Research on the Coupling and Coordinated Development of Digital Economy and Rural Revitalization in the Yangtze River Delta Basin

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Abstract

The Yangtze River Delta basin is an important region for high-quality development in China. Based on the panel data of three provinces and one municipality directly under the Central Government in the Yangtze River Delta basin from 2019 to 2023, the comprehensive evaluation index of the digital economy and rural revitalization in the Yangtze River Delta basin and the coupling coordination degree between them were calculated using the entropy method and the coupling coordination degree model. The results show that the digital economy and rural revitalization in the Yangtze River Delta basin are highly coupled as a whole, and the coordination degree is increasing year by year, but it shows the characteristics of regional differences. Therefore, it is necessary to strengthen digital construction. For the rural areas in the Yangtze River Delta region, digital infrastructure construction is the top priority. Strengthen regional cooperation to achieve high-quality coordinated development of the digital economy and rural revitalization, actively promote integrated construction, strengthen policy support, and achieve balanced development, so as to realize China's modernization development and promote common prosperity.

Keywords

Coupling and Coordinated Development, Digital Economy, Rural Revitalization.

1. Introduction and Literature Review

1.1. Introduction

High-quality economic development is an important development strategy for China's economic and social development during the "14th Five-Year Plan" period, and rural revitalization is an important part of high-quality economic development. To achieve rural revitalization, it is necessary to rely on the new driving force of the digital economy, and the revitalization of digital villages can promote the innovation and upgrading of the digital economy. Therefore, studying the coupling and coordination relationship between the digital economy and rural revitalization has important theoretical and practical significance. To achieve rural revitalization, it is necessary to rely on the new driving force of the digital economy to enhance the level of digital penetration, and rural revitalization can promote the innovation and upgrading of the digital economy and enhance the adaptation level of the digital economy. Therefore, clarifying the coupling mechanism between the digital economy and rural revitalization systems has important theoretical significance and enriches the theoretical connotation and research methods of the coupling and coordination between the digital economy and rural revitalization. This paper conducts an empirical study taking the Yangtze River Delta region as an example, provides an implementation path for the coupling and coordinated development of the digital economy and rural revitalization, and can provide

certain references for policy adjustment and formulation, which has relatively important practical significance for promoting high-quality economic development and modernization transformation in China.

1.2. Research Status at Home and Abroad

(1) Research on the digital economy. Zhao believes that the rise of the digital economy originated from the emergence of the Internet in the 1990s. [1] ZHU W proposed that many scholars and institutions have discussed the concept, characteristics and measurement methods of the "digital economy". [2]YAN M proposed that with the continuous deepening of research on the digital economy, more and more studies have focused on the enabling effect of the digital economy on economic development. [3] This is due to the characteristics of high innovation, wide coverage and fast growth of the digital economy, which has brought new development opportunities for various regions (Li H). [4] In addition, a large number of studies have proved that the enabling of the digital economy on economic development and different industries has a spatial effect. For example, Hu M found through empirical research that there is an obvious spatial spillover effect of the digital economy on the improvement of total factor productivity, that is, the digital economy has a significant impact on the total factor productivity of the local region and neighboring regions. [5]

(2) Research on rural revitalization. In October 2017, the rural revitalization strategy was clearly proposed in the report of the 19th National Congress of the CPC, pointing out that the solution of the problems of agriculture, rural areas and farmers is a necessary condition for rural development. Scholars have conducted in-depth research on the rural revitalization strategy from the perspective of the relationship between poverty alleviation and rural revitalization. Li analyzed the difficulties and key measures in the organic connection between precision poverty alleviation and rural revitalization [6]; Zhao G pointed out that to achieve industrial prosperity in rural areas, it is necessary to first base on the development of modern agriculture and then promote the integration of rural tertiary industries [7]. Zhao G proposed that the core factor in transforming traditional agriculture is technological progress, and the technological progress of agriculture requires external intervention [7]. In improving the rural social and economic environment, rural revitalization is of great significance. All regions should take active and effective policy measures to guide the construction of rural infrastructure and tourism, improve the level of talent cultivation and management, and improve relevant supporting measures [8] to attract more enterprises with excellent regional conditions. The fundamental purpose of rural revitalization is to improve the rural social and economic situation, enhance the living standards of residents, and promote the common prosperity of all people (Yuan B) [9].

(3) Research on the relationship between digital economy development and rural revitalization. The enabling of digital economy on productivity development can be analyzed from different perspectives. Yan believes that the rural digital economy empowers farmers in many aspects and stimulates the internal driving force of rural development. From the perspective of data elements as a new production factor enabling new-quality productivity and the development of digital technology innovation driving new-quality productivity development (Hwang K Y) [10]. From the perspective of the impact of the digital economy on rural economic development, the digital economy forms digital empowerment, promotes the optimal allocation of rural resources through the circulation of urban and rural technologies, resources and markets, strengthens the effective connection of urban and rural markets, promotes the integration of rural industries, and promotes the development of rural industries (Lyu Y) [11]. The digital economy provides more entrepreneurial opportunities and development space for rural labor, promotes the expansion of the scale, optimization of the structure and improvement of the quality of migrant workers returning to their hometowns to

start businesses, and effectively promotes the upgrading of the consumption structure of rural residents in China (Zhang X) [12]. Digital technology innovation drives productivity development. Digital information technologies such as the Internet of Things, big data and artificial intelligence are increasingly penetrating into the field of rural industrial economic development, promoting the rapid development of the rural economy and the improvement of the income level of rural residents. Xiong Genhua summarized the integration and development of the digital economy and agricultural and rural economy at home and abroad and believed that the integration and development of the two can promote agricultural upgrading, rural progress and farmer development [13].

1.3. Development Trend Analysis

When many existing literatures study the issues related to the digital economy and rural revitalization, they mostly stay on the impact mechanism of the digital economy on rural revitalization, and there are few analyses of the coupling mechanism between the two. At present, for the research on these two concepts, most of the relevant literatures focus on a single province or city, and there is a relative lack of research on rural revitalization and the digital economy among regions and urban agglomerations. Moreover, when focusing on the coupling effect, the feedback effect of rural revitalization on the digital economy is rarely mentioned. Therefore, this paper will take the Yangtze River Delta region as an example to empirically analyze the coupling and coordination mechanism and influencing factors between the digital economy and rural revitalization.

2. Index System Construction and Data Sources

2.1. Construction of the Index System of Digital Economy and Rural Revitalization in the Yangtze River Delta Region

Scholars have done a lot of research on rural revitalization and digital economy development. This paper established a coupling and coordination evaluation index system for digital economy and rural revitalization development by searching data and referring to the measurement index systems of the two in the academic community. The digital economy is composed of eight dimensions of data, including the number of Internet broadband access users, the number of Internet domain names, software business income, e-commerce sales volume, R&D funds of industrial enterprises above designated size, telecom business volume, mobile phone penetration rate, and optical cable length. See Table 1 for details. According to the general requirements of the rural revitalization strategy proposed in the report of the 19th National Congress of the CPC, a rural revitalization evaluation system was constructed from five dimensions: prosperous industries, ecological livability, civilized rural customs, affluent life, and effective governance. See Table 2 for details.

2.2. Data Sources

Based on the availability and authenticity of the data, this paper selected the data of Anhui Province, Zhejiang Province, Shanghai Municipality and Jiangsu Province, which constitute the Yangtze River Delta region, from 2019 to 2023 to deeply analyze the development levels and coupling coordination degrees of the digital economy and rural revitalization in the four provinces. The data required for the research were sourced from the China Statistical Yearbook, Anhui Statistical Yearbook, Shanghai Statistical Yearbook, Jiangsu Statistical Yearbook and Zhejiang Statistical Yearbook.

Table 1. Indexes of the Digital Economy Subsystem in the Yangtze River Delta Region

Subsystem	Index System	Attribute	Index Weight
Digital Economy	Number of Internet broadband access users (10,000 people)	+	0.1137
	Mobile phone penetration rate (number per 100 people)	+	0.0889
	Software business income (10,000 yuan)	+	0.1032
	Optical cable length (km)	+	0.1108
	Number of Internet domain names (10,000)	+	0.0517
	Telecom business volume (100 million yuan)	+	0.1204
	E-commerce sales volume (10,000 yuan)	+	0.1346
	R&D funds of industrial enterprises above designated size (10,000 yuan)	+	0.1919

Table 2. Indexes of the Rural Revitalization Subsystem in the Yangtze River Delta Region

First-level Index	Second-level Index	Index Attribute	Index Weight
Prosperous Industries	Agricultural labor productivity	+	0.1088
	Comprehensive grain productivity	+	0.1482
	Degree of agricultural mechanization	+	0.1219
Ecological Livability	Coverage rate of solar water heaters	+	0.0777
	Water use penetration rate	+	0.0548
Civilized Rural Customs	Proportion of local fiscal expenditure on culture and sports	+	0.0585
	Proportion of local fiscal expenditure on education	+	0.0698
	Proportion of rural public service expenditure	+	0.08717
Effective Governance	Number of rural residents receiving minimum living allowances	-	0.0693
	Engel's coefficient	-	0.0567
Affluent Life	Rural residents' income	+	0.0648
	Per capita housing area	+	0.0823

2.3. Determination of Index Weights

2.3.1. Data Standardization

When choosing the research method and model, considering the accuracy and empirical nature of the research results, this paper chose a data standardization method based on objective data

and not affected by subjective factors to evaluate the development levels of the digital economy and rural revitalization in the four provinces in the Yangtze River Delta region, so as to effectively avoid human interference. The range standardization method is a method to eliminate the influence of variable dimensions and variation ranges. Through range standardization processing, the positive and negative indicators of each observation value of the variable are unified into positive indicators with the same direction. The calculation formulas are as follows:

Positive indicator:

$$x_i^* = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

Negative indicator:

$$x_i^* = \frac{x_{max} - x_i}{x_{max} - x_{min}}$$

2.3.2. Calculation of Index Weights by Entropy Method

The entropy method can overcome the influence of subjective factors to a certain extent. The smaller the information entropy value, the greater the dispersion degree of the index value and the more information it provides, and the greater the weight of the index. Therefore, the information entropy can be used to determine the weights of each index. The calculation process is as follows:

Calculate the proportion of the i-th sample value of the j-th index:

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{n} y_{ij}}$$

Calculate the information entropy value of the j-th index:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij} \qquad k = \frac{1}{\ln n}$$

Calculate the weights of each index through the entropy value and obtain the comprehensive score:

$$g_j = 1 - e_j$$

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j}$$

$$U_i = \sum_{j=1}^{m} w_j y_{ij}$$

2.3.3. Coupling Coordination Degree Model

The coupling coordination degree model is used to measure the degree of interaction and coordinated development among multiple systems. Its basic principle is to first determine the evaluation indexes of each system, calculate the comprehensive development level values of each system after data standardization processing, then measure the degree of close interaction among systems according to the coupling degree formula, and then combine the coordination degree formula to comprehensively consider the differences in system development levels and obtain the coupling coordination degree. This model has significant advantages. It can

quantitatively analyze the relationships among complex systems, making abstract relationships intuitive and measurable; it can comprehensively reflect the coordinated status among systems and is not limited to the evaluation of a single system; and it has a wide range of applications. It can play an important role in analyzing issues such as industrial collaboration and the relationship between environment and development in economic, ecological, social and other fields, and contribute to the research on the coordinated development of multiple systems.

In the model, the C value (coupling degree) mainly measures the intensity and coordination degree of interaction among systems, reflecting the close situation of mutual influence and interaction among different systems, with a value ranging from 0 to 1. The larger the value, the higher the coupling degree among systems and the stronger the interaction. The T value (comprehensive evaluation index) is used to comprehensively consider the development levels of each subsystem, integrating multiple indicators into a single value to reflect the overall development status of the system and can reflect the overall development trend and level of the system. The D value (coupling coordination degree) is calculated based on the C value and T value, integrating the coupling degree and comprehensive evaluation index, not only reflecting the coupling degree among systems but also reflecting the overall coordinated development level of the system, more comprehensively and accurately measuring the coordinated status among systems, and used to judge whether the system is in a coordinated development state and the degree of coordination. Since only the coupling coordination degree model of the digital economy and rural revitalization is studied, n=2 can be taken in the formula. The calculation methods are as follows::

Coupling degree C:

$$C = \left\{ \frac{\prod_{i=1}^{n} U_i}{\left[\frac{1}{n}\sum_{i=1}^{n} U_i\right]^n} \right\}^{\frac{1}{n}}$$

Comprehensive evaluation index T:

$$T = \sum_{i=1}^{n} \alpha_i U_i$$

Coupling coordination degree D:

$$D = \sqrt{C \times T}$$

2.3.4. Classification of Coupling Coordination Degree Levels

Referring to the classification standards of related research types and the actual situation, the coordination of the digital economy and rural revitalization in the Yangtze River Delta basin is divided into four levels.

Table 3. Types of Coordination Degree between Digital Economy and Rural Revitalization

Coupling Coordination Degree D	Coupling Coordination Level
(0,0.4]	Low coordination
(0.4,0.5]	Moderate coordination
(0.5,0.8]	High coordination
(0.8,1]	Extremely high coordination

3. Empirical Analysis and Results

Based on the above data and formulas, the coupling coordination degree of the digital economy and rural revitalization in the Yangtze River Delta basin was measured. Combined with the research results, the overall development levels of the digital economy and rural revitalization, as well as the coupling and coordinated development of the digital economy and rural revitalization were analyzed respectively.

3.1. Analysis of Digital Economy Development Level

The development level of the digital economy in the Yangtze River Delta basin shows an overall upward trend, but the overall value is relatively low, and there are large differences in values among cities. As shown in Table 4, from 2019 to 2023, the average value of the digital economy development in the Yangtze River Delta basin gradually increased from 0.3406 to 0.5120, with large room for improvement. In addition, there are large differences in the development level of the digital economy in the Yangtze River Delta basin. Among them, Jiangsu Province has the highest development level, with an average annual score above 0.6, while the overall level of Anhui Province is relatively low, exceeding 0.2 in 2023. The development levels of Zhejiang Province and Shanghai Municipality are in the middle.

Table 4. Digital Economy Development Index of Each Province in the Yangtze River Delta Basin from 2019 to 2023

Region	2019	2020	2021	2022	2023
Anhui Province	0.1237	0.1548	0.1765	0.1872	0.2148
Zhejiang Province	0.4364	0.4491	0.4895	0.5600	0.6257
Shanghai Municipality	0.1779	0.2061	0.2488	0.2934	0.3595
Jiangsu Province	0.6243	0.6567	0.7001	0.7637	0.8482
Yangtze River Delta Average	0.3406	0.3667	0.4037	0.4511	0.5120

3.2. Analysis of Rural Revitalization Development Level

The rural revitalization level in the Yangtze River Delta basin also shows a steadily rising trend, but the overall level is not high, and there are significant differences among provinces. As shown in Table 5, between 2019 and 2023, the rural revitalization index in the Yangtze River Delta basin increased relatively slowly from 0.4673 to 0.5582, still leaving much room for improvement. There are large gaps in the development indices of different provinces. The development index of Jiangsu Province is three times that of Shanghai Municipality. Moreover, the rural revitalization development index of Shanghai Municipality shows a fluctuating trend, while the rural revitalization development levels of Zhejiang Province and Anhui Province are similar, but the growth rate of the rural revitalization development index of Zhejiang Province is relatively fast, belonging to the medium level of rural revitalization development. Shanghai Municipality is a region with a low level of rural revitalization development.

Table 5. Rural Revitalization Development Index of Each Province in the Yangtze River Delta Basin from 2019 to 2023

Region	2019	2020	2021	2022	2023
Anhui Province	0.4431	0.4968	0.5019	0.5053	0.5585
Zhejiang Province	0.4879	0.5236	0.5525	0.5556	0.5836
Shanghai Municipality	0.2228	0.2403	0.2357	0.2284	0.3023
Jiangsu Province	0.7155	0.7446	0.7469	0.7680	0.7885
Average	0.4673	0.5013	0.5092	0.5143	0.5582

3.3. Analysis of the Coupling and Coordinated Development of Digital Economy and Rural Revitalization

3.3.1. Coupling Degree Analysis

The digital economy and rural revitalization in the Yangtze River Delta basin are highly coupled. By calculating the coupling degree (the C value mainly measures the intensity and coordination degree of interaction among systems, reflecting the close situation of mutual influence and interaction among different systems, with a value ranging from 0 to 1. The larger the value, the higher the coupling degree among systems and the stronger the interaction) of the digital economy and rural revitalization in the Yangtze River Delta from 2019 to 2023, it can be found that the coupling degree in the Yangtze River Delta basin shows an upward trend, and the growth rate accelerates between 2019 and 2020, and then develops stably after 2020, and the values all exceed 0.95, showing a highly coupled state (Figure 1). This indicates that there is a strong mutual influence relationship between the digital economy and rural revitalization, ultimately benefiting rural areas and farmers. The two are complementary and promote each other, contributing to China's modernization drive.
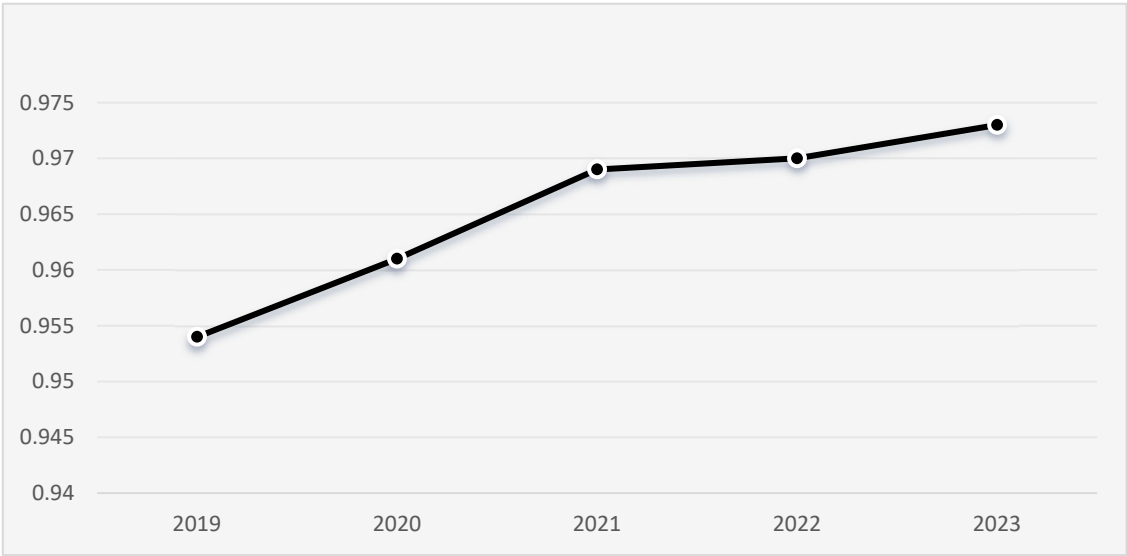

Figure 1. Coupling Degree Values of Digital Economy and Rural Revitalization in the Yangtze River Delta Basin from 2019 to 2023

3.3.2. Coordination Degree Analysis

Overall analysis (see Table 6) shows that the coordination degree of the digital economy and rural revitalization in the Yangtze River Delta basin shows an upward trend year by year, but the overall value is relatively low, and there is still much development space. The coordination degree index D values from 2019 to 2023 were obtained through empirical research, and the average value of the Yangtze River Delta basin was calculated based on the coordination indices of the digital economy and rural revitalization of the four cities to represent the overall coupling and coordinated development level. Overall, the coordination index of the Yangtze River Delta increased from 0.6067 to 0.7111. According to Table 3, the coordination type of the Yangtze River Delta basin is highly coordinated, indicating that the coordination level of the Yangtze River Delta basin is increasing year by year. This is the result of the joint efforts of all provinces. Since the COVID-19 pandemic, the connection between the digital economy and rural revitalization has become increasingly close. The provincial governments have actively explored, and finally, the entire Yangtze River Delta basin has maintained a significant improvement, making all provinces attach importance to and actively practice the integrated development of the digital economy and rural revitalization.

However, there are still significant differences in the coupling and coordination degree of the digital economy and rural revitalization among the provinces in the Yangtze River Delta basin. The difference between Jiangsu Province and the other three cities is increasing. The coupling and coordination degree of Jiangsu Province is ahead of other cities, with a value above 0.8, belonging to the extremely high coordination stage. The coupling development levels of Anhui Province and Shanghai Municipality have also achieved great breakthroughs. In 2019, the coordinated development degree of Anhui Province was 0.4839, and that of Shanghai Municipality was 0.4462, both in the moderate coordination stage. In 2023, both Anhui Province and Shanghai Municipality entered the high coordination stage, achieving significant breakthroughs. The coupling and coordination degree of the digital economy and rural revitalization in Zhejiang Province has been above 0.6 for years and reached 0.7773 in 2023, close to the extremely high coordination stage and has great potential to enter the extremely high coordination stage. These differences reflect the imbalance of regional development and are related to the basic endowment conditions, economic development conditions and social specific situations of each province.

Table 6. Coordinated Development Status of Digital Economy and Rural Revitalization in Each Province of the Yangtze River Delta Basin from 2019 to 2023

Region	2019	2020	2021	2022	2023
Anhui Province	0.4839	0.5266	0.5455	0.5546	0.5885
Zhejiang Province	0.6793	0.6964	0.7211	0.7468	0.7773
Shanghai Municipality	0.4462	0.4718	0.4921	0.5088	0.5742
Jiangsu Province	0.8175	0.8362	0.8504	0.8751	0.9043
Average	0.6067	0.6327	0.6523	0.6713	0.7111

4. Conclusions and Suggestions

The digital economy and rural revitalization in the Yangtze River Delta basin are important issues for China's high-quality development. Based on relevant theories and literatures, a comprehensive evaluation method was used to construct an evaluation index system for the two, analyze the evaluation results, and establish a coupling coordination model to empirically

analyze the coupling and coordinated development relationship between digital agriculture and rural revitalization. The following conclusions and suggestions are drawn.

4.1. Conclusions

First, the development effects of the digital economy and rural revitalization in the Yangtze River Delta basin are significant, showing an upward trend year by year. Although the overall values are relatively low, there is still huge development space. In the era of digital development, the development trend of the Yangtze River Delta is obviously upward, and the digital economy and rural revitalization promote each other and are complementary.

Second, there is a highly coupled, mutually influential and mutually promoting relationship between the digital economy and rural revitalization in the Yangtze River Delta basin. The coordination state between the two shows an upward trend, and there is still room for improvement. The coupling degree between them exceeds 0.95, which is relatively high, indicating that they have a mutually promoting and influencing relationship and are closely connected. The coordination degree shows an upward trend and is generally in a high coordination state, but there is still a distance from extremely high coordination, indicating that there is still huge development potential.

Third, the digital economy and rural revitalization in the Yangtze River Delta basin are in an unbalanced state in space among the provinces. There are large differences in the coordination of the digital economy and rural revitalization in the Yangtze River Delta basin. The reason for this phenomenon lies in the unbalanced development of the economy, society and other aspects in the Yangtze River Delta basin.

4.2. Suggestions

First, strengthen digital construction. For the rural areas in the Yangtze River Delta region, digital infrastructure construction is the top priority. We should increase efforts to ensure that 5G networks and fiber broadband cover every corner of the countryside. Just like in cities, villagers can enjoy stable and high-speed networks at home and in the fields. At the same time, build a rural big data center to integrate agricultural production data, rural governance situations and agricultural product sales data, making data the key to rural development and providing a scientific basis for decision-making. In agricultural production, actively introduce Internet of Things, big data and artificial intelligence technologies. For example, use digital technology to monitor soil moisture and fertility in real time and automatically adjust irrigation and fertilization to achieve precision planting and improve crop yields and quality. Vigorously develop rural e-commerce and build an online sales platform for agricultural products to help farmers promote high-quality agricultural products to the national market. Also, create a digital rural governance platform to make village affairs management more transparent and villagers' participation more convenient and improve rural governance efficiency.

Second, strengthen regional cooperation. All regions in the Yangtze River Delta region should strengthen cooperation and establish a coordinated development mechanism. Different regions should share digital resources and jointly promote industrial development. Digital enterprises in cities can extend their industrial chains to the countryside to drive the development of rural digital industries and realize the complementary advantages of urban and rural areas. Establish a normalized communication and coordination mechanism in the Yangtze River Delta region and regularly hold seminars on digital economy and rural revitalization to promote the sharing of experiences and the discussion of difficulties among regions. In terms of industry, build cross-regional digital agriculture industrial clusters based on local characteristics. In talent exchange, carry out talent exchange and secondment. Digital talents in cities can go to the countryside to assist projects, and rural personnel can be selected to go to cities to learn advanced technologies and management experience. In addition, build a unified digital

resource sharing platform to integrate data such as agricultural technologies and market demands in different regions and realize information sharing, so that resources can flow efficiently within the region and comprehensively promote the integration of digital economy and rural revitalization.

Third, strengthen policy support. Formulate relevant laws and regulations for the development of rural digital economy in the Yangtze River Delta, clarify the ownership of digital intellectual property rights, and severely crack down on illegal acts such as network infringement and data leakage. Standardize the market access and trading rules of the digital economy to protect the legitimate rights and interests of market entities and create a fair and orderly development environment. Set up a special development fund for rural digital economy in the Yangtze River Delta and allocate a certain proportion of funds from the annual fiscal budget to ensure stable capital investment. This fund is specifically used for rural digital infrastructure construction, research and development and promotion of digital agriculture projects, and subsidies for the construction and operation of rural e-commerce platforms. Guide financial institutions to develop exclusive credit products and provide flexible loan terms and low-interest preferential policies according to the characteristics of rural digital economy projects.

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