical assistance to Anhui Province and strive to use the development of the digital economy as the driving force to promote the transformation and upgrading of local manufacturing industries. In addition, by establishing a digital economy development demonstration zone, the development experience and successful models of regions with a higher level of digital economic development can be promoted to regions with a lower level of digital economic development, strengthening inter-regional communication and cooperation and promoting resource elements and advanced technologies.

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