Hindawi
Mobile Information Systems
Volume 2022, Article ID 5470373, 12 pages
https://doi.org/10.1155/2022/5470373

Research Article

Spatial-Temporal Differentiation and Dynamic Evolution of Digital Finance Inclusive Development in the Yangtze River Delta Economic Cluster of China

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Received 19 August 2022; Accepted 8 September 2022; Published 3 October 2022

Academic Editor: Chia-Huei Wu

Clarifying the sources of the digital finance inclusive development gap helps profoundly understand the regional characteristics of inclusive digital finance and benefits and formulate and implement specific policies scientifically and reasonably. Based on the 2011–2020 "Peking University Digital Finance Inclusive Index," this study explores the regional disparity in digital finance inclusive development and its sources in the Yangtze River Delta economic cluster using the methods of the center of gravity shift, standard deviation ellipse, nested Theil index difference decomposition, and Kernel density. We found that inclusive digital finance shows a rising trend year by year, with evident heterogeneity and spatial agglomeration characteristics; interprovincial differences are the primary sources of the overall differences in inclusive digital finance in the Yangtze River Delta. The spatial effect of digital inclusion finance between the Yangtze River Delta regions has continuity. Because of the significant positive spatial correlation of digital inclusion finance between regions, digital inclusion finance in this region is vulnerable to potential shocks from neighboring regions. Moreover, with or without the spatial lag term, the level of inclusive digital finance in all regions of the Yangtze River Delta shows a leap forward. This paper looks at the regional gap of inclusive digital finance and its structural decomposition in the Yangtze River Delta city cluster from three perspectives: time trend, spatial structure, and dynamic evolution. This gives an empirical basis for the different kinds of digital finance inclusive development policies and a guide for making decisions to speed up the formation of a regional digital finance inclusive synergistic development path.

1. Introduction and Literature Review

Digital finance inclusive is vital in promoting high-quality economic development and achieving shared prosperity in the Yangtze River Delta economic cluster. Digital finance inclusive has profoundly changed the course of inclusive financial development, providing new ideas and a strong impetus for the sustainable and rapid development of inclusive finance. It has great potential for effectively cracking the problem of financial exclusion and solving the financial dilemma of the three rural areas and small and micro-enterprises. Unlike traditional inclusive financial services, which mainly rely on financial institutions and physical outlets to carry out business, inclusive digital finance relies on core digital technologies such as mobile terminals and big data analysis. Inclusive digital finance can help break through industry boundaries, break the "two-eight law" profit model, open up the long-tail financial services market, and enable more financially excluded groups to enjoy financial services. Financial services significantly improve the accessibility and coverage of financial services and promote a more inclusive modern financial system. Therefore, digital financial inclusion has received significant attention from the beginning of development. As the Yangtze River Delta Economic Belt is one of the three major support belts for China's economic development and the core area for the construction of the Common Wealth Demonstration Zone, research on how to promote the synergistic development of

inclusive digital finance in the Yangtze River Delta region has gradually become a hot topic of attention. Due to the varying levels of traditional financial development, Internet development, economic development, and structure of each region in the Yangtze River Delta Economic Belt, there are noticeable regional differences in the development of inclusive digital finance in the Yangtze River Delta, which restricts the sustainable and rapid coordinated development of inclusive digital finance and brings challenges to the construction of the commonwealth demonstration zone in the Yangtze River Delta. So, it makes a lot of sense to look into how inclusive digital finance is different in different places and how it changes over time in the Yangtze River Delta Economic Zone. This not only helps local governments reevaluate the status of inclusive digital finance development in the region, but it also gives them a scientific basis and a decision-making guide for the coordinated and fast development of inclusive digital finance.

Regarding regional differences and dynamic evolution studies, the existing literature has more analyses based on inclusive finance, but there is a lack of analyses based on inclusive digital finance. At present, the literature mainly adopts the following methods to analyze the regional differences in the development of inclusive finance: First, a simple data comparison of each region's inclusive financial development index. Based on the results of measuring the development level of inclusive finance in each region, a comparative analysis of the development status of local inclusive finance was conducted to explore the dynamic changes in the spatial distribution of inclusive finance in each region over time. There are obvious spatial differences and multipolar differentiation in the development level of inclusive finance. At the same time, the high and low levels of socioeconomic policy support and other factors lead to the uneven development of inclusive regional finance, and there are differences in where households are getting out of poverty [1–10]. The second is the Moran index. The index measures the regional differences in the development of inclusive finance, the distribution pattern of inclusive finance, and factors such as government intervention and market-based and informal finance closely related to the development of inclusive finance [2–4, 11–14]. Third, the distribution dynamics method analyzes the distribution and dynamic evolution process of regional differences in inclusive finance, mainly the Theil index, Dagum Gini coefficient, Kernel density, other analysis methods, and the distribution dynamics analysis method. The Dagum Gini coefficient measure is used to analyze the size and source of spatial disparities and their trends over time and to decompose regional disparities into intraregional and interregional [15–19]. The contribution of disparity sources to the overall disparity can be quantified, while Kernel density estimation is used to analyze the distribution location, shape, and extension, which makes up for the shortcomings of the Dagum Gini coefficient. However, the estimation can provide limited information on the internal dynamics of the distribution of regional financial development levels. It cannot reflect the relative positional changes of each region in the distribution of regional financial development levels and the probability of such changes [20–26]. The limitations of the current study are mainly reflected in the following: First, the evaluation system has different designs for various indicators. Some indicators are too subjective and cannot reflect the reality of the development of inclusive digital finance. Secondly, in terms of research methods, most of the existing studies use the coefficient of variation and Theil index to analyze the regional differences in inclusive digital finance and less involve the decomposition of regional differences. Third, most studies tend to analyze statically digital finance, while dynamic research lacks this.

This paper conducts the following explorations on the basis of the existing research results: Firstly, it presents the actual development status and geographical differentiation of digital inclusive finance at the municipal level in the Yangtze River Delta Economic Zone, a national strategic support area, to make up for the shortcomings of the previous mostly qualitative studies; secondly, it makes comprehensive use of analytical tools such as spatial gravity shift, standardized ellipse analysis, and Theil's Gini coefficient to decompose the regional differences of digital inclusive finance in the Yangtze River Delta Economic Zone. Secondly, we use the tools of spatial gravity shift, standardized ellipse analysis, and Theil Gini coefficient to decompose the regional differences in digital inclusion in the Yangtze River Delta economic zone. Again, the introduction of spatial Kernel density estimation reveals the dynamic distribution and spatiotemporal evolution of digital inclusive finance development in the Yangtze River Delta Economic Zone, further clarifying the aspects that should be focused on in the future to enhance the level of digital inclusive finance in the Yangtze River Delta Economic Zone, which is of great practical significance for implementing the innovation drive, achieving high-quality economic development, and realizing common prosperity.

2. Research Methodology and Data Processing

2.1. Spatial Elliptic Formula. The overall characteristics of the interannual variation and dynamic spatial process of the digital financial inclusion level in the Yangtze River Delta region are explained based on five basic parameters of the standard deviation ellipse (SDE) model [27–29]. The standard deviation ellipse is calculated as follows:

$$\begin{aligned}
\overline{X}_w &= \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}, \\
\overline{Y}_w &= \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i}, \\
\sigma_x &= \sqrt{\frac{\sum_{i=1}^{n} \left(w_i \tilde{x}_i \cos\theta - w_i \tilde{y}_i \sin\theta\right)^2}{\sum_{i=1}^{n} w_i^2}}, \\
\sigma_y &= \sqrt{\frac{\sum_{i=1}^{n} \left(w_i \tilde{x}_i \sin\theta - w_i \tilde{y} \cos\theta\right)^2}{\sum_{i=1}^{n} w_i^2}},
\end{aligned} \tag{1}$$

where $\overline{X}_w$ and $\overline{Y}_w$ are the mean centers in the Yangtze River Delta. σ_x denotes the x-axis standard deviation. σ_i is the y-axis standard deviation, w_i denote the weight. x_i and y_i are the spatial location of the Yangtze River Delta. $\tilde{x}_i$ and $\tilde{y}_i$ denote the coordinate deviation of the spatial locus of the study object to the mean center, and θ is the deflection angle.

2.2. Theil's Index and Its Nested Decomposition Method. The Theil index is an essential indicator of regional disparities. A more significant Theil coefficient indicates more significant regional economic disparities, while the opposite is true [30, 31]. The formula for calculating the Theil coefficient is as follows:

$$T = \sum_{i=1}^{N} y_i \ln \frac{y_i}{p_i}, \tag{2}$$

where y_i is the proportion of i provincial digital finance inclusive to the overall digital finance inclusive level in the Yangtze River Delta, p_i is the proportion of the i population of the region to the total population of the country, N is the number of regions, and takes the prefecture-level city as the primary regional unit. We can make a two-stage nested decomposition of the Thayer coefficient to decompose the overall difference of digital finance inclusive in the Yangtze River Delta. (T_d) is decomposed into intraprovincial differences (T_{wP}), interprovincial differences (T_{BP}), and interbelt variation (T_{BR}). The specific decomposition formula is as follows:

$$T_d = \sum \sum_i \sum_j \left(\frac{y_{ik}}{Y}\right) \ln\left(\frac{y_{iq}/Y}{p_{ijk}/P}\right), \tag{3}$$

where i is the interprovincial variation in regions as follows:

$$T_{pi} = \sum_j \frac{Y_{ij}}{Y_i} \ln \frac{Y_{ij}/Y_i}{P_{ij}/P_i}. \tag{4}$$

The intraprovincial variation in the province j:

$$T_{ij} = \sum_{ik} \frac{y_{ijk}}{Y_{ij}} \ln \frac{y_{ijk}/Y_{ij}}{p_{ijk}/P_{ij}}. \tag{5}$$

T_d can be further decomposed as follows:

$$\begin{aligned} T_d &= \sum_i \left(\frac{Y_i}{Y}\right)\left[\sum\left(\frac{Y_{ij}}{Y_i}\right)T_{ij} + T_{pi}\right] \\ &\quad + \sum_i \left(\frac{Y_i}{Y}\right) \ln\left(\frac{Y_i/Y}{P_i/P}\right) \\ &= \sum \sum_i \left(\frac{Y_{ij}}{Y}\right)T_{ij} + \sum_i \left(\frac{Y_i}{Y}\right)T_{pi} + \\ &\quad \sum_i \left(\frac{Y_i}{Y}\right) \ln\left(\frac{Y_i/Y}{P_i/P}\right) = T_{wP} + T_{BP} + T_{BR}, \end{aligned} \tag{6}$$

where y_{ijk} represents the level of digital financial inclusion in the regional administrative unit k in the j city of the i province, and p_{ijk} represents the population in regional administrative unit k of the province i and city j. Y_{ij} and P_{ij} are the levels of digital financial inclusion and the population in province and j municipality, respectively; Y_i and P_i are the i provincial digital financial inclusion and population, respectively; Y and P are the overall digital financial inclusion and population in the Yangtze River Delta region, respectively.

2.3. Estimation of Kernel Density under Spatial Conditions. The traditional Kernel density estimation can show the distribution pattern of variables but does not obtain the specific change after some time. In contrast, the Kernel density estimation method is used to estimate the probability density function of state transformation in a stochastic process under spatial conditions. It can accurately determine the changing pattern with the three-dimensional map of dynamic distribution of variables and density contour map, so it can be used to explore the changing trend of each region after some time [31, 32]. Therefore, it can be used to investigate the changing trend of each region after a while. In the stochastic Kernel density estimation, the Gaussian Kernel function is also used in this paper, and the expression is as follows:

$$g(y \mid x) = \frac{f(x, y)}{f(x)}, \tag{7}$$

where $f(x)$ denotes the marginal Kernel density function for x. $f(x, y)$ denotes the joint Kernel density function of x and y, with the expression

$$f(x, y) = \frac{1}{Nh_x h_y} \sum_{i=1}^{N} K\left(\frac{X_i - x}{h_x}\right) K_y\left(\frac{Y_i - x}{h_y}\right). \tag{8}$$

2.4. Study Area and Data Sources. The Yangtze River Delta urban agglomeration has undergone five expansions from 1992 to 2019, and the full coverage of the three provinces and one city was achieved in January, and the number of members increased from 15 to 41. Therefore, this paper selects three counties in three provinces and one city in the Yangtze River Delta region after the fifth expansion as the research sample. These include 16 counties in Shanghai, 96 counties in Jiangsu, 90 counties in Zhejiang, and 105 counties in Anhui. The "Peking University Digital Finance Inclusive Index," compiled by Peking University and Ant Financial using massive data on digital finance inclusive, calculates the digital finance inclusive index with 33 indicators in terms of coverage breadth and usage depth. It is a widely recognized index that can reflect the level and status of digital finance inclusive development, so this paper used the widely recognized index to reflect the level and status of digital finance inclusive development. Other data sources include the statistical yearbooks of three provinces and one city each year, as well as the China Statistical Yearbook.

3. The Spatial Pattern of Digital Finance Inclusive in the Yangtze River Delta

3.1. Spatial Distribution Characteristics of Digital Finance Inclusive in the Yangtze River Delta Region. As shown in

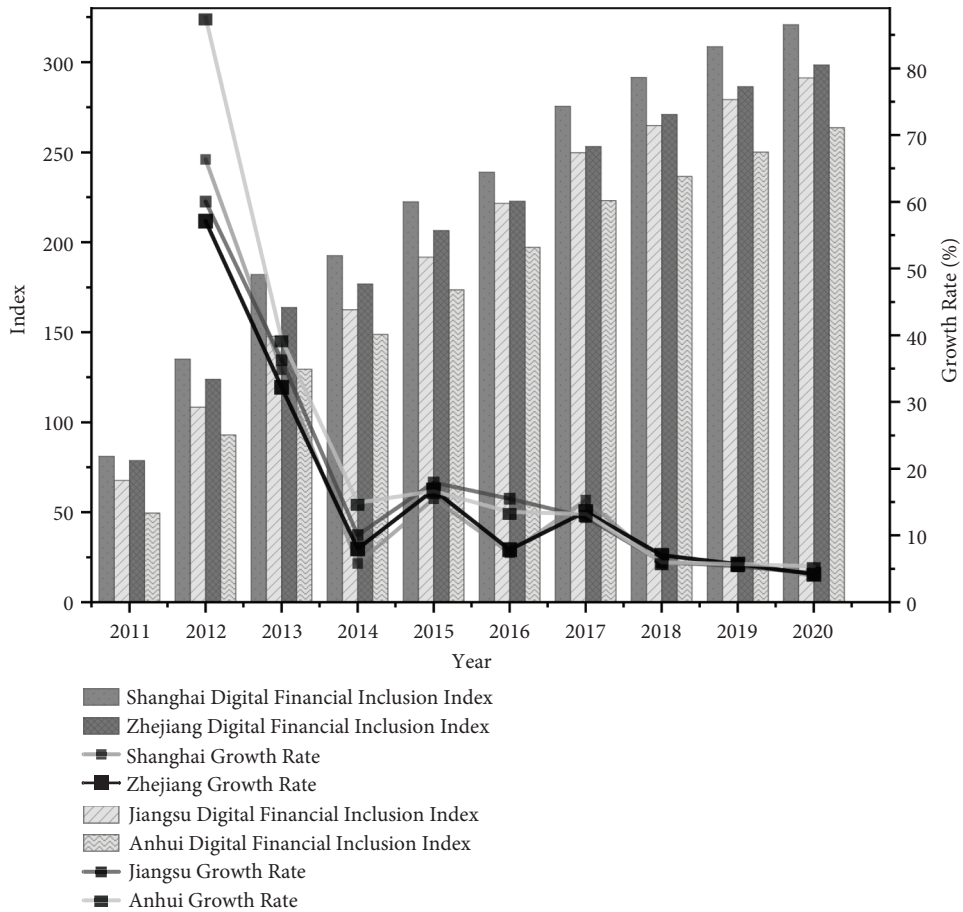


Figure 1: Spatial-temporal trends of digital finance inclusive development from 2011 to 2020.

Figure 1, the overall level of digital finance inclusive in the Yangtze River Delta region continued to rise during the period 2011–2020. Although it tends to level off and show an overall convergence trend after 2014, it still grows at a rate of about 10% per year, and the Yangtze River Delta is still in a period of opportunity for digital finance inclusive. The overall level of digital finance inclusive in the Yangtze River Delta region was 69.31 in 2000 and reached 170.19 in 2014 and 293.55 in 2020. The level of digital finance inclusive in the Yangtze River Delta economic cluster improves, but the growth rate gradually decreases. In 2011, the average annual growth rate of digital finance inclusive volume in 2011~2014 was 49.51, and the average annual growth rate in 2014~2020 decreased to 12.08%. It indicates that the development of digital finance inclusive in the Yangtze River Delta economic cluster has entered a stable stage from quantitative change to qualitative change, and the growth rate of digital finance inclusive has changed significantly. From the analysis of the structure of members within the Yangtze River Delta, the volume of digital finance inclusive shows prominent spatial and temporal divergence characteristics: Shanghai > Zhejiang Province > Jiangsu Province > Anhui Province, Shanghai, and Zhejiang Province have been in rapid development stage in the Yangtze River Delta region, and the level of digital finance inclusive is relatively high; Jiangsu Province is developing faster, and the gap between its level of digital finance inclusive and that of Shanghai and Zhejiang Province is gradually narrowing. Anhui Province has a lower level of digital finance inclusive but is driven by the rapid digital economy of Hefei and the radiation of Nanjing. Its growth rate has gradually continued in Shanghai, Zhejiang Province, and Jiangsu Province.

From the analysis of the growth rate of digital finance inclusive, the growth rate of digital finance inclusive in Shanghai and Zhejiang Province is consistent with the trend of the growth rate of digital finance inclusive in the Yangtze River Delta region. The growth rate of digital finance inclusive level in Jiangsu Province and Anhui Province is always higher than the overall growth rate of the Yangtze River Delta region. The growth rate of digital finance inclusive in Anhui Province is much higher than the average growth rate of other regions in the Yangtze River Delta economic group until 2017. After 2017, it is consistent with the growth rate of other regions. The growth rate of digital finance inclusive in Anhui Province was much higher than the average growth rate of other regions in the Yangtze River Delta economic group until 2014. After 2014, it was in line with the growth rates of other regions. In summary, digital finance inclusive in the Yangtze River Delta regions has changed from high growth to high quality, and the growth

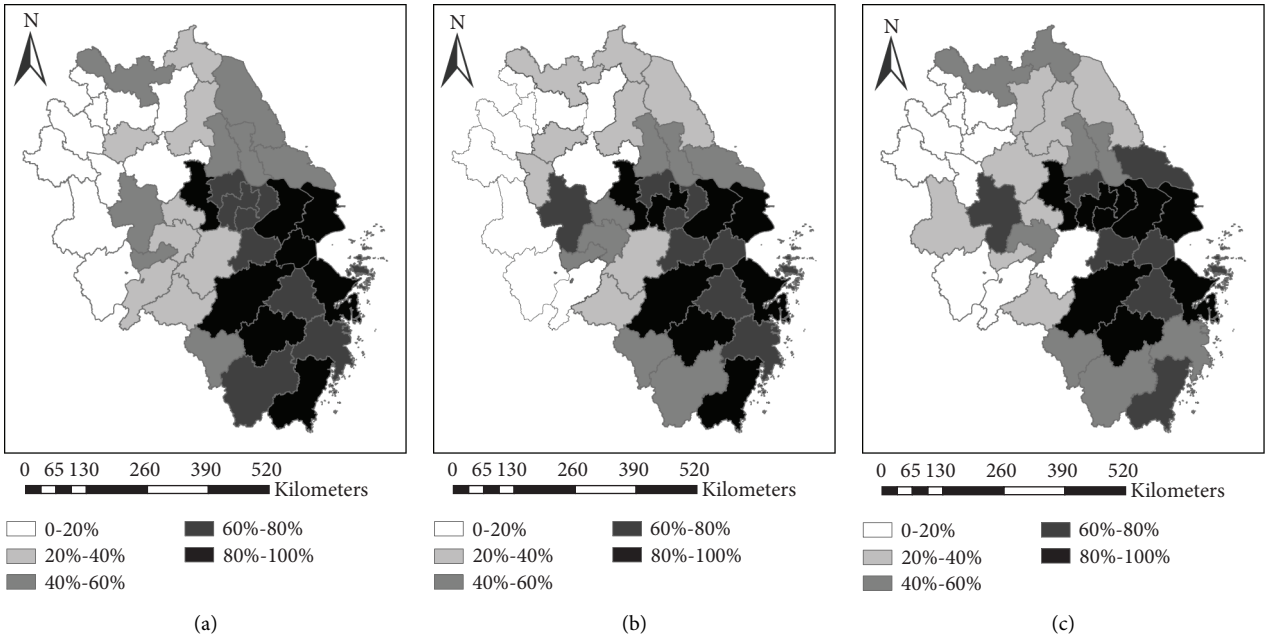


Figure 2: Spatial distribution of digital finance inclusive in Yangtze River Delta.

rate has declined significantly but still maintains a growth rate of about 10% in most years. It indicated that the Yangtze River Delta region is still in an opportunity period for the in-depth development of digital finance inclusive.

According to Figure 2, the Yangtze River Delta's digital finance inclusive at the local and municipal scales shows prominent spatially divergent characteristics. In Figure 2(a), the level of digital finance inclusive in Shanghai, Nanjing, Suzhou, Hangzhou, Jiaxing, Ningbo, Wenzhou, and Jinhua is relatively high in 2011 years, while the level of digital finance inclusive development in Anhui Province and northern Jiangsu Province is relatively low, and the overall level of digital finance inclusive development in the Yangtze River Delta is low. After 2015, with the rapid economic development in the Yangtze River Delta region and the continuous acceptance of developed countries and with the rapid economic development of the Yangtze River Delta region and the continuous industrial transfer from developed countries and regions, the differences in the positioning and development strategies of different regions in the Yangtze River Delta have caused significant changes in the spatial pattern of digital finance inclusive development between regions, resulting in more and more obvious spatial differences in the level of digital finance inclusive within the Yangtze River Delta region. Nanjing, CHangzhou, Suzhou, Shanghai, Hangzhou, Ningbo, Jinhua, and Wenzhou are continuously linked in an inverted "S" distribution and spread to the surrounding areas. The scale of digital finance inclusive in the above-mentioned central cities continues to rise, merging into a giant digital inclusive financial center, connecting with Hefei to the north and extending southward. It is connected with Hefei to the north and extends to Taizhou to the south, a more dense digital inclusive financial center with a centralized concentration and peripheral diffusion, forming the core network structure of digital finance inclusive in the Yangtze River Delta. Lishui City and Quzhou City also gradually connect and integrate to form the southern gathering area of digital finance inclusive in the Yangtze River Delta. Hefei City in Anhui Province has transformed into one of the cores of digital finance inclusive in the Yangtze River Delta region, and the center is spreading to the periphery. From 2015 to 2020, the southern part of Jiangsu Province in the Yangtze River Delta continues to develop and spread to the periphery, forming a linear radiation structure from the provincial capital cities and municipalities directly under the central government to the east and west. The development rate of digital finance inclusive in southern Jiangsu is relatively high and gradually forms a digital finance inclusive agglomeration in southern Jiangsu. The development of Wenzhou and the surrounding areas in southern Zhejiang is relatively slow. The Yangtze River Delta economic cluster shows a spatial pattern of "high in the east and low in the west" regarding digital finance inclusive development level.

3.2. Center of Gravity Shifts and Standard Deviation Ellipse Analysis of Digital Finance Inclusive in Yangtze River Delta Region. In order to accurately portray the morphological evolution trend of the spatial pattern of digital finance inclusive development in the Yangtze River Delta region, the digital finance inclusive evolution trend is quantitatively identified by ArcGIS software with three years as a period, from 2011 to 2020, and seven of them are selected as the characteristic time points. The trajectory of digital finance inclusive's center of gravity shift in the Yangtze River Delta (Figure 3) and the standard deviation ellipse-related parameters (Table 1) was calculated.

The center of gravity migration trajectory is shown in Figure 3, and the center of gravity of digital finance inclusive

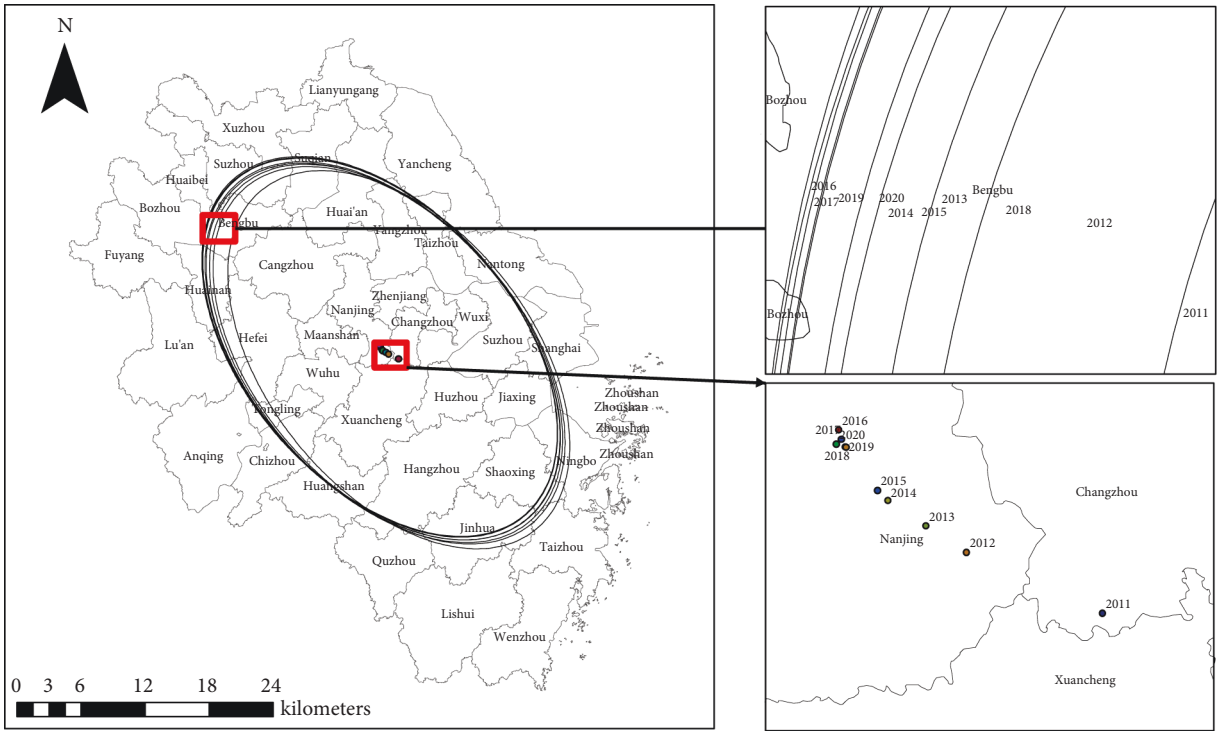


Figure 3: Transfer path of digital finance inclusive in Yangtze River Delta.

Table 1: Parameters of standard deviation ellipse of digital finance inclusive in Yangtze River Delta.

Year	2011	2013	2015	2017	2018	2019	2020
Center of gravity coordinates	119.25°E 31.27°N	119.10°E 31.37°N	119.05°E 31.41°N	119.02°E 31.46°N	119.03°E 31.45°N	119.03°E 31.45°N	119.02°E 31.45°N
The city where the coordinates are located	Changzhou	Nanjing	Nanjing	Nanjing	Nanjing	Nanjing	Nanjing
Travel distance (km)	—	18.64	5.7	6.00	0.87	0.08	0.89
Movement speed (km/a)	—	9.32	2.85	3.00	3.29	1.85	0.43
Turning angle (degrees)	142.87	140.99	140.67	140.80	140.83	140.86	140.73
Short half-axle (km)	172.18	175.56	175.89	176.65	176.61	176.59	176.90
Long half-axle (km)	288.57	292.36	293.06	293.18	292.93	293.10	293.03
Average shape index	0.597	0.600	0.600	0.603	0.603	0.602	0.604
Elliptical area ratio	1.000	1.033	1.004	1.005	0.999	1.000	1.002

Note: the average ellipse shape index is the ratio of the short semi-axis to the long semi-axis. The ellipse area ratio for the current period is the ratio of the ellipse area for the current period to the ellipse area for 1999, which is the base period for ellipse area. Therefore, the ratio of elliptical area in 1999 is 1.

in the Yangtze River Delta region moves in the range of 119.02°E ~119.25°E and 31.27°N ~31.46°N at the characteristic time points 11. Compared with the geometric center of the Yangtze River Delta region (119.14°E, 31.36°N, located in Gaochun District, Nanjing), the digital finance inclusive center shifts to the southeast, indicating that the volume of digital finance inclusive is higher in the eastern and southern municipal scales of the Yangtze River Delta region than in the northern and western regions. Looking at the trajectory and distance of movement of the overall center of gravity of digital finance inclusive distribution in the Yangtze River Delta region, the center of gravity of digital finance inclusive in the Yangtze River Delta region moves from Changzhou City to Nanjing City in 2011–2020. The center of gravity moved to the northwest 29.94 kilometers, the distance and speed of movement reached the maximum value of 18.63 kilometers and 9.32 kilometers/year, respectively. From 2013 to 2015, the distance and speed of movement of the center of gravity of the distribution decreased to 5.70 kilometers and 2.85 kilometers/year significantly, indicating that the spatial distribution of digital finance inclusive in the Yangtze River Delta region gradually stabilized. The digital finance inclusive's gravity center in the Yangtze River Delta region shifts to the northwest year by year. It may be because areas such as northern Jiangsu Province and Hefei City in Anhui Province have developed relatively fast in recent years by undertaking industrial transfer, and the growth rate of digital finance inclusive. The growth rate of digital finance inclusive in the western region is higher than that in the east because of Hefei City as the second comprehensive national science center in China. The establishment of "Science Island," in particular, has provided good technical support for industry gatherings. The establishment of new-generation information technology, automobile, and intelligent

Table 2: Decomposition method of Theil index.

Year	Overall difference	Interprovincial difference	Intraprovincial difference	Jingsu	Zhejiang	Anhui
2011	1.5702	0.6485	0.9217	1.0538	0.2087	2.7829
2012	1.3641	0.6803	0.6838	0.7211	0.3219	0.9662
2013	0.8868	0.4237	0.4631	0.5540	0.1831	0.5006
2014	0.6059	0.3595	0.2464	0.4774	0.1433	0.4218
2015	0.5076	0.2509	0.2567	0.3336	0.1076	0.2874
2016	0.3227	0.1475	0.1752	0.1445	0.0863	0.1981
2017	0.3055	0.1297	0.1758	0.1333	0.1058	0.1449
2018	0.3221	0.1317	0.1904	0.1374	0.0940	0.1557
2019	0.3185	0.1318	0.1867	0.1303	0.0966	0.1609
2020	0.2751	0.1187	0.1564	0.1140	0.0922	0.1439

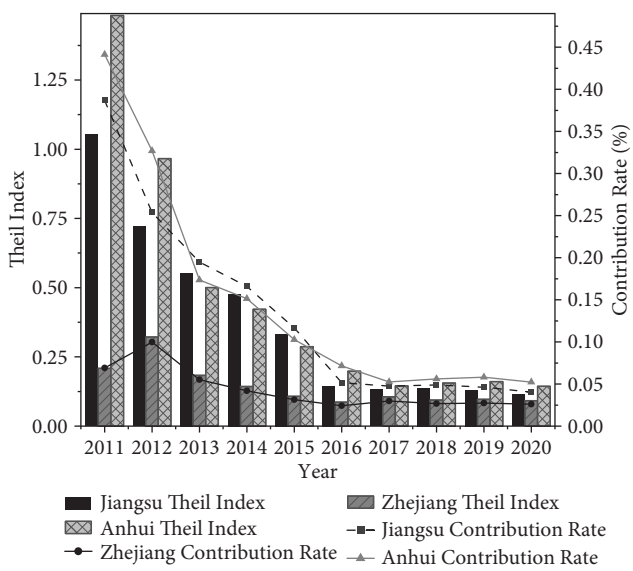


Figure 4: Inequality decomposition by Theil index.

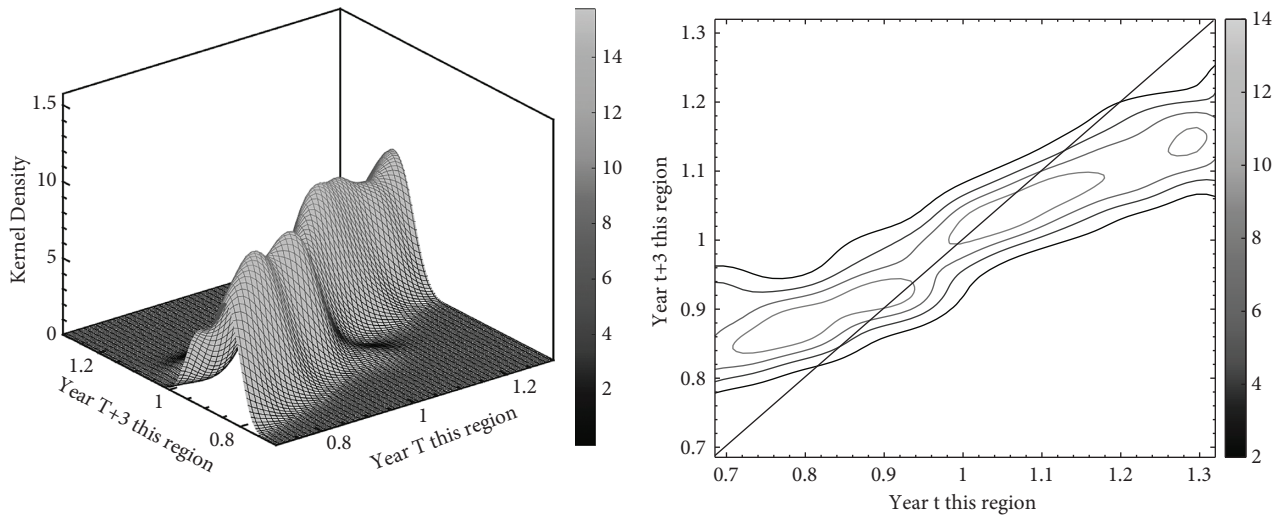
network-connected automobile industry clusters, home appliances, intelligent home, high-end equipment manufacturing, energy conservation, environmental protection, photovoltaic, and new energy industries has enabled Hefei to develop digital finance inclusive faster than the eastern region. Overall, the spatial center of gravity of digital finance inclusive in the Yangtze River Delta region shows characteristics of moving to the northwest, with the growth rate of digital finance inclusive in the northern region slightly higher than that in the southern region, and the growth rate in the western region slightly higher than that in the eastern region.

The long and short semiaxes of the standard deviation ellipse represent the degree of spatial dispersion and the range of spatial distribution of the amount of digital finance inclusive, respectively. The more significant the difference between the two (the more considerable the variability of the ellipse), the more significant the directionality of digital finance inclusive, and the shorter the short semiaxis, the stronger the centripetal force of digital finance inclusive in the Yangtze River Delta region. As shown in the table, the long semiaxis of the digital finance inclusive ellipse in the Yangtze River Delta region increases by 14.46 km and the short semiaxis increases by 4.72 km, indicating that digital finance inclusive in the Yangtze River Delta region shows a slight trend of spatial diffusion. The average shape index gradually increases from 0.597 to 0.604. The elliptical shape gradually approaches the positive circle, indicating that the trend of digital finance in the Yangtze River Delta region tends to disperse. The θ trend of digital finance inclusive in the Yangtze River Delta region is decreasing, from 42.871° in 2011 to 140.73° in 2020. The distribution direction shows a 'southeast-northwest' trend, indicating that the pattern of digital finance inclusive in the Yangtze River Delta region is changing, with the northwest (such as Hefei City) and southeast (Taizhou City, Wenzhou City). The southwest (Taizhou City, Wenzhou City, etc.) is changing. The digital finance inclusive in the northwest (such as Hefei City) and southeast (Taizhou City and Wenzhou City) has a balanced development trend.

3.3. Spatial Difference Decomposition. The interprovincial differences and intraprovincial-level administrative differences of digital finance inclusive in the Yangtze River Delta region are calculated by the nested decomposition method of the Theil index. As shown in Table 2 and Figure 4, the overall difference of interprovincial digital finance inclusive in the Yangtze River Delta region shows a gradual decline from 2011 to 2020, with the Theil index decreasing from 1.35 in 2011 to 0.12 in 2020. The interprovincial difference of digital finance inclusive within provincial-level administrative regions in the Yangtze River Delta region gradually decreases, and the contribution of intraprovincial difference to the overall difference of digital finance inclusive in the Yangtze River Delta as a whole decreases year by year, from 112.61% to 9.21%.

4. The Evolution of the Dynamic Distribution of Digital Finance Inclusive

The previous section focuses on the impact of the differences in digital finance inclusive at each scale of the Yangtze River Delta overall. This section uses the Kernel density method to portray the dynamic evolutionary trend of digital finance inclusive in the Yangtze River Delta. First, the unconditional Kernel density estimation method is used to study the dynamic evolution of digital finance inclusive at the local and municipal scales in the Yangtze River Delta over three years. The spatially conditional static Kernel density estimation is



(a) (b)

Figure 5: Unconditional Kernel density map and density contour map.

used to examine the impact of neighboring regions on local digital finance inclusive under static conditions; finally, the spatially conditional dynamic Kernel density estimation is used to introduce a time factor into the model and classify neighboring regions into two types: high-level digital finance inclusive. Finally, we use dynamic Kernel density estimation with spatial conditions, introduce the time factor in the model, and classify the neighboring regions into two types of high-level digital inclusion and low-level digital inclusion to reveal the dynamic evolution law of the influence of neighboring regions on local digital inclusion under different levels of digital inclusion.

4.1. Unconditional Kernel Density Estimation for Digital Finance Inclusive in Yangtze River Delta. The two subplots on the left side of Figure 5 represent the unconditional Kernel density and density contours of digital inclusion in the Yangtze River Delta region from 2011 to 2020. The x-axis is the digital inclusion in the region in year t, and the y-axis is the digital inclusion in year $t+3$. The Z axis perpendicular to the $X-Y$ plane represents the Kernel density of digital inclusion, i.e., the probability (x, y) density of points. In the contour plot of unconditional Kernel density, the probability decreases with the contour line from inside to outside. Its density represents the degree of convergence of digital finance inclusive in the Yangtze River Delta region, and the denser indicates a stronger convergence trend. If it is concentrated near the positive 45°line, it means the level of digital finance inclusive in this region in year $t+3$ is the same as that in period t, and there is no substantial change. If it is near a value on the Y-axis and parallel to the *x-axis*, all regional digital finance inclusive in the YRD converges to a certain level in year $t+3$. From Figure 5, it can be found that the digital finance inclusive in the Yangtze River Delta can be divided into two interval characteristics when the digital finance inclusive in the region in year t is higher than 0.8 and less than 1.2. The nuclear density contour is mainly distributed in the 45° diagonal position, indicating that the digital finance inclusive in the Yangtze River Delta regional unit gradually increases from year t to $t+3$. When the digital finance inclusive in the region in year t is higher than 1.2, the nuclear density contour is mainly distributed in the 45° diagonal below parallel to the *x-axis*, and the digital finance inclusive in year $t+3$ mainly shifts to about 1.2 to 1.3. Digital finance, inclusive of the Yangtze River Delta regional unit, shows a noticeable convergence trend. This conclusion is consistent with the above comparative analysis of digital finance inclusive in the Yangtze River Delta space.

4.2. Static Kernel Density Estimation under Spatial Conditions. In order to determine whether there is a spatial effect of digital finance inclusive in the Yangtze River Delta, static Kernel density estimation under spatial conditions is applied to explore the convergence pattern of digital finance inclusive in the Yangtze River Delta. As Figure 6 shows, the static Kernel density and density contours under the spatial conditions of digital finance inclusive in 2011 to 2020, the *x-axis* is the digital finance inclusive of the neighboring region in year t, and the Y-axis is the digital finance inclusive of the region in year t. If the region with high digital finance inclusive is adjacent to the region with high level and low digital finance inclusive is adjacent to the region with low level, the probability density in the figure will be concentrated near the 45° diagonal. They indicated an apparent spatial effect of digital finance inclusive in the Yangtze River Delta.

According to the static Kernel density and density contour maps under spatial conditions, it can be seen that the Kernel density contours show a positive 45° diagonal as well as a downward trend distribution, and the overall can be divided into three aggregation clusters. Digital finance inclusive is divided into low, medium, and high digital finance inclusive levels according to an interval. When the digital

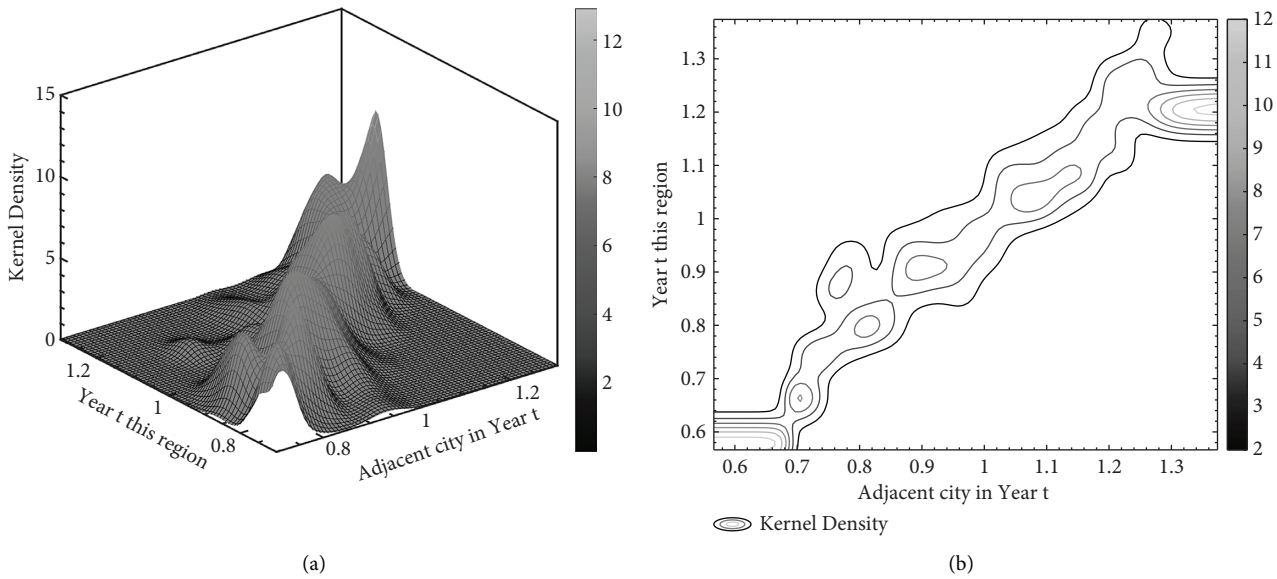


Figure 6: Static Kernel density map and density contour map.

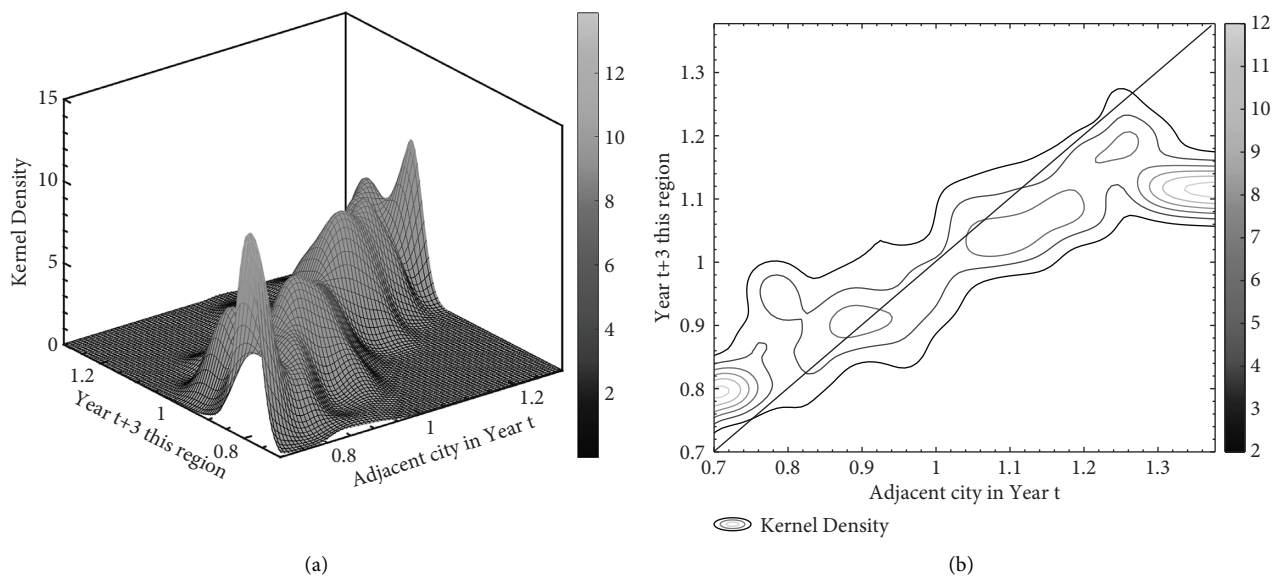


Figure 7: Dynamic Kernel density map and density contour map.

finance inclusive in neighboring counties is medium level in year t, there is an obvious positive spatial correlation of digital finance inclusive between regions. The density contour is near the positive 45° diagonal, showing a "medium-middle" digital finance inclusive spatial agglomeration trend. When the digital finance inclusive of neighboring regions is at low and high levels in year t, the contour of nuclear density is distributed below the positive 45° diagonal. The digital finance inclusive of this region grows more slowly with the increase of digital finance inclusive of neighboring regions, and the spatial effect at this time is relatively weaker and much smaller than that of the medium-level stage. Combined with the spatial distribution of digital finance inclusive in the Yangtze River Delta region, digital finance inclusive in the central Yangtze River Delta is generally in the medium level stage. The positive spatial correlation between digital finance inclusive in the region is significant, making digital finance inclusive in the region subject to the potential impact of neighboring regions in the middle.

4.3. Dynamic Kernel Density Estimation under Spatial Conditions. The impact of neighboring regions in the Yangtze River Delta region on digital inclusion finance in the region is further examined by adding the period factor based on the spatial static Kernel density estimation. The *x-axis* in the figure is the digital inclusion finance of neighboring regions in year t, i.e., the spatial lag term of digital inclusion finance in the region, and the Y-axis is the level of digital inclusion finance in the region in year $t+3$. As shown in Figure 7, in the low-level spatial lag term, the dynamic

Kernel density is distributed near the positive 45° diagonal and shifted above the 45° diagonal, which indicates that adjacent to the region with a low digital inclusion level, the digital inclusion in this region tends to shift upward. In the medium-level spatial lag term, the dynamic Kernel density is distributed near the positive 45° diagonal, which is adjacent to the high-level digital financial inclusion. The graph under the high-level digital finance inclusive spatial lag term is located below the positive 45° diagonal and parallel to the *x-axis*, which indicates that when the level of digital finance inclusive in a particular region rises to a certain degree and does not reach a high level. Even if it is adjacent to a high-level region, the amount of digital finance inclusive not only does not rise accordingly but also tends to shift downward. Figure 7 shows that the spatial effect of digital finance inclusive among the Yangtze River Delta regions has continuity, and the digital finance inclusive level of this region in year t not only has a spatial relationship with the digital finance inclusive level of the neighboring regions in year t but also with the neighboring regions in a lag of three periods. Specifically, under the conditions of spatial and temporal span, the digital finance inclusive of each region in the Yangtze River Delta will be influenced by the digital finance inclusive level of the neighboring regions and the region of a certain level of digital finance inclusive in year $t+3$ tends to converge to a specific intermediate level.

5. Conclusions and Recommendations

This paper examines the spatial distribution, spatial differences, and dynamic evolution of digital finance inclusive in the Yangtze River Delta region employing standard deviation ellipse, nested two-stage Theil index, and Kernel density estimation, based on the current situation of digital finance inclusive development in the Yangtze River Delta city cluster at the city scale. The results show that first, the overall trend of digital inclusive finance continued to rise from 2011 to 2020, and although it tends to level off and show an overall convergence trend after 2014, it still grows at a rate of about 10% per year, and the Yangtze River Delta is still in a period of opportunity for digital inclusive finance. The spatial differences in the development of digital inclusive finance in the Yangtze River Delta economic cluster mainly stem from interprovincial disparities. Both interprovincial spatial disparity and intraprovincial spatial disparity are the main causes of the overall spatial disparity in the short term. Secondly, in terms of spatial distribution, digital inclusive finance in the Yangtze River Delta has a distribution pattern of high in the east and low in the west, high in the south and low in the north, with the center of gravity of distribution gradually shifting to the northwest, with the growth rate of digital inclusive finance in the northern region slightly higher than that in the southern region, and the growth rate in the western region slightly higher than that in the southern region. The reason for this may be that areas such as the northwestern Yangtze River Delta, such as Hefei City, have developed relatively quickly in recent years by undertaking industrial transfer, and the growth rate of digital inclusive finance is significantly higher than that of the eastern region, which has many national research and development institutions and higher education institutions, providing good technical support for the development of the digital economy. The creation of industrial clusters for new-generation information technology, automotive and smart-net-connected vehicles, home appliances and smart homes, high-end equipment manufacturing, energy conservation and environmental protection, photovoltaics, and new energy has made the development of digital inclusive finance in the northwestern Yangtze River Delta faster than that in the eastern region. Third, in terms of spatial differences, the overall difference in digital finance inclusive between provinces in the Yangtze River Delta region shows a gradual decline from 1.35 in 2011 to 0.12 in 2020. The interprovincial difference in digital finance, inclusive within provincial administrative regions in the Yangtze River Delta region, gradually decreases. The contribution rate of provinces to the overall difference in digital finance inclusive in the Yangtze River Delta decreases year by year, from 112.61 percent to 9.21 percent. In terms of spatial and temporal evolution trends, the spatial distribution of internal differences and impacts of digital finance inclusive in the Yangtze River Delta counties is relatively stable, showing a Central > South > North pattern. Fourth, in terms of the dynamic evolution of the distribution, the unconditional Kernel density estimation results indicate that digital finance inclusive in the counties of the Yangtze River Delta will still show a trend of increasing year by year in the future period. The results of static and dynamic Kernel density estimation under spatial conditions illustrate that the spatial effect of digital finance inclusive among the Yangtze River Delta regions has continuity, and the positive spatial correlation of digital finance inclusive among regions is significant, making digital finance inclusive in this region among the potential shocks from neighboring regions. Considering the spatial factor in the short term, the level of digital finance inclusive in each region still overgrows, and with or without the spatial lag term, the level of digital finance inclusive in each region of the Yangtze River Delta shows a leapfrog increase.

From a comprehensive perspective, digital finance inclusive in the Yangtze River Delta region is still growing, and there are apparent spatial differences and spatial correlation effects on the geospatial scale. Therefore, it is necessary to combine the spatial characteristics of digital finance inclusive in the Yangtze River Delta to formulate specific policies and prevent the simple adoption of a "one-size-fits-all" approach. Based on this, this paper puts forward the following suggestions: On the one hand, to promote the balanced development of financial services through the synergistic development of digital finance in urban clusters. The gap between the development of inclusive finance in the Yangtze River Delta urban agglomerations has been narrowing and showing convergence characteristics, which provides the possibility for urban agglomerations with relatively backward economies to achieve the catch-up development of inclusive finance. By vigorously developing inclusive digital finance, lagging regions can enable low- and middle-income people to access financial services more

efficiently and alleviate the region's financial services imbalance. At the same time, the government should speed up the interconnection of financial infrastructures between city clusters and cities within city clusters. It should also encourage the synergistic development of digital finance in city clusters by using the radiation effect and driving effect of the interconnection of financial infrastructures to fix the imbalance of financial services between regions.

On the other hand, the central and eastern Yangtze River Delta regions should fully exploit their comparative advantages. It takes advantage of cloud computing, big data, and other technologies and capital. Deepening financial supply-side reform and continuously optimizing the financial market, organization, and protection system, paying more attention to "quality" improvement, financial structure optimization, service environment improvement, and actively exploring convergence with international development to promote high-quality development of digital finance inclusive. To promote the high-quality development of digital finance inclusive, including radiating better and driving the northern and western regions, the northern and western regions should speed up to make up for the shortcomings in the development of digital finance inclusive, solidify the foundation for development and improve the overall development level of the region while narrowing the development differences within the region. In addition, the government should accelerate the pace of financial infrastructure construction, enhance financial agglomeration and digital technology application capabilities, promote the deep integration of traditional financial services with digital technology, and continuously innovate products and services, extending the reach and scope of financial services opens up the "last mile" of financial services and meets the diversified financial needs of the public.

Data Availability

The data used to support the findings of this study are included within the Pratt &Whitney financial index of Peking University (PKU-DFIIC) (https://idf.pku.edu.cn/zsbz/index.htm).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the projects of Social Science Foundation for Youths of Liaoning Province (Grant no. L20CJY001), Science and Technology Plan Projects in Liaoning Province Soft Science Research Plan (Grant no. 2021JH4/10100074), and 2022 Wenzhou Philosophy and Social Science Planning Subjects (Grant no. 22wsk057).

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