

Network Effect and Degree of Influence of Digital Economy Empowering the Real Economy

-- Take the Yangtze River Delta region as an example

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Abstract: The development of digital economy is an important path to promote the integration and high-quality development of the Yangtze River Delta region, so this paper firstly measures the correlation between the development level of digital economy in the Yangtze River Delta in 2018 and 2019, and analyzes the characteristics of its network structure by using the social network model; secondly, it establishes the panel fixed-effects model, and empirically analyzes the relationship between the development of digital economy in the Yangtze River Delta and the real economy. It is found that the degree of aggregation of the digital economy network model is inversely correlated with the level of development of the real economy; the digital economy has a facilitating effect on the real economy, and green finance is an important positive transmission mechanism. This paper provides new ideas and paths for how the digital economy empowers the high-quality development of the Yangtze River Delta integration, as well as empirical evidence and effective suggestions on how to promote the better development of the real economy.

Keywords: Digital economy; Real economy; Social network model.

1. Introduction

In recent years, in order to implement the national policies related to the development of the digital economy, the Yangtze River Delta, based on the local reality, based on "integration" and "high quality", actively combines the digital economy with economic and social development, and introduces relevant planning programs and special policies for big data, smart cities, artificial intelligence and other subsectors. In 2018, the Three-Year Action Plan for the Integrated Development of the Yangtze River Delta Region (2018-2020) was put forward, which pointed out that the construction of a modernized economic system, vigorously develop core industries such as the Internet of Things, big data, artificial intelligence, 5G, integrated circuits and other core industries, and boost the high-quality development of the Yangtze River Delta region with the digital economy. Therefore, it is particularly important to explore the relevance of the digital economy among cities in the Yangtze River Delta, to study the effectiveness of the digital economy on the integration of the Yangtze River Delta, and the effectiveness of the digital economy in improving the development of the real economy in the Yangtze River Delta region. This paper takes the Yangtze River Delta as a region as a research sample, uses social networks to analyze the correlation between digital economy and cities and the network characteristics after policy implementation, and at the same time empirically analyzes the impact effect and transmission mechanism of digital economy on the development of the real economy, and puts forward the corresponding policy recommendations for the integration and high-quality development of the Yangtze River Delta region.

At the level of empirical research on the digital economy on the real economy, domestic studies, relying on microdata, have discussed the impact of the digital economy on the level of development of the real economy in the following four

aspects: first, the role of the digital economy in promoting the real economy and the transmission mechanism are discussed separately. Zhao Tao et al. (2020)^[1] found that the digital economy has a significant driving effect on regional high-quality development. Song Qinghua et al. (2022)^[2] argued that industrial digitization would enhance the total factor productivity of manufacturing enterprises, especially small and medium-sized enterprises (SMEs), and could be enhanced by adjusting the way of embedding in the value chain. Song Xuguang et al. (2022)^[3] argued that the digital economy can have a dynamically enhanced promotional effect on the real economy and can indirectly promote the development of the real economy by strengthening the internal control and cost management of enterprises. Guo Jinhua et al. (2021)^[4] concluded that the construction of digital infrastructure is conducive to promoting the total factor productivity of enterprises, and can promote the total factor productivity of enterprises by replacing part of the human capital input, alleviating the financing constraints and reducing the cost of business operations. Yan Wu, Wan Liangwei (2022)^[5] concluded that the digital economy has an inhibitory effect on the financialization of enterprises, which can be inhibited by reducing the degree of financing constraints and improving the quality of enterprise internal control. Li Zhiguo, Wang Jie (2021)^[6] concluded that the development of digital economy has the double dividend of manufacturing productivity improvement and data factor allocation optimization, and through the multi-dimensional data factor optimization allocation to improve manufacturing productivity. Jiang Hongli et al. (2022)^[7] concluded that the development of the digital economy significantly promotes enterprise entity investment, and can improve the efficiency of entity investment by alleviating enterprise financing constraints and improving the quality of enterprise internal governance. He Fan, Liu Hongxia (2019)^[8] concluded that digital change significantly improves the economic efficiency of real enterprises, and it promotes the economic efficiency of

digital change of real enterprises by reducing costs and expenses, improving the efficiency of asset use, and enhancing the ability to innovate. Hu Xijuan et al. (2022)^[9] concluded that the digital economy significantly promotes the development of China's real economy, and science and technology innovation and human capital are important intermediary transmission mechanisms. Secondly, the inhibitory effect of the digital economy on the real economy is discussed separately. Jiang Song, Sun Yuxin (2020)^[10] concluded that at the overall level of the digital economy has produced a dampening effect on the real economy, and has an "inverted U-shaped" characteristic threshold effect. Ma Yong et al. (2021)^[11] that the digital economy in general has produced a certain degree of extrusion effect on the real economy in the central region, but the effect of its impact on the existence of the law of marginal diminution. Zhou Xiaoliang, Baozhe (2021)^[12] concluded that the digital economy development has produced a certain degree of extrusion on the real economy, and shows a marginal diminishing law of east-central-west. Third, the promotion and inhibition of the digital economy on the real economy are discussed at the same time. Yang Mingyan and Pu Zhengning (2022)^[13] studied the impact of the digital economy on enterprise financialization, and concluded that the digital economy has promoted enterprise financialization by alleviating the enterprise financing constraints and exacerbating the "contagion effect" of enterprise financialization, but it can also alleviate enterprise financialization to a certain extent through the investment in and use of digital technology assets. The following is an example of the "contagion effect" of the financialization of firms. Liu Yiwen et al. (2022)^[14] analyzed the impact of the real economy on enterprise investment efficiency, and concluded that the real economy has a threshold effect on enterprise investment efficiency, which is mainly inhibitory before crossing the threshold, and after crossing the threshold, it can enhance the enterprise investment efficiency through the regulation of over-investment behaviors of enterprises. Wang Ruqi, Tao Shigui (2022)^[15] concluded that the digital economy can indirectly promote the development of the real economy through technological innovation and foreign investment, and at the same time, it will also produce a certain inhibitory effect by affecting the development of traditional finance. Fourth, the characteristics and utility of the deep integration of digital economy and real economy are discussed. Tian Xiujuan, Li Rui (2022)^[16] concluded that the integrated integration of digital technology with the production sector in the long term and the deep integration of digital technology with the financial sector in the short term jointly promote the improvement of enterprise economic efficiency. Guo Han, Quan Qinhui (2022)^[17] concluded that the coupling and coordination of digital economy and real economy in each province continues to deepen, but the development of digital economy in most provinces lags behind the real economy. Zhang Shuai et al. (2022)^[18] concluded that the level of integration between China's digital economy and the real economy has shown a continuous upward growth trend year by year, but its overall level is still relatively low, and there is a growing disparity between regions. Hu Xijuan et al. (2022)^[19] concluded that the level of integration between the digital economy and the real economy is on the rise, and the integration development index shows spatial non-equilibrium and gradual expansion, and the net difference between regions is the dominant factor in the

overall regional divergence.

At the level of theoretical elaboration, Zhang Kaihui (2022)^[20] analyzes the significance of the integration of the digital economy and the real economy in the "14th Five-Year Plan" period and the problems faced, and ultimately comes up with an innovative mechanism for the integration and development of the digital economy and the real economy. Kuang Jinsong, Peng Wenbin (2020)^[21] sorted out the historical and practical logic of the digital economy to drive the high-quality development of the economy, and put forward the countermeasures that should be taken, and at the same time, the center of gravity should be placed on the promotion of the integration of the digital economy and the real economy. Lu Minfeng (2023)^[22] puts forward the intrinsic advantages of the digital economy to empower the development of the real economy, the operation mechanism and the realistic practical path. Yang Hutao (2021)^[23] distinguishes between micro, meso, and macro levels to elaborate the internal logic and policy focus of digital economic development and the construction of a new development pattern, and focuses on the importance of the digital economy to promote the development of the real economy and the practical path. Xia Jiechang and Liu Hui (2023)^[24] illustrate the role mechanism of the integration and development of the digital economy and the real economy from the perspective of the integration of industry and reality, the new problems faced, and put forward the corresponding solution strategies. Jing Wenjun and Sun Baowen (2019)^[25] study the connotation of digital economy on the high-quality development of China's economy from both macro and micro perspectives based on the current situation of China's economy.

At the level of spatial effects of digital economy, Hu Yan et al. (2022)^[26] used social network model to analyze the structural characteristics of digital economy network in the Yangtze River Delta (YRD), and concluded that the nodes of the YRD digital economy network are relatively sparse among each other, but the overall structure is stable, and the digital economy resources show a trend of convergence towards the central YRD. Ding Shulei (2022)^[27] used the social network model to analyze the relationship between Internet usage and employment quality, and concluded that social network and Internet usage can improve employment quality, and that social network has a boosting effect on employment quality. Jin Canyang (2022)^[28] used the modified gravity model to measure the strength of association, structural characteristics and change trends of digital economic development between provinces in China, and the results show that China's digital economic development is imbalanced among regions, and the digital economic development shows a tendency to gather inland.

The above studies have explored the relationship and utility between the digital economy and the real economy, but in the context of China's current active promotion of the "dual-carbon" goal, the current studies have only discussed the impact of the digital economy on the real economy after considering the green indicators, and few of them have included the corresponding carbon emissions or green indicators in the framework of empirical analysis. At the same time, in terms of the spatial effect of the digital economy on the real economy, although the current research has indicated the characteristics and influencing factors of this spatial effect, most of them have been discussed at the general level, and the spatial correlation effect and transmission mechanism within a specific region have been less discussed. The Yangtze River

Economic Belt, as the front-runner and leading region of China's economic development, is unique in its impact of the development of digital economy on the real economy. Therefore, the research in this paper is based on the Yangtze River Economic Belt region, based on the micro-data of urban data, constructing corresponding variable indicators, on the basis of empirical research on the impact of digital economy on the level of real economic development and the transmission mechanism, referring to the research ideas of Xia Jiechang and Liu Hui (2023) [24] in the academic theory, incorporating the green index of green finance index into the empirical analytical framework and exploring the impact of digital economy on the real economy under different levels of carbon emissions in the region. the heterogeneous role of the digital economy on the real economy in regions under different carbon emission levels; meanwhile, we establish the theoretical model of social network model to explore the spatial correlation of the impact of the digital economy on the real economy and the characteristics of intra-regional network linkage in the specific region of the Yangtze River Economic Belt, and finally derive corresponding empirical evidences and policy recommendations.

2. Research Hypotheses

2.1. Direct transmission mechanisms

In the process of integration of modern digital technology and the real economy, the digital economy should be born in the distance, and gradually penetrate into all aspects of the development of the real economy, so as to make up for the many deficiencies in the field of the traditional real economy, and promote the transformation and upgrading of the real economy. However, while the digital economy promotes the development of the real economy, it will also exacerbate the "real financialization" characteristics of some enterprises, which will have a certain extrusion effect on the real economy. First, China's current laws and regulations in the field of digital economy and the development speed of the digital economy does not match, there are many "regulatory vacuum", will lead to part of the digital economy enterprises to use improper means to squeeze the space of the development of real enterprises; Secondly, due to the digital economy has a strong virtual and covert, part of the regulator will produce Secondly, due to the strong virtual and hidden nature of the digital economy, some regulators will generate rent-seeking behavior, disrupting the normal order of market operation, which will hit the enthusiasm of other enterprises to participate in the real economy (Wang Ruqi, Tao Shigui, 2022) [15]; Thirdly, some large head platform enterprises, using their dominant position in the market, use algorithms and "big data to kill maturity" and other ways to establish their own monopoly position, which will gradually relegate the real enterprises to the real economy, and will gradually reduce them to the real economy. Thirdly, some large head platform enterprises use their dominant position in the market to establish their market monopoly by using algorithms and "big data to kill matches", which gradually categorize the real enterprises as the dependence of the platform enterprises and hinder the healthy development of the real economy.

Accordingly, the first research hypothesis can be put forward:

H1: The development of digital economy can have a positive role in promoting the real economy of the Yangtze River Delta, but at the same time, it will also have a certain

inhibitory effect.

2.2. Intermediation effect

The development of the digital economy is based on the big data platform, China's current financial system is still based on indirect finance, that is, the commercial banks dominate the operation of the financial system, so in green finance, the green credit led by commercial banks plays a key role. In reality, China's green credit investment and industrial demand there is a financial mismatch phenomenon, resulting in part of the green credit funds did not really support the development of green industry, low efficiency. The digital economy has given rise to various types of big data platform can effectively solve this problem, commercial banks through the big data platform and related industries and enterprises docking, can be more clear understanding of its total and subdivided capital demand, in order to achieve the policy purpose of accurate investment, can more effectively support the development of green industry, while other financial institutions can also use information technology and big data platform, the development of different types of green financial products At the same time, other financial institutions can also develop different types of green financial products with the help of information technology and big data platforms, thus the development of the digital economy can effectively promote the improvement of the development level of green finance. Green finance can further promote the high-quality development of the real economy of the city (Liu Huake, He Chun, 2021), and the improvement of the development level of green finance can, on the one hand, put more funds into the green industry, reduce the financing cost of the relevant enterprises, especially small and micro-enterprises, and at the same time promote the transformation, upgrading, optimization and restructuring of the traditional industry, and on the other hand, it can give rise to a new type of green consumer demand and expand the effective market of the country. On the other hand, it can generate new type of green consumption demand and expand the domestic effective market, so as to jointly promote the development level of urban real economy at both the supply and demand levels.

Accordingly, the second research hypothesis can be proposed:

H2: The digital economy can significantly promote the development of green finance, and can promote the development of real economy through this mechanism.

3. Study Design

3.1. Social Network Modeling Analysis

3.1.1. Description of measurement indicators

In 2018, the Three-Year Action Plan for the Integrated Development of the Yangtze River Delta (YRD) Region was proposed, and this paper chooses three years, 2011, 2018, and 2019, as the research samples for the social network model, and applies Gephi to study the linkage of the digital economy among the YRD city-regions.

The digital economy development level indicators selected in this paper draw on Liu Jun et al. (2020) [29] and Zhao Tao et al. (2020) [1] to measure the linkage of the digital economy development level with the Internet as the measurement center, combined with the digital transaction to measure the comprehensive development level of the digital economy at the city level, and the 27 cities in the Yangtze River Delta as nodes.

3.1.2. Building a horizontal network for digital economy development in the Yangtze River Delta

The construction of spatial correlation network matrix of financial risk in Yangtze River Delta region is based on the determination of spatial correlation relationship, and the data of empirical research is "attribute data", while the data of social network analysis research is "relationship data". From the previous literature, gravity model and VAR model are mainly used to realize the transformation from "attribute data" to "relationship data". However, the latter cannot show the dynamic evolution of spatial correlation network, and is too sensitive to the choice of lag order. Therefore, this paper chooses the gravity model, which is more suitable for macroeconomic data, to build the spatial correlation matrix of municipal financial risk, and includes the economic development level and geographic distance of various municipalities in the scope of research, so as to obtain the modified gravity model. The formula of the modified gravity model is as follows.

$$x_{ij} = con_{ij} \frac{\sqrt[3]{RFRL_i POP_i GDP_i} \sqrt[3]{RFRL_j POP_j GDP_j}}{\left(\frac{dis_{ij}}{pGDP_i - pGDP_j} \right)^2} \quad (1)$$

$$con_{ij} = \frac{RFRL_i}{RFRL_i - RFRL_j}$$

Where, x_{ij} denotes the strength of the association relationship between the level of financial risk in the municipal area; $RFRL_i$ is the level of financial risk in the municipal area of city i ; dis_{ij} denotes the shortest highway distance between the municipal governments of the two cities (the data is obtained from the Gaode map); con_{ij} denotes the contribution rate of city i in the association of the financial risk of cities i and j , where the contribution rate can be interpreted as the contagion ability of city i to the financial risk of city j ; POP_i denotes the indicator of the end-of-the-year population scale of city i ; GDP_i and $pGDP_i$ represent the accounting indicators of the overall economic scale and per capita economic scale of city i , i.e., the Gross Regional Product (GRP) and the Gross Regional Product (GRP) per capita, respectively. According to the above formula to calculate the spatial correlation of financial risk in the Yangtze River Delta region, in order to establish the spatial correlation network matrix of municipal financial risk M , in order to facilitate the study, it is necessary to binarize the matrix M , that is, the average value of each column in the matrix M as the row of the critical value of the degree of correlation between the city's financial risk and the other city's financial risk, and if x_{ij} is greater than or equal to the critical value, then the value is taken to be 1, which means that the row of the city's financial risk If it is greater than or equal to the critical value, it takes the value of 1, indicating that there is risk contagion from the row city financial risk to the column city financial risk; otherwise, it takes the value of 0, indicating that there is no risk contagion from city i to city j . Since the value of the correlation relationship between individual cities is too large, which will affect the effect of the correlation

relationship between other cities in their rows when binarization is processed, the great value of each row is removed and then binarized, so as to get the unweighted directed matrix to study the spatial correlation characteristics of the financial risk between cities and the evolution of the law.

3.1.3. Social network analysis

Social network analysis is a study of "relationships" in the "aggregate", focusing not only on theories, methods and methodologies, but also on the survival, life and existence of social actors. Simply put, "social network" is a collection of social actors and their relationships as nodes. However, there is a tendency in the social network academic circles at home and abroad, that is, in the research seems to pay attention to the general attributes of the nodes, but in essence, it generally ignores the individual attributes of the network nodes, especially the dynamic attributes, and regards the nodes as nodes that are influenced by the structure, and do not have the ability of "reflection" and "action". The nodes are regarded as nodes affected by the structure and do not have "reflection" and "action power", which is inconsistent with the actors in the real world. Therefore, in this paper, we emphasize that the actors as network nodes are not puppets, but actors with "subjective mobility".

1. Overall network characteristics

Overall network density (D) refers to the closeness of the connection between the members of the network, and the larger the value of this indicator, the stronger the correlation of digital economic development between cities. Network density is a measure of whether the entire network structure is dense or loose, and is obtained from the actual number of edges present in the entire network compared to the theoretical maximum number of edges present. The formula for calculating network density in directed relational networks is as follows:

$$D = \frac{M}{N(N-1)} \quad (2)$$

Where M is the number of city financial risk association relationships that actually exist in the entire network; N is the number of established nodes in the network, i.e., the number of cities; and $N(N-1)$ is the maximum number of relationships that theoretically exist in the entire network.

2.the average degree of the network

The average degree is the degree of the entire network of individual nodes, and a node degree is defined as the node should be how many other nodes associated with it, so the average degree of the entire network can be expressed to a certain extent a network nodes directly associated degree.

3.2. Econometric modeling

3.2.1. Model building

First, in order to verify the utility of the digital economy to the real economy, the following panel two-way fixed effects model needs to be constructed:

$$REAL_{it} = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 Z_{it} + u_i + \delta_t + \varepsilon_{it} \quad (3)$$

Where $REAL_{it}$ is the level of real economy of each city i in different year t , Dig_{it} is the level of digital economy of

each city i in different year t , and Z_{it} it is a series of control variables, which include Consumption level (Consum), Fiscal decentralization (Finadp), Population size (PEO), Green coverage of built-up area (Green), Urban pollution level (POLL). u_i is individual fixed effect, δ_t is time fixed effect, and ε_{it} is a random disturbance term.

Secondly, in order to test the mediating effect of STI and financial development, the following mediating effect model needs to be constructed.

$$Mediat_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 Z_{it} + u_i + \delta_t + \varepsilon_{it} \quad (4)$$

$$REAL_{it} = \gamma_0 + \gamma_1 Dig_{it} + \gamma_2 Mediat_{it} + \alpha_2 Z_{it} + u_i + \delta_t + \varepsilon_{it} \quad (5)$$

$Mediat_{it}$ is the mediating variable, including science and technology innovation (Innov), financial development (Fin), green finance (Gfinace). At the same time, the test steps of mediation effect are as follows: under the basis of significant regression coefficient α_1 of digital economy on real economy, test whether the regression coefficient β_1 of digital economy on mediator variable and the regression coefficient γ_2 of mediator variable on real economy are significant or not, if both regression coefficients are significant, it can be directly judged that the mediator variable has the mediation effect; if β_1 is not significant and γ_2 is significant, then it is necessary to further Bootstrap test, if the confidence interval does not contain 0 in the test results, the test results are significant, can also be concluded that the intermediary variable has an intermediary effect. $Mediat_{it}$ is the intermediary variable, including science and technology innovation (Innov), financial development (Fin), green finance (Gfinace). At the same time, the test steps of mediation effect are as follows: under the basis of significant regression coefficient α_1 of digital economy on real economy, test whether the regression coefficient β_1 of digital economy on mediator variable and the regression coefficient γ_2 of mediator variable on real economy are significant or not, if both regression coefficients are significant, it can be directly judged that the mediator variable has the mediation effect; if β_1 is not significant and γ_2 is significant, then it is necessary to further Bootstrap test, if the confidence interval does not contain 0 in the test results, the test results are significant, can also be concluded that the intermediary variable has an intermediary effect.

3.2.2. Description of variable selection

1. Explained Variables

Real economic development level (REAL): considering the availability of data from prefecture-level cities in the Yangtze River Delta and referring to the measurement method of Wang Ruqi et al. (2022)^[15], the output value of the secondary industry of each city is selected as an indicator of the real economic development level.

2. Core Explanatory Variables

The level of digital economy development (Dig): Referring to the research method of Zhao Tao et al. (2020)^[1], the level of digital economy development at the city level is measured from the two levels of digital finance and Internet

development: for digital finance, Peking University's Digital Inclusive Finance Index is used, and for the level of Internet development, the number of Internet users per 100 people, the percentage of computer services and software employees, and the total amount of telecommunication services per capita are selected, The four sub-indicators of cell phone subscribers per 100 people are measured comprehensively, and the entropy value method is finally applied to derive the level of digital economy development of each city.

3. Control Variables

In this aspect, five control variables are set: Consumption level (Consum), measured by the level of per capita consumption expenditure; Fiscal decentralization (Finadp), measured by the ratio of budgeted revenue to budgeted expenditure; Population size (PEO), measured by the number of household population at the end of each year in the city; Green coverage of built-up area (Green), measured by the ratio of the area of built-up area and the area of built-up area; and the ratio of the area of built-up area and the area of built-up area to the area of built-up area. Green coverage rate of built-up area (Green), measured by the ratio of green space area of built-up area to the area of built-up area of the city; Pollution level of the city (POLL), measured by the sulfur dioxide emissions of the city.

4. Mediating Variables

Green finance refers to the measurement method of Liu Huake and He Chun (2021)^[30], firstly, the level of green credit, green investment, green insurance, green bonds and green support of each prefecture-level city is measured separately, and secondly, the green financial index of each prefecture-level city is calculated by entropy value method. Green credit is measured by the ratio of total city credit for environmental protection projects to total city credit, green investment is measured by the ratio of city investment in environmental pollution control to GDP, green insurance is measured by the ratio of city revenue from environmental pollution liability insurance to total premium revenue, green bonds are measured by the ratio of total city green bond issuance to total bond issuance of all bonds, and green support is measured by the ratio of city financial environmental protection expenditure to financial general budget expenditures measured.

4. Analysis of Empirical Results

4.1. Characterization of network structure

The overall characteristics of the digital economy network in the Yangtze River Delta are shown in Table 1, the density of the network model of the level of digital economic development was 0.521 in 2011, and 0.521 and 0.444 in 2018 and 2019, respectively, and the tightness of the relationship between the development of the digital economy in the Yangtze River Delta city-region was the highest in 2018, so it can be seen that the Three-Year Action Plan for the Integration and Development of the Yangtze River Delta Region, put forward in 2018, has a significant impact on the local digital economy development has a driving effect. Superimposed on the rapid development of the Internet, the 27 cities in the Yangtze River Delta city region have a higher demand for mutual cooperation after the rapid progress of digital economy cooperation, and the three provinces and one city have more confidence in the implementation of the policy. In addition, from the network density values of the three years, it can be seen that the digital economy in the Yangtze River

Delta region has the strongest correlation in 2018, the network structure is stable, and clustering occurs among cities.

Table 1. Overall network structure characteristics

Year	2011	2018	2019
network density	0.369	0.521	0.444

The digital economy network of the Yangtze River Delta (YRD) city area is shown in Figure 1-Figure 3. Among them, the inter-node density is the strength of connection between cities in the Yangtze River Delta in terms of their level of digital economy development. As shown in the figure, YC, TL and HZ were at the core of the network in 2011, with strong interconnections with other cities in the YRD region. It was found that the three cities were also at the forefront of the real economy in 2011. In 2018, four cities - YC, WH, CZ and HF - were at the center of the network, with the strongest linkages with other cities in the YRD; followed by nine cities in the outer circle, including NB and NT. In 2019, three cities - TZ, NB, as well as HF - were at the center of the network as front-runners of the YRD region in terms of the level of digital economy development. This is followed by nine cities such as Ningbo and Nantong in the outer circle. Comparison can be found, at first, Anhui regional network structure is more complex, Anhui cities with Shanghai, Suzhou and Zhejiang, along with Hefei's economic stride forward in recent years, Hefei and other cities more frequently, while with the passage of time, the level of development of the digital economy by the southeast to the middle of the convergence. The development of the digital economy in Zhejiang Province has benefited from the advantages of local industry and trade, and the influence of the digital economy on other cities has become stronger. During the 13th Five-Year Plan period, Zhejiang Province will play an extremely important role in the digital industrialization and digitalization of industries.

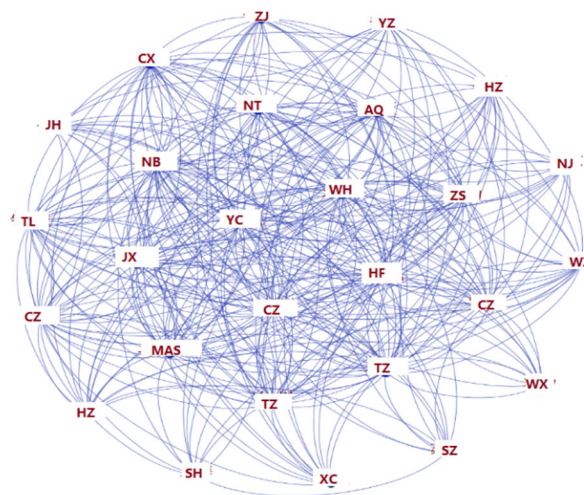


Figure 2. 2018 Network model

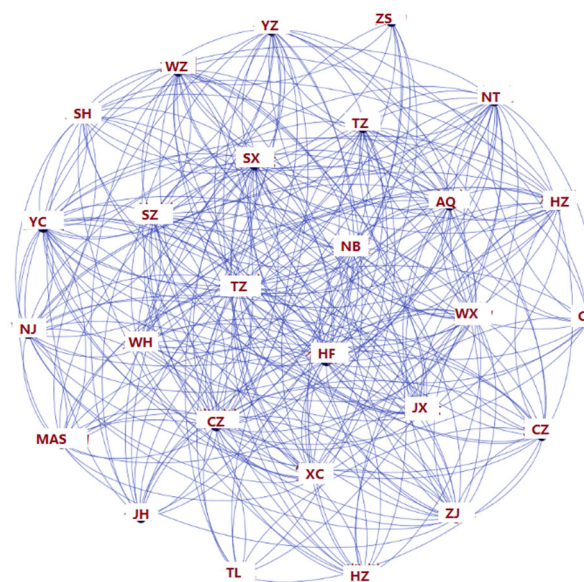


Figure 3. 2019 Network model

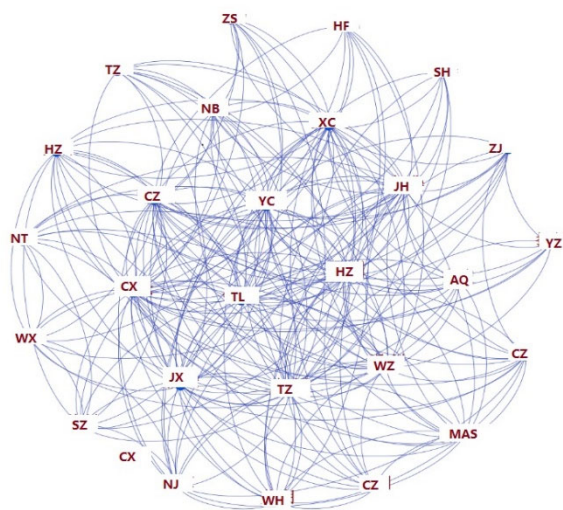


Figure 1. 2011 Network model

Table 2. Overall average

Year	2011	2018	2019
average	9.593	13.556	11.556

The network average degree of the digital economy development level in the Yangtze River Delta city region is shown in Table 2, and the distribution of the network directed average degree in 2018 is more concentrated, with a clustering effect. The network tightness in 2011 is the smallest among the three years, which is related to the low penetration rate of the digital economy at that time and the slow development of the Internet, and at the same time, the level of the real economic development of the Yangtze River Delta region in 2011 is much lower than that of the years after 2018. With the implementation of the YRD integration strategy, cities gained benefits through digital economic development, with Zhejiang Province favoring e-commerce, Jiangsu Province focusing on the Internet of Things, and Anhui focusing on gathering talents through Hefei, thus radiating economic benefits to neighboring cities.

4.2. Return to baseline

As can be seen from model (1) in the table, the estimated coefficient value of the digital economy index is significantly positive; after adding control variables in model (2), the estimated coefficient of the digital economy index on the development level of the real economy is 1.865, and it is significantly positive. Both indicate that the development of the digital economy will significantly enhance the development level of the real economy in the Yangtze River Delta cities, and for every unit increase in the digital economy, the development level of the real economy in this region will increase by 1.865 units. This also verifies the research hypothesis H1.

Table 3. Benchmark regression results

variant	REAL(1)	REAL(2)
Dig	4.838*** (7.86)	1.865*** (3.38)
Consum		0.049** (2.82)
Finadp		0.046 (0.37)
PEO		0.001* (1.78)
Green		0.001 (0.45)
POLL		-0.466*** (-12.49)
C	-3.080** (-8.46)	-0.703 (-0.98)
Year	YES	YES
Area	YES	YES
R²	0.631	0.762
Obs	369	369

4.3. Heterogeneity analysis

Referring to the research method of Hu Xijuan et al. (2022)^[9] to define the level of science and technology innovation, this section is divided with the help of the average value. Firstly, the average value of the STI level of each city during 2011-2019 is calculated separately; secondly, the average value of the STI level of all cities in each year is calculated separately, and finally the average value of the total STI level of all cities is calculated again. If a city's average STI level is higher than the total average, it is a city with high STI level, and vice versa, it is a city with low STI level, and then group regression is carried out.

Table 4 shows that in cities with a high level of science and technology innovation, the digital economy plays a more significant role in promoting the development of the real economy, while in cities with a low level of science and technology innovation, the digital economy still plays a significant role in promoting the real economy, but its effect has weakened. The reason for this phenomenon is that in cities with high level of scientific and technological innovation, the digital infrastructure is more complete, the scientific research capacity and the level of basic research are higher, which is more conducive to the rapid development of the digital economy, thus accelerating the progress of the integration of the digital economy with the real economy and playing a more significant role in promoting the development of the real economy; whereas in cities with a low level of scientific and technological innovation, the level of development of the

digital economy has to be improved, and the degree of integration of the digital economy is low, which has a significant impact on the real economy. In cities with a low level of science and technology innovation, the level of development of the digital economy needs to be improved, and the degree of digital-real integration is low, thus weakening the promotion of the real economy.

Table 4. Heterogeneity analysis

variant	technological level---High	technological level---Low
Dig	1.663** (2.04)	1.082* (1.70)
Consum	0.020 (0.23)	0.118 (0.67)
Finadp	-0.022 (-0.14)	-0.925** (-2.1)
PEO	0.004 (0.56)	0.004 (0.66)
Green	0.003 (1.10)	0.006 (0.77)
POLL	-0.370*** (-8.23)	-0.172*** (-4.66)
C	-1.509 (-1.36)	-0.272 (-0.14)
Year	YES	YES
Area	YES	YES
R²	0.8134	0.6833
Obs	369	369

4.4. Intermediary effect

In order to explore the impact of green finance on the digital economy, this paper launched an empirical analysis of the results as shown in Table 5, the digital economy has a significant role in promoting green finance. After adding the intermediary variables, the results show that the digital economy still has a significant driving effect on the real economy, and the intermediary effect of green finance on the real economy is still significant. After Bootstrap test of self-sampling 300 times, the variable is still significant, that is, green finance has a positive mediating effect on the real economy. Therefore hypothesis 2 is proved.

Table 5. Intermediary effect

variant	Gfinance	REAL
Dig	0.208** (2.10)	3.60*** (5.71)
Gfinance		1.120*** (3.36)
C	-0.395*** (-6.62)	-5.279*** (-12.83)
Year	YES	YES
Area	YES	YES
R²	0.5924	0.701
Obs	369	369
FIN Bootstrap		95% confidence interval
Bs 1		[-4.265, -0.509]
Bs 2		[5.618, 12.936]

4.5. Robustness and endogeneity

The robustness test adopts the replacement of explanatory

variables, selecting the digital economy index with one period lag as the explanatory variable, denoted as LDig; the endogeneity test refers to the method of Zhou Xiaoliang et al. (2021)^[12] and combines with the scope of this paper, selecting the number of people who accessed the Internet in the cities of the Yangtze River Delta (YRD) in the previous year and the number of telephones per 100 people in the YRD in 1984 to construct the interaction term, which is taken as an instrumental variable that can be applied to the panel-fixed model, and selecting the two-stage least-squares (2SLS) method to carry out regression analyses. In Table 6, (1) is the robustness test, (2) and (3) are the endogeneity test.

Table 6. Robustness and endogeneity

variant	REAL(1)	REAL(2)	REAL(3)
Dig		4.008*** (2.71)	3.892*** (5.01)
LDig	1.530*** (2.75)		
C	-0.425 (-0.60)	-10.293 (-16.45)	4.920*** (4.03)
Year	YES	YES	YES
Area	YES	YES	YES
R²	0.7533	0.9101	0.6666
Obs	369	369	369

5. Conclusions and Recommendations

5.1. Conclusions

Based on the Yangtze River Delta (YRD) region, this paper explores the network effects and the degree of influence of digital economy development on the real economy. It first qualitatively analyzes the network structure of the digital economy of cities in the Yangtze River Delta region through the modified gravity model and social network analysis, and then uses the panel fixed-effects model to study the degree of influence of the digital economy on the level of development of the real economy in the Yangtze River Delta region. It is found that, firstly, due to the different economic adaptability of different regions, which leads to significantly different degrees of aggregation and clustering effects in the network model of the digital economy development level in the Yangtze River Delta in different years; secondly, the development of the digital economy in the Yangtze River Delta region can promote the development of the local real economy; thirdly, the results of the intermediary effect test show that green finance is an important transmission mechanism, and has a positive intermediary effect on the real economy. effect.

5.2. Recommendation

First, balance the development capacity of the regional digital economy and accelerate the realization of the integration of the digital economy in the Yangtze River Delta. The second is to further enhance the overall level of digital economy development in the Yangtze River Delta region, especially in cities with relatively weak development bases.

Thirdly, relevant policies should be formulated to promote the in-depth integration of the digital economy and the real economy in the Yangtze River Delta, so as to further bring into full play the facilitating effect of the digital economy and curb the crowding-out effect.

Fourth, first, to continue to promote the green development

of the Yangtze River Delta region and reach the development goals of carbon peak and carbon neutrality at an early date, it is necessary to focus on the various difficulties faced by the real economy in the process of green transformation, and to introduce corresponding initiatives to promote the real economy to go through the transition period.

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References

- [1] ZHAO Tao, ZHANG Zhi, LIANG Shangkun. Digital economy, entrepreneurial activity and high-quality development - Empirical evidence from Chinese cities[J]. *Management World*, 2020,36(10):65-76.
- [2] Song Qinghua, Zhong Qiming, Wen Huwei. Industrial digitization and corporate total factor productivity: Evidence from listed companies in China's manufacturing industry[J]. *Journal of Hainan University (Humanities and Social Sciences Edition)*, 2022,40(04):74-84.
- [3] Song Xuguang, He Jiajia, Zuo Ma Huaqing. Digital industrialization empowers the development of real economy: mechanism and path[J]. *Reform*,2022(6):76-90.
- [4] GUO Jinhua, GUO Leminan, GUO Shufen. How does digital infrastructure construction affect firms' total factor productivity? --A quasi-natural experiment based on the "Broadband China" strategy[J]. *Securities Market Herald*,2021(06):13-23.
- [5] Yan Wu, Wan Liangwei. Research on the impact mechanism of digital economy on the financialization of real enterprises[J]. *Jiangxi Social Science*,2022,42(10):44-53+206.
- [6] Li Zhiguo, Wang Jie. Digital economy development, data factor allocation and manufacturing productivity improvement[J]. *Economist*,2022(10):41-50.
- [7] JIANG Hongli, HOU Yan, JIANG Pengcheng. Does the development of digital economy promote or inhibit firms' real investment-empirical evidence from Chinese listed companies[J]. *Modern Finance and Economics (Journal of Tianjin University of Finance and Economics)*, 2022, 42(05):78-94.
- [8] He Fan,Liu Hongxia. Evaluation of performance enhancement effect of digital change in physical enterprises under the perspective of digital economy[J]. *Reform*,2019(04):137-148.
- [9] Hu Xijuan, Shi Bo, Yang Jianfei. Mechanism identification and empirical evidence of digital economy growing real economy development[J]. *Economic Issues*,2022(12):1-8.
- [10] JANG Song, SUN Yuxin. An empirical study on the impact effect of digital economy on real economy[J]. *Research Management*, 2020,41(05):32-39.
- [11] MA Yong, WANG Hui, XIA Tian. Study on the crowding-out effect of digital economy on real economy in central region[J]. *Jiangxi Social Science*, 2021,41(10):48-57.
- [12] ZHOU Xiaoliang, BAO Zhe. Does the development of digital economy have a squeezing effect on the real economy? [J] *Economic System Reform*,2021(05):180-186.
- [13] YANG Mingyan, PU Zhengning. The Impact of Digital Economy on the Economy's "Deradicalization": Evidence from Listed Companies[J]. *Economic Review*,2022(03):110-126.
- [14] Liu Yiwen, Tan Huizhong, Chen Xijun, Yang Chao. Research on the impact of digital economy development on investment

- efficiency improvement of real economy[J]. *China Soft Science*,2022(10):20-29.
- [15] WANG Ruqi, TAO Shigui. How Digital Economy Affects the Development of Real Economy: Mechanism Analysis and China's Experience[J]. *Modern Economic Discussion*,2022(05):15-26.
- [16] Tian Xiujuan, Li Rui. Digital technology empowers the transformation and development of real economy--an analytical framework based on Schumpeter's endogenous growth theory[J]. *Management World*, 2022,38(05):56-74.
- [17] GUO Han, QUAN Qinhui. Integration of Digital Economy and Real Economy: Measurement, Evaluation and Realization Path[J]. *Economic Journal*,2022(11):72-82.
- [18] ZHANG Shuai, WU Zhenwei, LU Chaoyang, ZHANG Na. Evolutionary characteristics and driving factors of the integration of digital economy and real economy in Chinese provinces[J]. *Economic Geography*, 2022,42(07):22-32.
- [19] HU Xijuan, SHI Bo, YANG Jianfei. Drivers and regional differences in the integration of China's digital economy and real economy[J]. *Learning and Practice*,2022(12):91-101.
- [20] Zhang Kaihui. "Innovative Mechanisms for the Deep Integration of Digital Economy and Real Economy in the 14th Five-Year Plan Period[J]. *Economic System Reform*,2022(04), 88-94.
- [21] Kuang Jinsong, Peng Wenbin. Logical Explanation and Practical Progress of Digital Economy Driving Economic Development of High Quality[J]. *Exploration and Controversy*,2022(12):132-136+200.W.-K. Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.
- [22] Lu Minfeng. Digital science and technology empowering the high-quality development of real economy: integration advantages, operation mechanism and practical path[J]. *Journal of Xinjiang Normal University (Philosophy and Social Science Edition)*, 2023,44(01):136-144.
- [23] Yang Hutao. Construction of new development pattern and development of digital economy: internal logic and policy focus[J]. *Academic Monthly*,2021, 53(12):60-73.
- [24] XIA Jiechang, LIU Hui. Strengthening the Real Economy through Industrial Integration: Role Mechanisms and Promotion Strategies[J]. *Financial Issues Research*,2023(01):3-12.
- [25] Jing Wenjun, Sun Bowen. Digital economy for high-quality economic development:a theoretical analysis framework[J]. *Economist*,2019(02), 66-73.
- [26] HU Yan, CURI Mingyu, TANG Rui. Characteristics of digital economic network structure and influencing factors in Yangtze River Delta[J]. *East China Economic Management*, 2022,36(12):26-34.
- [27] Ding Shulei, Liu Cuihua. A study on the impact of Internet use on employment quality in the digital economy era - based on the perspective of social network[J]. *Economic and Management Research*, 2022,43(07):97-114.
- [28] JIN Can-Yang, XU Ai-Ting, QIU Ke-Yang. Measuring the development level of digital economy and its spatial correlation in Chinese provinces[J]. *Statistics and Information Forum*, 2022,37(06):11-21.
- [29] LIU Jun, YANG Yuanjun, ZHANG Sanfeng. Research on the measurement and driving factors of China's digital economy[J]. *Shanghai Economic Research*,2020(06):81-96.
- [30] LIU Huake, HE Chun. Mechanisms and Tests of Green Finance for High-Quality Urban Economic Development-Empirical Evidence from 272 Prefecture-Level Cities in China[J]. *Investment Research*,2021,40(07):37-52.B. Smith, "An approach to graphs of linear forms (Unpublished work style)," unpublished.