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Study on the Synergy between Digital Finance and Regional Innovation

-- Based on the Yangtze River Delta City Cluster

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Abstract

With the rapid development of digital technology, digital finance continues to flourish globally. The innovations brought about by digital finance are expected to drive regional economic growth and social development. This paper aims to explore the synergistic development between digital finance and regional innovation in the Yangtze River Delta region. By constructing a coupled and coordinated model of digital finance and regional innovation, the level of synergistic development between digital finance and regional innovation and the dynamic relationship between them in 27 cities of the Yangtze River Delta city cluster from 2011 to 2020 are explored, and the development of the two subsystems of digital finance and regional innovation in the Yangtze River Delta city cluster during this 10-year period is analysed in detail. The study shows that the level of synergistic development between digital inclusive finance and regional innovation in China's Yangtze River Delta city cluster is improving year by year. Before 2017 the digital inclusive finance and regional innovation synergy system, digital inclusive finance system are in the lagging stage of development. By 2020, the digital inclusive financial system and the regional innovation system reach a stage of quality synergistic development. To this end, governments and financial institutions need to work together to enhance the synergistic development of digital finance and regional innovation in order to promote sustainable, healthy and stable economic development.

Keywords

Digital Finance; Regional Innovation; Synergistic Development; Policy Recommendations.

1. Introduction

Digital finance and regional innovation are two important areas of economic development in today's world. The rise and development of digital finance has brought about huge changes to the financial sector, transforming people's financial consumption and investment behaviour, while also providing new opportunities for regional economic development. Regional innovation, in turn, is one of the key drivers of economic growth and social development, and has become an important source of competitiveness for governments and companies. In the context of digitisation and informatisation, the synergies between digital finance and regional innovation are increasingly evident. The application of digital financial technology can promote the spread and improvement of regional financial services and provide more convenient and efficient financial services for the development of the regional economy. At the same time, regional innovation can also provide more application scenarios and innovation opportunities for the development of digital finance.

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Chinese digital finance company Ant Financial listed in Hong Kong in November 2021. Ant Financial Services is one of the world's largest digital payment and wealth management platforms and a leading player in China's digital finance industry. Its IPO has attracted global attention and reflects the rapid growth of digital finance in China and globally. In April 2022, the 4th Digital China Construction Summit was held in Fuzhou, Fujian Province, with the theme of "Digital Innovation for a Shared Future". The summit focused on the latest developments and trends in the digital economy, digital government, digital society and digital ecology, and explored the synergies and future prospects of digital finance and regional innovation. It is evident that digital finance and regional innovation are gaining more and more attention and support as important areas of economic development in the world today. In the future, the development of digital finance and regional innovation will provide more opportunities and impetus for global economic growth and social development.

Dong Shugong[1] and Zhao Qingtuan[2] showed that digital finance can promote the development of regional innovation. And the promotion effect of digital finance development is more obvious for regions with low innovation level. Zhang Bin[3] showed that digital inclusive finance can optimize regional resource allocation; upgrade regional payment and clearing system; and improve regional wealth management capacity, thus significantly improving the level of regional innovation. Teng Zhou[4] found that digital finance has a stronger innovation-driving effect on eastern regions, i.e. innovation activities and innovation investment are also more concentrated and innovation performance is higher in regions with faster development of digital finance. Digital inclusive finance is based on digital technology and requires continuous technological innovation to drive its high-quality development and core competitiveness, Guo Zhenzhou [5]; Wang Yang et al. (2021). In the context of the global economy being hit by the new crown pneumonia epidemic, Zhou Xiaochuan[6] points out that the development of digital inclusive finance can be promoted through innovation.

Wang Yang [7] and Wang Liang [8], on the other hand, explored the mutual facilitation between digital finance and regional innovation. There is not only a two-way promotion effect between digital finance and regional innovation, but also a significant spatial interaction effect. In summary, scholars have conducted extensive research on digital finance and regional innovation. However, relatively few studies have been conducted on the synergistic development of digital finance and regional innovation. As the Yangtze River Delta city cluster is an important region for China's economic development, the study of the coordinated development of digital finance and regional innovation in the region has important theoretical and practical significance. Therefore, this paper aims to explore the synergistic development between digital finance and regional innovation in the Yangtze River Delta region. Firstly, a theoretical mechanism analysis of the synergistic development of digital finance and regional innovation is conducted, and then the coupling synergy between digital finance and regional innovation is further measured. While the literature has focused more on the impact of digital finance on regional innovation, little empirical research has been conducted on the impact of regional innovation on digital finance. This paper examines the mutual impact of the two and measures the coupling and synergy between them, so as to gain a deeper understanding of their dynamic relationship. By constructing the coupling synergy degree of digital finance and regional innovation, we analyse the level and dynamic development of the synergy between the two subsystems of digital finance on regional innovation in the Yangtze River Delta city cluster, and provide theoretical basis and practical suggestions for promoting the synergy development of digital finance and regional innovation.

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2. Mechanisms of Synergistic Development between Digital Finance and Regional Innovation

2.1. The Role of Digital Finance as a Catalyst for Regional Innovation

Digital finance can facilitate the development of regional innovation in the following ways: first, by providing financing support: digital finance platforms can provide financing support to innovative enterprises and promote their R&D and innovation activities. Digital finance platforms can provide innovative enterprises with diversified financing channels through inclusive finance, crowdfunding and equity financing, alleviating the problem of difficult financing for innovative enterprises. Second, reduce financing costs: digital finance platforms can reduce financing costs through the application of information technology. For example, the use of big data analysis technology for credit assessment of borrowers reduces financing costs and improves financing efficiency. Third, providing risk management: digital finance platforms can provide risk management services to innovative enterprises and reduce their risks. For example, digital finance platforms can provide insurance services to provide risk protection for innovative enterprises. Fourth, promote cross-regional cooperation: Digital financial platforms can promote cross-regional cooperation and exchange, and promote cooperation and sharing of innovation results among innovative enterprises. Digital finance platforms can provide an open platform for innovative enterprises to promote inter-regional cooperation and exchange, and facilitate cross-border integration of technology and innovation. In summary, digital finance can help promote the development of regional innovation by providing financing support, reducing financing costs, providing risk management and promoting cross-regional cooperation.

2.2. The Role of Regional Innovation in Driving Digital Finance

Regional innovation can drive the development of digital finance in four ways: First, the needs of innovative enterprises drive the development of digital finance. Innovative enterprises need services such as financing support, risk management and cross-regional cooperation in the innovation process, and digital finance platforms can provide these services to meet the needs of innovative enterprises. The demand of innovative enterprises is an important driving force for the development of digital finance. Second, regional innovation drives the innovation of digital finance. The development of regional innovation activities needs the support of digital finance, and digital finance platforms can innovate financial products and services to meet the needs of regional innovation according to the characteristics and needs of different regions. For example, digital finance platforms can launch customised financing products for innovative enterprises to provide more personalised services for innovative enterprises. Third, digital finance platforms promote exchanges and cooperation in regional innovation. Digital finance platforms can provide an open platform for regional innovation and promote exchanges and cooperation in regional innovation. Digital finance platforms can provide innovative enterprises with cross-regional financing support and cross-regional cooperation opportunities, facilitating the exchange and sharing of technology and knowledge between different regions. Fourth, digital finance platforms provide data support for regional innovation. Data is an important driver of regional innovation, and digital finance platforms can provide data support for regional innovation through technologies such as big data analysis and artificial intelligence. For example, digital financial platforms can provide scientific risk assessment and better risk management services for innovative enterprises through analysis of their data. In summary, regional innovation and digital finance are mutually reinforcing; regional innovation can promote the development of digital finance, and digital finance can provide support for regional innovation. Regional innovation and digital finance are two

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mutually reinforcing areas; regional innovation can drive the development of digital finance, and digital finance can provide support for regional innovation.

3. Analysis of the Degree of Synergy between Digital Finance and Regional Innovation Coupling

3.1. Data Sources and Processing

3.1.1. Digital Financial System Evaluation Indicator System

Table 1. Comprehensive evaluation index of digital finance in 27 cities of the Yangtze River Delta city cluster

City	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Shanghai	81.18	135.03	182.03	192.59	222.45	238.96	275.55	291.44	308.64	320.79
Nanjing	79.76	131.13	173.08	186.44	217.24	244.38	271.9	289.18	303.29	313.9
Wuxi	78.6	118.68	161.77	178.59	206.26	230.5	260.18	276.08	289.48	301.63
Changzhou	78.45	120.27	162	175.81	206.67	232.18	260.34	279.53	293.47	304.52
Suzhou	80.58	124.29	165.86	181.1	208.81	236.99	267.44	281.97	297.87	309.8
Nantong	71.18	110.42	150.37	164.71	191.11	217.01	246.18	264.52	280.28	293.12
Yancheng	59.16	97.46	133.93	145.12	177.64	211.96	239.55	251.02	263.72	276.5
Yangzhou	68.16	105.78	146.75	163.72	195.19	226.78	251.6	263.82	277.15	289.86
Zhenjiang	72.64	110.47	148.82	168.42	197.83	222.83	252.55	267.95	280.65	293.47
Taizhou	65.62	105.41	145.03	161.96	186.47	220.16	247.08	260.34	274.89	287.34
Hangzhou	86.18	147.96	189.27	199.4	231.13	246.92	285.43	302.98	321.65	334.48
Jiaxing City	86.51	128.16	165.88	175.41	205.98	220.65	252.92	272.74	287.34	300.48
Huzhou City	77.79	119.58	160.91	172.7	201.49	218.39	249.64	269.89	283.8	295.53
Zhoushan City	76.74	120.64	157.51	174.58	201.37	222.24	247.96	264.49	278.4	291.14
Jinhua	79.46	125.47	166.92	179.43	209.87	222.1	253.8	277.19	294.95	307.33
Introduction	77.1	118.88	156.07	175.02	204.52	220.6	245.75	262.11	281.78	293.21
Wenzhou	81.83	127.24	169.68	180.98	211.38	229.53	260.22	273.98	286.74	297.22
Taizhou	77.26	124.81	160.81	172.87	203.35	218.68	246.88	263.88	278.92	290.21
Ningbo	81.77	129.17	168.04	186.1	213.31	228.33	258.55	274.4	288.94	301.13
Xuancheng City	56.03	92.7	136.96	155.21	175.35	192.92	223.42	238.48	251.22	263.5
Chuzhou	45.43	85.67	125.84	152.03	171.48	196.14	222.28	236.42	249.86	264.88
Chizhou	51.82	91.46	127.68	142	172.78	198.56	221.9	234.76	247.05	258.29
Hefei	71.58	114.66	155.02	172.25	201.48	222.57	256.24	272.52	288.08	299.16
Tongling	63.69	113.18	142.16	170.17	191.15	195.18	219.11	237.18	252.91	264.99
Ma'anshan	57.1	108.43	140.99	166.44	187.29	207.94	234.34	249.31	262.61	274.73
Wuhu City	57.03	104.45	140.36	159.18	186.64	206.82	241.64	254.9	273.16	290.05
Anqing	42.34	85.25	125.14	145.56	167.7	193.09	217.4	231.25	243.65	257.72

Indicator measurement of digital finance subsystem. This paper draws on the Digital Inclusive Finance Development Index published by the Digital Finance Research Centre of Peking University to measure the comprehensive evaluation index of digital finance in each region. The index is based on data support from Ant Financial Services and is constructed from three dimensions: the breadth of coverage of digital financial services, the depth of use of digital financial services and the degree of digitalisation of inclusive finance. Following the principles of science, dynamics, typicality and systematization, this paper also adopts the Peking University Digital Inclusive Finance Index as a measure of the digital financial development of 27 cities in the Yangtze River Delta city cluster. Table 1 shows the comprehensive evaluation index of digital finance of the 27 cities in the Yangtze River Delta city cluster, and Figure 1 shows the trend of the average value of the digital finance index of the Yangtze River Delta city cluster in each year.

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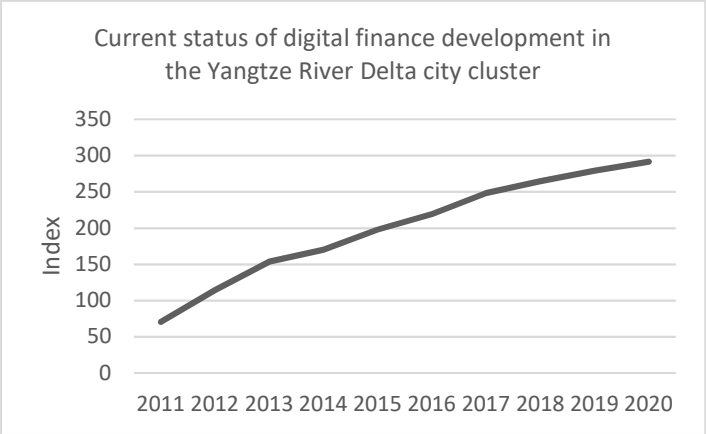

Figure 1. Average development status of digital finance in the Yangtze River Delta city cluster

Figure 1 illustrates the general trend of the level of digital financial inclusion development in China's Yangtze River Delta city cluster from 2011-2018. To measure the overall level of development in that year, this paper uses the average value of 27 cities for measurement. The results show that the level of digital inclusive finance development in China's Yangtze River Delta city cluster shows a fluctuating upward trend, rising from 70.56 in 2011 to 291.67 in 2020.

3.1.2. Regional Innovation System Evaluation Index System

Table 2. Comprehensive regional innovation evaluation index of 27 cities in the Yangtze River Delta city cluster

City	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Shanghai	89.07	90.63	91.78	95.21	96.67	97.09	97.19	98.23	98.34	98.75
Nanjing	96.49	96.85	97.9	98.68	99.36	99.71	99.56	99.76	99.82	99.85
Wuxi	97.27	97.16	97.12	97.66	98.43	98.74	98.86	99.08	99.05	99.19
Changzhou	93.47	94.63	95.54	95.97	96.98	97.16	98.12	98.13	98.36	98.51
Suzhou	98.72	98.82	98.97	99.13	99.5	99.69	99.78	99.83	99.83	99.88
Nantong	95.02	95.11	94.82	95.21	96.74	97.58	98.09	98.57	98.38	98.78
Yancheng	92.78	91.58	91.98	93.76	94.99	96.15	97.21	98.09	97.74	98.12
Yangzhou	91.59	90.26	91.32	91.56	94.25	95.04	95.85	96.88	96.4	96.97
Zhenjiang	89.35	90.48	89.79	91.82	93.35	94.99	96.01	96.35	96.08	96.58
Taizhou	89	88.6	88.85	89.58	93.4	94.13	95.38	96.57	96.37	97.39
Hangzhou	98.28	98.45	98.87	99.2	99.72	99.81	99.86	99.89	99.91	99.93
Jiaxing City	93.23	92.71	95.26	96.23	97.42	98.18	98.4	98.77	98.69	98.95
Huzhou City	86.73	89.15	92.44	93.94	95.83	96.66	97.11	97.85	98.14	98.32
Zhoushan City	71.37	68.51	73.42	74.3	83.2	87.17	89.56	91.92	90.43	90.75
Jinhua	91.09	90.97	93.1	94.86	96.52	97.88	98.4	98.83	98.98	99.28
Introduction	92.17	91.77	93.83	95.05	96.19	96.66	97.64	98.21	98.29	98.55
Wenzhou	90.24	93.46	95.44	95.49	96.36	97.04	98.01	98.6	98.58	99.06
Taizhou	87.61	73.96	93.02	80.88	94.88	96.42	96.72	97.38	97.74	98.34
Ningbo	96.53	96.67	98.01	98.54	99.07	99.35	99.52	99.67	99.63	99.67
Xuancheng City	75.46	76.82	80.54	81.88	82.97	87.64	89.89	91.24	92.25	92.48
Chuzhou	79.83	63.69	79.18	85.74	88.39	90.58	90.47	93.87	94.7	95.73
Chizhou	56.4	71.83	75.66	79.38	82.34	81.57	84.27	84.61	84.71	88.38
Hefei	94.46	95	96.33	97.35	98.46	98.99	99.14	99.34	99.4	99.38
Tongling	71.54	74.27	73.41	79.15	77.32	83.51	83.51	86.11	90.32	89.76
Ma'anshan	61.77	75.65	80.18	85.49	88.52	90.5	91.01	93.69	93.09	92.55
Wuhu City	90.87	90.89	91.26	91.44	94.59	96.46	96.68	96.84	97.15	97.62
Anqing	72.68	77.44	80.3	85.29	84.92	90.89	91.2	93.29	93.5	95.41

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Regional innovation level: In order to measure the regional innovation level of each city in the Yangtze River Delta city cluster, this paper adopts the China Regional Innovation and Entrepreneurship Index (IRIEC) compiled by the Enterprise Big Data Research Centre of Peking University. By combining big data thinking and technology, based on the three core elements of entrepreneurs, capital and technology, and using the full volume of enterprise information from the national industrial and commercial enterprise registration database from 1990 to 2020, the index constructs a Chinese regional innovation and entrepreneurship index that is both objective, real-time and multidimensional in five dimensions, including the number of new enterprises, attracting foreign investment, attracting venture capital, the number of patents granted and the number of trademarks registered. The Innovation and Entrepreneurship Index was constructed to reflect the innovation and entrepreneurship vitality and performance of each region in China. Table 2 shows the comprehensive regional innovation evaluation index of 27 cities in the Yangtze River Delta city cluster from 2011 to 2020. Figure 2 shows the trend of the average value of the regional innovation evaluation index of the Yangtze River Delta city cluster for each year.

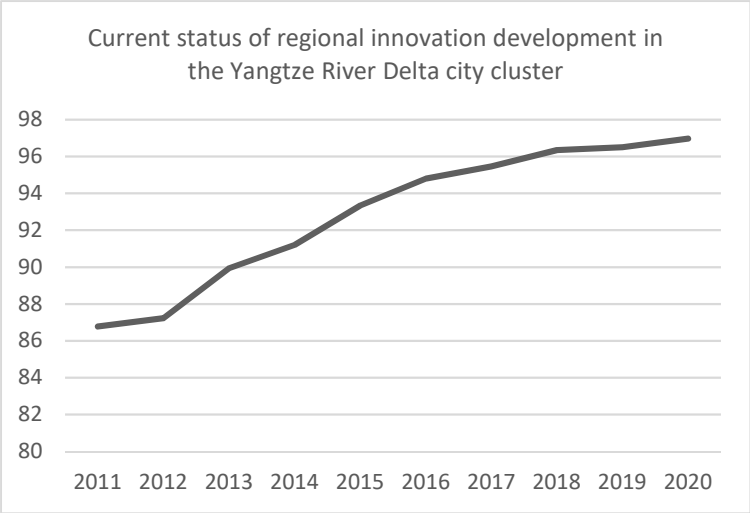

Figure 2. Current status of regional innovation development in the Yangtze River Delta city cluster

Figure 2 illustrates the general trend of the regional innovation level of the Yangtze River Delta city cluster in China from 2011 to 2018. In order to measure the overall development level in that year, this paper uses the average value of 27 cities for the measurement. The results show that the regional innovation level of China's Yangtze River Delta city cluster shows a fluctuating upward trend, rising from 86.78 in 2011 to 96.97 in 2020. based on the trend of the average development of each year in the figure, it can be seen that the comprehensive regional innovation evaluation index of the Yangtze River Delta city cluster has been increasing year by year since 2011.

3.1.3. Data Processing

In empirical analysis, multi-indicator data may have different properties, quantity sets and scales, which can lead to quantitative differences between indicators and thus affect the accuracy and reliability of the results. Therefore, these indicators need to be standardised so that they have the same scale and importance. There are two common methods of standardisation: z-score standardisation and min-max standardisation. In this case, z-score normalisation converts the data into a standard normal distribution centred on the mean with standard deviation. The min-max normalisation transforms the data linearly by minimum and

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maximum values, so that the data are mapped to the interval [0,1]. In this study, we use the min-max normalisation method to normalise the data. In order to eliminate the effect of extreme values, the method is improved by multiplying the maximum and minimum values by factors of 1.1 and 0.9, respectively, when calculating them. This makes the maximum and minimum values relatively more stable and avoids the effect of extreme values on the standardisation of the data.

$$Y_{ij} = \frac{X_{ij} - \alpha \min(X_{ij})}{\beta \max(X_{ij}) - \alpha \min(X_{ij})} \tag{1}$$

Here α is taken as 0.9 and β as 1.1, where X_{ij} is the j indicator for the i region and Y_{ij} is the normalised value.

3.2. Coupling Synergy Evaluation Model

The Coupled Synergy Evaluation Model is a model for assessing the degree of coupling and coordination between the various subsystems in a system. The model helps system designers and managers to understand the interactions and influences between the various parts of a system so that the design and operation of the system can be optimised. Coupling refers to the degree of dependencies and interactions between different parts of a system. In a highly coupled system, changes in one part may have a serious impact on other parts. Coordination refers to the degree of co-ordination and cooperation between the various parts of a system. In a highly coordinated system, the parts are able to cooperate and collaborate effectively to achieve the overall objectives of the system. Synergistic development refers to a development model in which all aspects of economic, social and environmental development are coordinated with each other to achieve overall development. In the process of coordinated development, different aspects need to be balanced, coordinated and integrated with each other in order to achieve sustainable development. Digital finance and regional innovation are two important directions of current economic development, and the synergistic development of the two is of great significance in promoting economic transformation and upgrading and regional development. Therefore, this paper introduces the coupled synergy model to measure the level of synergistic development between the two, which consists of three main elements: first, the coupling degree C between subsystems, second, the coordination degree T between systems, and third, the coupling synergy degree D between systems. The coupled synergy model of digital finance and regional innovation can be constructed, while referring to Gaimei [12], the relative development index E is introduced to measure and analyze the relative development degree of coupled synergy between digital finance and regional innovation development in 27 cities of the Yangtze River Delta city cluster.

The model equation is as follows:

$$C = \frac{innovation \times digital}{[(innovation + digital)/2]^k} \tag{2}$$

$$D = \sqrt{C \times T}, T = \alpha innovation + \beta digital \tag{3}$$

$$E = innovation - digital \tag{4}$$

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Wherein, innovation, digital denotes the comprehensive evaluation index of regional innovation and digital finance respectively, C, T and D denote the coupling degree, development degree and coupling coordination degree of the two respectively, k is a parameter, this paper studies the synergistic development between the two systems of digital finance and regional innovation, so here k is equal to 2, E denotes the relative development degree of regional innovation and digital finance. Table 3 shows the classification criteria for measuring the level of synergy between the coupling of digital finance and regional innovation. Wu Rulian [11].

Table 3. Classification criteria for the level of synergy between digital finance and regional innovation coupling

Coupling coordination D	Grade	Relative development E	Type of coordinated development
$0.8 < D \leq 1$	Quality coordination	$-0.1 < E < 0.1$	Regional Innovation - Digital Finance Simultaneous Development Type
		$E < -0.1$	Regional innovation development lags behind
		$0.1 < E$	Digital finance lagging type
$0.7 < D \leq 0.8$	Good coordination	$-0.1 < E < 0.1$	Regional Innovation - Digital Finance Simultaneous Development Type
		$E < -0.1$	Regional innovation development lags behind
		$0.1 < E$	Digital finance lagging type
$0.6 < D \leq 0.7$	Intermediate coordination	$-0.1 < E < 0.1$	Regional Innovation - Digital Finance Simultaneous Development Type
		$E < -0.1$	Regional innovation development lags behind
		$0.1 < E$	Digital finance lagging type
$0.5 < D \leq 0.6$	Primary coordination	$-0.1 < E < 0.1$	Regional Innovation - Digital Finance Simultaneous Development Type
		$E < -0.1$	Regional innovation development lags behind
		$0.1 < E$	Digital finance lagging type
$0.4 < D \leq 0.5$	Mild disorders	$-0.1 < E < 0.1$	Regional Innovation - Digital Finance Simultaneous Development Type
		$E < -0.1$	Regional innovation development lags behind
		$0.1 < E$	Digital finance lagging type
$0.3 < D \leq 0.4$	Moderate disorder	$-0.1 < E < 0.1$	Regional Innovation - Digital Finance Simultaneous Development Type
		$E < -0.1$	Regional innovation development lags behind
		$0.1 < E$	Digital finance lagging type
$0 < D \leq 0.3$	Extreme disorders	$-0.1 < E < 0.1$	Regional Innovation - Digital Finance Simultaneous Development Type
		$E < -0.1$	Regional innovation development lags behind
		$0.1 < E$	Digital finance lagging type

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4. Analysis of the Results of Measuring the Coupling Synergy between Digital Finance and Regional Innovation Development

4.1. Degree of Coupling

The degree of coupling is an important indicator in the coupling coordination evaluation model and is used to assess the degree of coupling between multiple systems. It refers to the degree of interdependence and influence between individual systems and is usually expressed as a numerical value. The higher the coupling degree, the greater the degree of interdependence and influence between systems, and the higher the degree of coordination between systems; conversely, the lower the coupling degree, the less the degree of interdependence and influence between systems, and the lower the degree of coordination between systems. The coupling degree of the Yangtze River Delta city cluster from 2011 to 2020 is measured respectively according to the constructed model. Figure, depicts the development trend of the coupling degree of digital finance and regional innovation in 27 cities of the Yangtze River Delta city cluster from 2011 to 2020. From Figure 3, it can be seen that the coupling degree of digital finance and regional innovation in the Yangtze River Delta city cluster is increasing year by year.

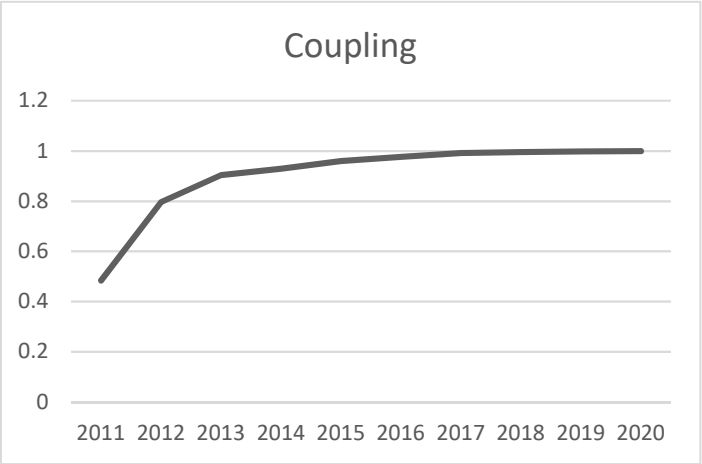

Figure 3. Development trend of digital finance and regional innovation coupling in the Yangtze River Delta city cluster

4.2. Coherence

In coupling coordination evaluation models, the degree of coordination is usually assessed by calculating the coupling strength and the consistency of the coupling direction between individual systems. If the coupling strength between individual systems is high and the direction of coupling is consistent, the degree of interaction and coordination between the systems is good and the degree of coordination is higher; conversely, if the coupling strength between individual systems is low or the direction of coupling is inconsistent, the degree of interaction and coordination between the systems is poor and the degree of coordination is lower.

Figure 4, which depicts the development trend of the synergy between digital finance and regional innovation in the 27 cities of the Yangtze River Delta city cluster from 2011 to 2020, is based on the model constructed to measure the synergy degree from 2011 to 2020. From Figure 4, it can be seen that the synergy between digital finance and regional innovation in the Yangtze River Delta city cluster is increasing year by year.

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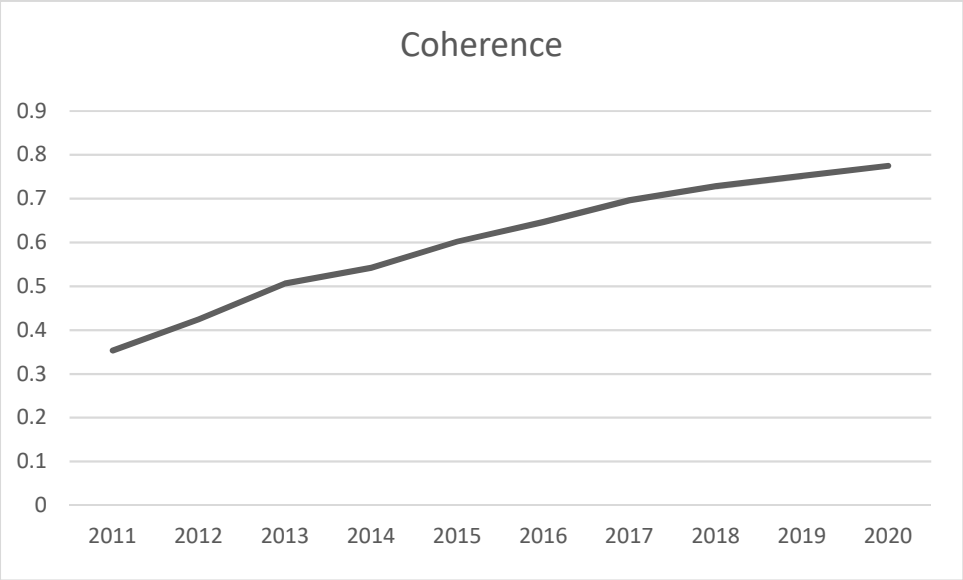

Figure 4. Development trend of digital finance and regional innovation synergy in the Yangtze River Delta city cluster

4.3. Coupling Synergies

In order to measure the level of synergistic development of digital inclusive finance and regional innovation for the 27 cities in the Yangtze River Delta city cluster in China, it is necessary to first standardise the digital inclusive finance development index and the comprehensive regional innovation evaluation index, as the two indices are not of the same order of magnitude. After the standardisation process, the synergistic development level measurement formula can be used to calculate the level of synergistic development of digital inclusive finance and regional innovation in these 27 cities. Table 4 shows the table of the level of synergistic development of digital finance and regional innovation for each city in China's Yangtze River Delta city cluster during the sample study period, and Figure 5 shows the average value of the coupling and coordination degree of digital finance and regional innovation for each year in China's Yangtze River Delta city cluster during the sample study period.

From Table 4, we can calculate that the current average value of the synergistic development of digital finance and regional innovation in China is 0.733. Since the measurement range of the synergistic development of digital finance and regional innovation is between 0 and 1, the better the synergistic development of digital finance and regional innovation, the closer the level of synergistic development of digital finance and regional innovation is to 1; on the contrary, if the synergistic development of digital finance and regional innovation is worse, the level of synergistic development of digital finance and regional innovation is closer to 0. From this, we can see that the average level of synergistic development between digital finance and regional innovation in China is at a relatively high level. Overall, the level of synergistic development between digital finance and regional innovation in the 27 cities in the Yangtze River Delta region shows a fluctuating upward trend. In 2011, most of the cities in the Yangtze River Delta region ranked within 0.3 to 0.5 in terms of the level of synergistic development of digital finance and regional innovation, while by 2020, most of the cities in the Yangtze River Delta region will be within 0.3 to 0.5 in terms of the level of synergistic development of digital finance and regional innovation. After 10 years of development, the level of synergistic development of digital finance and regional innovation in the Yangtze River Delta region has been improved as a whole.

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Table 4. Levels of synergistic development of digital finance and regional innovation in the 27 cities of the Yangtze River Delta City Cluster, 2011 to 2020

City	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Ranking
Hangzhou	0.496728	0.686565	0.765657	0.782515	0.828017	0.847324	0.887617	0.903615	0.919225	0.92926	1
Nanjing	0.465952	0.643543	0.735349	0.760492	0.808644	0.844011	0.873189	0.890685	0.903567	0.912663	2
Shanghai	0.466216	0.639739	0.731866	0.759628	0.806106	0.827735	0.866574	0.885919	0.901195	0.912953	3
Suzhou	0.471434	0.62882	0.724629	0.752744	0.797328	0.835148	0.869551	0.8842	0.898863	0.909391	4
Ningbo	0.475483	0.63819	0.726384	0.759534	0.802294	0.823184	0.859149	0.876142	0.889896	0.901012	5
Wenzhou	0.470313	0.627095	0.722545	0.742152	0.790458	0.816311	0.854818	0.871217	0.883239	0.894823	6
Jiaxing City	0.493654	0.6279	0.715126	0.73489	0.786566	0.809187	0.848607	0.870719	0.88428	0.897164	7
Wuxi	0.460849	0.610365	0.712177	0.744403	0.790258	0.823753	0.858252	0.875316	0.887839	0.89926	8
Jinhua	0.460225	0.617413	0.710868	0.737674	0.788956	0.810022	0.849566	0.875327	0.892453	0.904535	9
Changzhou	0.457378	0.610688	0.708585	0.73484	0.786076	0.819985	0.855398	0.874521	0.888319	0.898566	10
Hefei	0.422447	0.595192	0.696788	0.732391	0.783365	0.814505	0.855154	0.872896	0.888096	0.897978	11
Introduction	0.449762	0.601607	0.692576	0.730805	0.780366	0.803705	0.837647	0.857612	0.877347	0.888955	12
Huzhou City	0.448201	0.598187	0.697986	0.723514	0.774823	0.800845	0.839828	0.863973	0.878563	0.889952	13
Nantong	0.420536	0.582471	0.68353	0.712819	0.762232	0.802289	0.839902	0.861592	0.87633	0.889918	14
Taizhou	0.446562	0.561031	0.699461	0.673309	0.77418	0.800352	0.83521	0.855937	0.872218	0.885316	15
Zhenjiang	0.424787	0.575087	0.667046	0.709606	0.760937	0.800242	0.83837	0.855498	0.866248	0.879977	16
Yangzhou	0.401233	0.560266	0.667078	0.700505	0.760282	0.805272	0.836683	0.853728	0.864506	0.878681	17
Taizhou	0.384408	0.556243	0.656682	0.691134	0.744265	0.793574	0.829851	0.84886	0.862249	0.87839	18
Wuhu City	0.325267	0.557033	0.653279	0.69184	0.748445	0.784523	0.829188	0.844358	0.864108	0.881878	19
Yancheng	0.342258	0.534285	0.640365	0.669805	0.735079	0.790501	0.828887	0.845291	0.857302	0.871588	20
Zhoushan City	0.418713	0.522376	0.6101	0.636927	0.721318	0.765154	0.803674	0.831271	0.835664	0.847745	21
Ma'anshan	0.296577	0.531982	0.619178	0.684102	0.727619	0.763517	0.796737	0.82482	0.835253	0.843711	22
Xuancheng City	0.310114	0.490537	0.612959	0.651109	0.686805	0.731797	0.779473	0.802241	0.820114	0.833129	23
Tongling	0.356475	0.538	0.588145	0.660719	0.675537	0.715538	0.742404	0.774936	0.812313	0.820513	24
Chuzhou	0.206135	0.416849	0.585152	0.660354	0.70315	0.748189	0.780786	0.811708	0.82988	0.849716	25
Anqing	0.157527	0.465909	0.587606	0.646657	0.683827	0.745109	0.778199	0.803383	0.818014	0.841129	26
Chizhou	0.240633	0.471675	0.574573	0.617696	0.680219	0.709255	0.749526	0.764164	0.776014	0.807057	27

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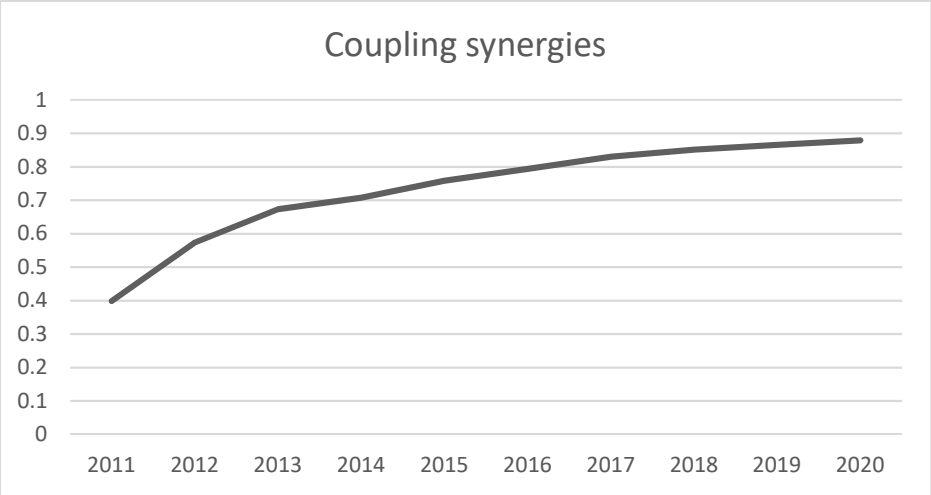

Figure 5. General trend of the annual digital finance and regional innovation coupling coordination in the Yangtze River Delta city cluster

Based on the measured data, we counted the coupling coordination status of 27 cities in the Yangtze River Delta region and presented the statistics on the coordination status of digital finance and regional innovation in the region from 2011 to 2020 in Table 5. According to Table 5, from 2011 to 2020, the development of the digital finance and regional innovation subsystem has undergone a process from uncoordinated to coordinated. In 2011, the two systems of digital finance and regional innovation were generally uncoordinated, with 18 cities mildly out of alignment, 5 cities moderately out of alignment and 4 cities extremely out of alignment. By 2012, these two subsystems began to gradually harmonise, with 11 cities reaching intermediate level of harmonisation and 12 cities reaching primary level of harmonisation. By 2020, the two systems of digital finance and regional innovation in the Yangtze River Delta city cluster have reached high quality coordination.

Table 5. shows the status of coordination between digital finance and regional innovation in the Yangtze River Delta city cluster from 2011 to 2020

Year	Quality coordination	Good coordination	Intermediate coordination	Primary coordination	Mild disorders	Moderate disorder	Extreme disorders
2011					18	5	4
2012			11	12	4		
2013		10	13	4			
2014		16	11				
2015	4	19	4				
2016	17	10					
2017	21	6					
2018	25	2					
2019	26	1					
2020	27						

Table 6 shows the type of synergistic development of the two systems of digital finance and regional innovation each year based on the introduced relative development degree E and the measured coupling coordination degree of digital finance and regional innovation. As can be seen from Table 6, before 2017, the development of digital finance was lagging behind in the synergistic development system of digital finance and regional innovation, while after 2017, the two systems of digital finance and regional innovation reached synergistic development.The

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main reason why the overall development of the digital finance system was lagging behind relative to the regional innovation system before 2017 may be due to the fact that the development of digital technology is still at the breakthrough As digital technology continues to break through, the digital finance subsystem shows rapid development in the coupled and coordinated system of digital finance and regional innovation, until the two subsystems of digital finance and regional innovation reach a state of quality coordination in 2020.

Table 6. provides statistics on the types of synergistic development of digital finance and regional innovation in the Yangtze River Delta city cluster from 2011 to 2020

Year	Regional innovation and digital finance synergies	Regional innovation development lags behind	Digital finance development lags behind
2011	1		26
2012	2		25
2013	2		25
2014	1	1	25
2015		1	26
2016	3		23
2017	7		20
2018	16		11
2019	24	1	2
2020	27		

5. Policy Recommendations and Conclusions

According to the research on the synergistic development of digital finance and regional innovation, this paper analyzes the interaction between the two subsystems of digital finance and regional innovation, proposes the research on the level of synergistic development of digital finance and regional innovation, measures the coupling synergy degree of digital finance and regional innovation in China's Yangtze River Delta region respectively by constructing a coupling synergy evaluation model, and further analyzes the dynamic relationship between the two. The following are the conclusions obtained from this study: First, the level of synergistic development of digital inclusive finance and regional innovation in China's Yangtze River Delta city cluster is improving year by year, and the current overall level of synergistic development of digital finance and regional innovation in China's Yangtze River Delta city cluster is at a relatively high level on average. Secondly, the level of synergistic development of digital inclusive finance and regional innovation in the Yangtze River Delta city cluster has experienced a stage from a mild disorder in 2011 to a high-quality coordination stage in 2020. Thirdly, before 2017 the digital inclusive finance and regional innovation synergistic system, digital inclusive finance were in a lagging stage of development, with the continuous innovation of digital technology and rapid development of digital finance in recent years, by 2020, the digital inclusive finance system and regional innovation system reached a stage of quality synergistic development.

Based on the above research, the following policy recommendations are proposed: First, strengthen the synergy between digital finance and regional innovation: the government and financial institutions should focus on the synergy between digital finance and regional innovation, promote the integration of policies, financial resources and technologies, and facilitate the joint development of digital finance and regional innovation. Second, optimise the allocation of financial resources: the government should guide financial resources towards innovative industries and high-tech industries, and increase the support of digital finance for innovative enterprises. Financial institutions can optimise the allocation of financial resources

by adjusting credit policies and issuing innovation bonds. Third, enhance the capacity of digital financial services: financial institutions should increase their investment in financial technology, improve the quality and level of digital financial services, and enhance the efficiency of financial services. At the same time, the government should strengthen the regulation of digital finance to ensure the stability and safety of the financial market. Fourth, strengthen the construction of the innovation ecosystem: The government and financial institutions should jointly promote the construction of the innovation ecosystem, including policy, capital, talent, technology and market elements, to form a favourable environment conducive to innovation. Fifth, promote regional synergistic development: The government should strengthen inter-regional policy coordination and resource integration, promote close linkage of industrial, innovation and capital chains between regions, and promote inter-regional synergistic development. Sixth, encourage technological innovation and intellectual property protection: the government should increase support for technological innovation, improve the intellectual property protection system, and stimulate the innovation enthusiasm of enterprises and research institutions. Seventh, deepen financial reform and innovation: the government should deepen financial reform, promote the opening and diversification of financial markets, and innovate financial products and services to meet the financial needs of regional innovation and development. In summary, the government and financial institutions need to work together to strengthen the synergistic development of digital finance and regional innovation in order to promote sustainable, healthy and stable economic development.

References

[1] Dong Shugong, Yang Zilin. Can the development of digital inclusive finance promote regional innovation in China? [J/OL]. Financial Development Research:1-10 [2023-04-17].

[2] Zhao Qingtuan,Luo Shuai. Research on the impact of digital inclusive finance on regional innovation development--an empirical analysis based on data from 269 prefecture-level cities in China[J]. China Agricultural Accounting,2022,No.376(11):21-24.

[3] Zhang Suan. A study on the impact of digital inclusive finance on regional innovation - an empirical analysis based on provincial panel data [J]. Price Theory and Practice,2021,No.449(11):134-137+198.

[4] Teng Zhou. Digital financial development and regional innovation level enhancement - based on aggregate and structural perspectives[J]. Shandong Textile Economy,2021,No.291(05):14-19.

[5] Guo Zhenzhou. Technological innovation to build the core competitiveness of digital inclusive finance[J]. Tsinghua Financial Review,2017,No.39(02).

[6] Zhou Xiaochuan. The interaction of information technology and financial policy[J]. China Finance,2019,No.909(15):9-15.

[7] Wang Yang, Xie Zhonghui, Li Yueyue. Research on the coupled and coordinated development of digital inclusive finance and innovation development[J]. Journal of Harbin University of Commerce (Social Science Edition),2021,No.181(06):17-26.

[8] Wang L,Liu LY. Interactive impact and spatial spillover of digital inclusive finance and regional innovation-an empirical test based on spatial association equation and heterogeneity SDM[J]. Financial Development Research,2022,No.489(09):26-35.

[9] Guo Xiangyang, Mu Xueqing, Ding Zhengshan, et al. A study on the coordination pattern of tourism efficiency and high-speed traffic under the integration of "transportation and tourism": an example of 41 cities in the Yangtze River Delta[J]. Geography Research,2021,40 (4):1042-1063.

[10] Cong Xiaonan. The form, nature and some misuses of coupling degree models in geography[J]. Economic Geography,2019,39(04):18-25.

[11] Gai Mei, Qin Bing, Zheng Xiuxia. Analysis of the evolution of the spatial and temporal pattern of coupling and coordination between economic growth dynamics transformation and green development[J]. Geographical Research,2021,40(09):2572-2590.

ISSN: 2688-9323

[12] Wu Rulian. Study on the measurement, evolution and spatial effects of coupling and coordination between high-quality tourism development and rural revitalization [D]. Jiangxi University of Finance and Economics, 2022.

[13] Guo Feng, Wang Jingyi, Wang Fang, Kong Tao, Zhang Xun, Cheng Zhiyun. Measuring the development of digital inclusive finance in China:Indexing and spatial characteristics[J]. Econometrics (Quarterly),2020,19(04).