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Article

The Temporal and Spatial Evolution of Digital Inclusive Finance and Its Boosting Effect on Rural Revitalization in China

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Abstract: Using the 2011-2020 digital inclusive finance data released by Peking University and the index system constructed by the Blue Book of China Rural Revitalization and Development Index (2018), this paper analyzes the dynamic evolution of the digital inclusive finance and the rural revitalization from time and space dimensions with the help of kernel density estimation, Markov chain and Moran index. Using The Gini coefficient decomposition method to analyze the source of differences in digital inclusive finance, and then using the spatial autoregressive (SAR) model and geographically weighted regression (GWR) model to study the boosting effect of digital inclusive finance on rural revitalization from the perspective of spatial aggregation and spatial differentiation, respectively. The results show that: (1) The growth rate of China's digital inclusive finance slows down year by year, and the inter-provincial differences increase year by year and show gradient characteristics, indicating that there may be a trend of multipolar differentiation. The overall level of Rural Revitalization shows an increasing trend, and the gap between provinces is still apparent. (2) The evolution of digital inclusive finance and rural revitalization is a slow adjustment process, and there has been no cross-level jump in the past ten years. In digital inclusive finance, the liquidity from the highest and lowest levels to the medium level is high. However, the liquidity in the states of rural revitalization development level is not high. (3) Rural revitalization has a positive spatial spillover effect. The level of rural revitalization in the western area is significantly lower than in the eastern area. At the same time, there is no significant difference between the east and central areas. The depth of the use of digital inclusive finance has a significant positive impact on the revitalization and development of rural areas, indicating that the further promotion of digital inclusive finance business in rural areas can substantially boost the revitalization of rural areas. (4) The boosting effect of digital inclusive finance on rural revitalization shows prominent spatial differentiation characteristics. The depth of use and the degree of digitization generally show a positive impact. The central and eastern coastal cities have the highest impact, decreasing toward the southwest and northeast. The areas with the lowest usage depth impact are clustered in the northeast, and the areas with the lowest digitization impact are clustered in the southwest.

Keywords: digital inclusive finance; rural revitalization; spatio-temporal evolution; Gini coefficient; GWR model

1. Introduction

The Sixth Plenary Session of the 19th CPC Central Committee proposed to promote common prosperity through high-quality development. Implementing rural revitalization is a vital grasp to narrow the gap between urban and rural areas and promote common prosperity. Industrial revitalization is one of the essential aspects of rural revitalization, and industrial development requires a constant flow of capital investment. The inclusive feature of digital finance can better match the demand for small and medium-sized enterprises and disadvantaged groups in rural areas for small capital loans and realize the advantage of benefiting a wide range of targets. With the support of policy documents, it

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is of great value to study digital inclusive finance to help rural revitalization. Using python software to crawl the texts of policy documents related to digital inclusive finance and rural revitalization in different years to extract keywords shows that: the policy focus in 2018 is on using information technology to promote rural revitalization and making farmers feel the convenience of digital inclusive finance through products; more comprehensive digital inclusive finance policies related to credit and other policies are introduced in 2019, making words such as data privacy and creditworthiness push to the hot topic; The policy focus in 2020 falls on digital technology, with big data and artificial intelligence as the center to help rural revitalization.

The concept of digital inclusive finance, first introduced by the United Nations in 2005, has lasted for dozens of years and has been allowed to play a broader role with the addition of digital technology today. On the one hand, in existing studies, digital inclusive finance is defined as using digital technology to widely and effectively provide financial services to all segments of society at a lower cost [1]. It can significantly narrow the urban-rural income gap, promote residents' consumption, alleviate corporate financing constraints and thus promote economic development [2-4]. On the other hand, according to the evaluation system constructed under the guidance of the Blue Book on Rural Revitalization Index, the level of rural revitalization is measured from five systems: prosperous rural industry, ecological livability, civilized rural style, effective governance, and affluent living [5,6]. Precise poverty alleviation, cultivation of rural talents, reform of the rural land system, and optimization of the spatial pattern of "three lives" in rural areas are effective ways of rural revitalization [7-10]. Spatial and temporal distribution patterns, spatial and temporal evolution, and spatial and temporal differences are the mainstream of current geographical research [11-14]. In the studies related to digital inclusive finance for rural revitalization, some scholars have studied the spatial dynamic distribution and the evolution process of digital inclusive finance in China from a geographical perspective [15-18]. Still, such studies lack the study of the problem of the source of distribution differences. Some scholars also constructed an index system to measure the rural revitalization index, used statistical models to find the causes of poverty, and proposed opinions on rural revitalization strategies [19]. Some scholars choose digital inclusive finance and other related indicators to build panel regression models to explore their effects on rural revitalization [20] or use the depth of digital inclusive finance use as a threshold to study its impact on rural revitalization, and none of these studies consider spatial effects. Among the few studies that consider spatial correlation, the consideration of regional differentiation is missing [21]. Rural revitalization, as the critical content of the “Three Rural” work, has been influenced by factors such as the introduction of listed companies [22] and has also been affected by the factors of rural digital inclusive finance. So how has the spatial and temporal pattern of digital financial inclusion and rural revitalization changed in the past ten years? What are the spatial and regional influencing factors of rural revitalization? What is the effect of digital inclusive finance in boosting rural revitalization? This is the primary concern of this study.

Different from existing studies, this paper links digital inclusive finance with rural revitalization from a spatial and temporal perspective and explores the following three aspects: first, with the help of kernel density estimation, Moran index, and Markov chain method, we explore the spatial distribution pattern and dynamic evolution path of digital inclusive finance and rural revitalization index from the temporal and spatial dimensions. Second, with the help of the Gini coefficient decomposition method, we explore the differences in digital inclusive finance development in three areas of China, namely, East, Central, and West, and find out the sources of their differences. Third, a spatial panel econometric model is constructed by introducing area factors to study the boosting effect of digital inclusive finance on rural revitalization from the perspective of spatial aggregation. Further, a geographically weighted regression model is used to study the impact effect of digital inclusive finance on rural revitalization from the perspective of spatial

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differentiation. It is hoped that the findings of this paper can provide an essential theoretical foundation and basis for how to make full use of digital inclusive finance to realize the comprehensive and balanced development of rural revitalization in the future to enhance the common prosperity of the countryside..

2. Materials and Methods

2.1. Data source

This paper is based on all provinces and autonomous areas in China. Due to the lack of data in the Tibet Autonomous Area, the research area covers a total of 30 provinces, cities, and the autonomous regions (excluding Hong Kong, Macao, and Taiwan). The digital inclusive finance data required in this paper are obtained from the Digital Inclusive Finance Index published by the Digital Finance Research Center of Peking University in 2021. The rural revitalization index refers to the Blue Book of China Rural Revitalization Development Index (2018) released by the State Council, constructing the relevant index system for measurement, in which the index data are obtained from the China Urban Statistical Yearbook, statistical bulletins on the national economic and social development of various areas, Wind database, and CCER rural economy database. The geographic information base data were obtained from the standard map service website of the Map Technical Review Center of the Ministry of Natural Resources.

2.2. Construction of Indicator System of Digital Inclusive Finance for Rural Revitalization

2.2.1. Digital Inclusive Finance

This paper selects the Digital Inclusive Finance Index published by the Digital Finance Research Center of Peking University in 2021. To reflect the comprehensiveness of the digital inclusive finance index, this paper selects digital inclusive finance from three perspectives: horizontal, vertical, and cross-sectional. Digital inclusive finance is measured in terms of breadth of coverage (DIF1), depth of use (DIF2), and degree of digitization (DIF3). The range of coverage and depth of use measure digital financial inclusion's penetration in rural areas from horizontal and vertical perspectives. The degree of digitalization measures the level of digital development in rural areas from a cross-sectional and comprehensive view. Table 1 reports the mean and standard deviation of the total digital inclusion indicators and the three significant indicators selected in this study.

Table 1. Digital Financial Inclusion Indicator System

Indicators	Indicator Meaning	Average value	Standard deviation
Total Index Breadth of coverage Depth of use	The comprehensive development level of digital financial inclusion in the region	216.235	60.440
Degree of digitization Total Index	The penetration breadth of regional digital financial inclusion	196.670	49.102
Breadth of coverage Depth of use Total Index	The penetration depth of regional digital financial inclusion	211.121	55.493
Breadth of coverage	Measuring the comprehensive digital development level of the area	290.142	51.989

2.2.2. Rural revitalization

In this paper, the rural revitalization index system is constructed under the guidance of the Blue Book of China Rural Revitalization Development Index (2018-2022). Under existing studies, rural revitalization is measured through five dimensions: prosperous rural industry, ecological livability, civilized rural style, effective governance, and affluent

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Table 2. Rural revitalization index system.

Dimensionality	Indicators	Indicator meaning (unit)	Weights
Prosperous rural industry	The integrated capacity of food production	Total weight of food produced per 10,000 people per year (million tons)	0.0541
	The contribution rate of agricultural science and technology progress	Amount of contribution of agricultural scientific and technological advancement to the growth rate of agricultural production (%)	0.0963
	Effective irrigated area	Per capita mechanized irrigated farmland area (mu)	0.0219
	Agricultural products processing capacity	Agricultural product sales value etc. accounted for the proportion of the output value of the primary industry (%)	0.1507
Ecological livability	Natural Ecological Livability	Rural forest vegetation cover (%)	0.0112
	Eco-friendly living for villagers	Rural toilet renovation rate (%)	0.1104
	Ecological livability of the countryside	Percentage of the number of rural health technicians (%)	0.0454
Civilized rural style	Farmers' literacy	The average number of years of education for rural residents (years)	0.0039
	Cultural and entertainment consumption	Per capita recreational consumption expenditure of rural residents (yuan/person)	0.0416
	Accessibility to recreational facilities	The average number of township recreation sites in villages (each/town)	0.0165
Effective governance	Village planning and management coverage	The proportion of village built-up area to the total village area (%)	0.0520
	Engel coefficient of rural residents	Mean value of Engel's coefficient for rural residents (%)	0.0520
	Per capita disposable income of farm households	Per capita disposable income of rural residents (yuan)	0.0596
Affluent living	Income level of rural residents	Per capita net income of rural residents (yuan/person)	0.2058
	Income structure of rural residents	Share of wage income in total income (%)	0.1118
	Quality of life of rural residents	Effective housing area per capita of rural residents (square meters/person)	0.0187

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living (Table 2). The rural revitalization value of each province is calculated through the entropy weight method [19]. Table 2 gives the selected indicators under different dimensions, the meanings, and the weights, calculated for each indicator under the entropy weighting method.

2.3. Research methods

Li and Ma (2021) studied the specific path of digital inclusive finance to help rural revitalization [6]. The study showed that digital inclusive finance has a noticeable driving effect on rural revitalization. Different from their research methods, this paper firstly analyzes the dynamic temporal evolution of digital inclusive finance and rural revitalization indices in China's provinces and cities from a spatial and temporal perspective by using the Kernel density estimation method, analyzes the changes in the spatial pattern of the two indices with the help of heat map, and analyzes the changes in the horizontal shift of the two indices by Markov chain; then, with the use of global as well as local Moran ' I indices to explore the characteristics of the overall spatial aggregation and cold hotspot areas. With the help of Dagum Gini coefficient decomposition method [23,24], we deeply explore the area differences and the sources of differences in the development of digital inclusive finance in the whole country and the three areas of the East, Central, and West. Finally, a spatial regression model of digital inclusive finance contributing to rural revitalization is introduced to establish a spatial regression model to explore the overall impact of digital inclusive finance on rural revitalization and further explore its impact effects in different provinces from the perspective of spatial differentiation using the GWR model. All the analysis methods in this paper will be introduced below.

2.3.1. Kernel density estimation

As one of the nonparametric estimation methods, the kernel function estimation method can effectively test the dynamic evolution trend of sample distribution. The main functions of kernel function used in this paper are weighting and smooth transformation. Taking Gaussian kernel density as an example for estimation, the main form of kernel function is:

$$f(x)=\frac{1}{\sqrt{2\pi}}\exp(-\frac{x^2}{2}) \tag{1}$$

Generally speaking, from the curve image obtained by kernel density estimation, we can observe the density function, function distribution pattern, function curve extensibility and polarization phenomenon of digital inclusive finance and rural revitalization in China. The density function reflects the level of development, and the distribution form of the function (peak, height and width of the density function) is used to analyze the regional differences. The extensibility of the curve is used to describe the regional difference between the provinces with the highest or lowest development level of digital inclusive finance and other provinces. The longer the extensibility, the greater the difference. The polarization phenomenon refers to the number of peaks, which reflects the degree of polarization.

2.3.2. Dagum Gini coefficient decomposition method

In order to analyze the regional differences and sources of digital inclusive finance in China, this paper adopts Dagum Gini coefficient method. Overall Gini coefficient G is:

$$G=\frac{(\sum_{i=1}^{n}\sum_{r=1}^{n}|y_i-y_r|)}{2n^2\overline{y}}-\frac{\sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}|y_{ji}-y_{hr}|}{2n^2\overline{y}} \tag{2}$$

Among them, j and h denote subscripts of different regions, i and r denote subscripts of 31 provinces, n denotes the total number of provinces, k denotes the total number of

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regional divisions, n_j、n_h denotes the number of provinces in j and h regions, $y_{ji}(y_{hr})$ denotes the development degree of digital inclusive finance in $i(r)$ provinces in $y_{ji}(y_{hr})$ region, and $\overline{y}$ denotes the average development degree of digital inclusive finance in all provinces in China. The subgroup decomposition method of Gini coefficient proposed by Dagum(1997) is as follows: firstly [25], k regions are ranked according to the average development level of digital inclusive finance in each region, assuming that the development level of h region is lower than that of j region, and then Gini coefficient G can be decomposed into three parts, namely G_w, G_{nb}, G_t, the contribution of intra-regional (intra-group) differences to G, the contribution of inter-regional (inter-group) differences to G, and the contribution of inter-regional (inter-group) super-variable density to G. Among them:

$$G_w = \sum_{i=1}^{n_j} G_{jj} P_j S_j \tag{3}$$

$$G_{nb} = \sum_{j=1}^{k} \sum_{h=1}^{j-1} G_{jh} (P_j S_h + P_h S_j) D_{jh} \tag{4}$$

$$G_t = \sum_{j=1}^{k} \sum_{h=1}^{j-1} G_{jh} (P_j S_h + P_h S_j)(1 - D_{jh}) \tag{5}$$

$$P_j = n_j / n, \ \ S_j = n_j \overline{y}_j / (n\overline{y}), \ \ j = 1,2,3...k; \tag{6}$$

$$G_{jj} = \frac{1}{2\overline{y}_j} (\sum_{i=1}^{n_j} \sum_{r=1}^{n_j} \left| y_{ji} - y_{jr} \right|) / n_j^2 \tag{7}$$

$$G_{jh} = (\sum_{i=1}^{n_j} \sum_{r=1}^{n_h} \left| y_{ji} - y_{hr} \right|) / n_j n_h (\overline{y}_j + \overline{y}_h) \tag{8}$$

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \tag{9}$$

$$\begin{aligned} d_{jh} &= \int_0^{\infty} dF_j(y) \int_0^{y} (y - x) dF_h(x) \\ p_{jh} &= \int_0^{\infty} dF_h(y) \int_0^{y} (y - x) dF_j(x) \end{aligned} \tag{10}$$

2.3.3. GWR model

Spatial data exists widely in many fields such as geography, economics, environmental science, ecology and meteorology. According to Tobler's "First Law of Geography", everything is spatially related, and the closer the distance, the greater the spatial correlation between things. Therefore, different from the traditional cross-sectional data, the spatial correlation of spatial data will lead to the spatial nonstationarity (spatial heterogeneity) of the regression relationship. In order to explore the spatial nonstationarity of spatial data, Brunsdon et al. (1996) put forward a geographically weighted regression model for the first time [26].

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$$Y_i = \beta_0(u_i, v_i) + \sum_{j=1}^{p} \beta_j(u_i, v_i) X_{ij} + \varepsilon_i \quad (11)$$

$\beta_j(u,v)(j = 0,1,\cdots,p)$ is a function of spatial geographic location. In R software, RPACAKGE-GW Model can be called to realize the parameter process of geographically weighted regression model.

3. Analysis of the Dynamic Evolution of Digital Inclusive Finance and Rural Revitalization Development

3.1. Time dimension

Figure 1 shows the annual average and median values of the digital inclusive finance index and rural revitalization index for 31 provinces in mainland China from 2011 to 2020. From this, we can see China's rapid development of digital inclusive finance and rural revitalization. Among them, the Digital Inclusive Finance Index has been steadily increasing during the ten years, with an index growth of about 300%, but there is a significant decrease in the growth rate. The rural revitalization index grew by about 60%, and the growth rate declined in 2013, but the growth rate is generally accelerating.

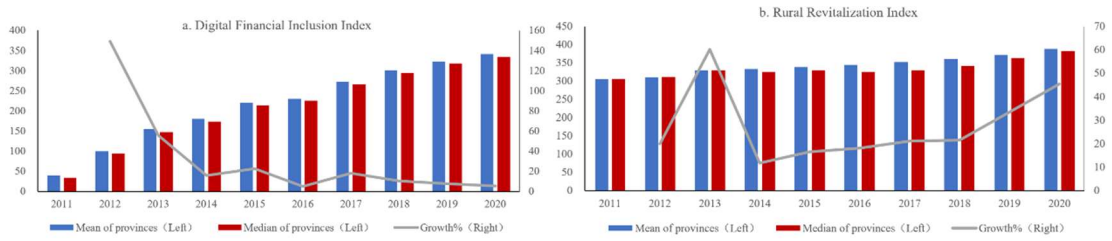

Figure 1. Evolution of Digital Inclusive Finance and Rural Revitalization Index in China, 2011-2020.

The kernel density estimation method is chosen for further analysis to portray the dynamic evolutionary trend of digital inclusive finance and rural revitalization development. From the inter-provincial Kernel density function distribution Figure 2(a), the digital inclusive finance Kernel density curve gradually moves to the right in the distribution position, indicating that the level of inter-provincial digital inclusive finance development in China is continuously improving. In terms of function distribution, the height of the curve shows a decreasing trend from 2017 onward, and the width of the Kernel curve shows a "narrowing-widening" evolutionary trend, from the angle "rightward stagnation," "height drop" and other characteristics. The features of "rightward stagnation" and "height drop" show that the development of digital financial inclusion among provinces in the late stage of the observation range is relatively slow. In terms of function curve extension, compared with 2016, in 2020, the Kernel density function curve will become flatter, and the right tail of the Kernel curve will gradually become longer, indicating that the level of digital inclusive finance developed more rapidly in some provinces, and the inter-provincial gap further increases. In terms of polarization, the density curve shows a "single peak - non-single peak" evolution, indicating a gradient in the development of digital inclusive finance in China, which suggests that the development of digital inclusive finance in China may have a multi-polar polarization phenomenon. Figure 2(b) shows that the dynamic evolution of the national inter-provincial rural revitalization index kernel density is relatively slow. In terms of the shape of the function distribution, the height of the curve only tends to fall significantly from 2018 onward, and the width of the curve expands greatly, reflecting that the differences in inter-provincial development are growing, which is inextricably related to the development of rural revitalization strategy in China in recent

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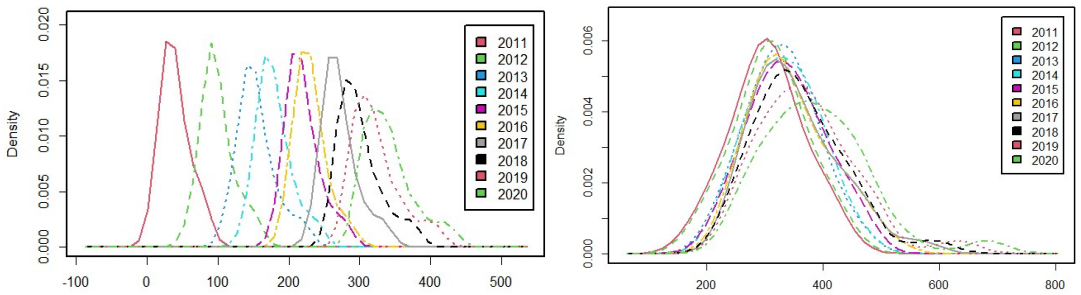
years. In terms of the extension of the function curve, the right tail of the Kernel curve gradually becomes longer in 2020 compared with 2016, indicating that the level of rural revitalization is improving more rapidly in some provinces, and the inter-provincial gap tends to increase. It can be seen that the development of rural revitalization is lower in the early stage of the observed range. Under the strong support of China's rural revitalization strategy, all provinces have accelerated the pace of rural revitalization, but the inter-provincial development gap is thus gradually accentuated.



(**a**) Digital Inclusive Finance (**b**) Rural Revitalization

Figure 2. China's digital inclusive finance and rural revitalization kernel density map, 2011-2020.

3.2. Spatial dimension

Based on the inter-provincial panel data on digital inclusive finance and rural revitalization from 2011 to 2020, and according to the kernel density evolution map at the national level, it can be found that digital inclusive finance and rural revival in China have achieved rapid development during the ten years. However, the degree of development varies among provinces. Taking the last four years as an example, the heat map of the digital inclusive finance index and rural revitalization index is drawn to analyze the differences in area distribution of the two indices, as shown in Figure 3 and Figure 4.

Figure 3 and Figure 4 show the current provincial development status of digital inclusive finance and rural revitalization, respectively. The digital inclusive finance index of the eastern coastal provinces is significantly higher than that of the inland provinces. The northeastern area demonstrates the current development status of digital inclusive finance centered on Beijing, while the western regions such as Qinghai, Tibet, and Gansu have a lower degree of digital inclusive finance development. The development of rural revitalization and the development of digital inclusive finance are similar, again showing that the eastern coastal provinces are better than the inland provinces, and the northeastern area also has Beijing as the center of development. In terms of development evolution, the development of digital inclusive finance and rural revitalization shows a development trend from the coastal area to the central area and finally to the western part, among which Gansu and Ningxia are relatively slow in development.

To further examine the spatial distribution status and structural characteristics of the development level of digital inclusive finance and rural revitalization, the development level is divided into four types [17]; see Table 3.

Table 3. Type Classification

Type	Index means u	Level Indicators
1	$X < 0.75u$	Low level
2	$0.75u \le X < u$	Low to medium level
3	$u \le X < 1.25u$	Medium to high level
4	$X \ge 1.25u$	High level

The Markov transfer probability matrix of the development level of digital financial inclusion is calculated separately.

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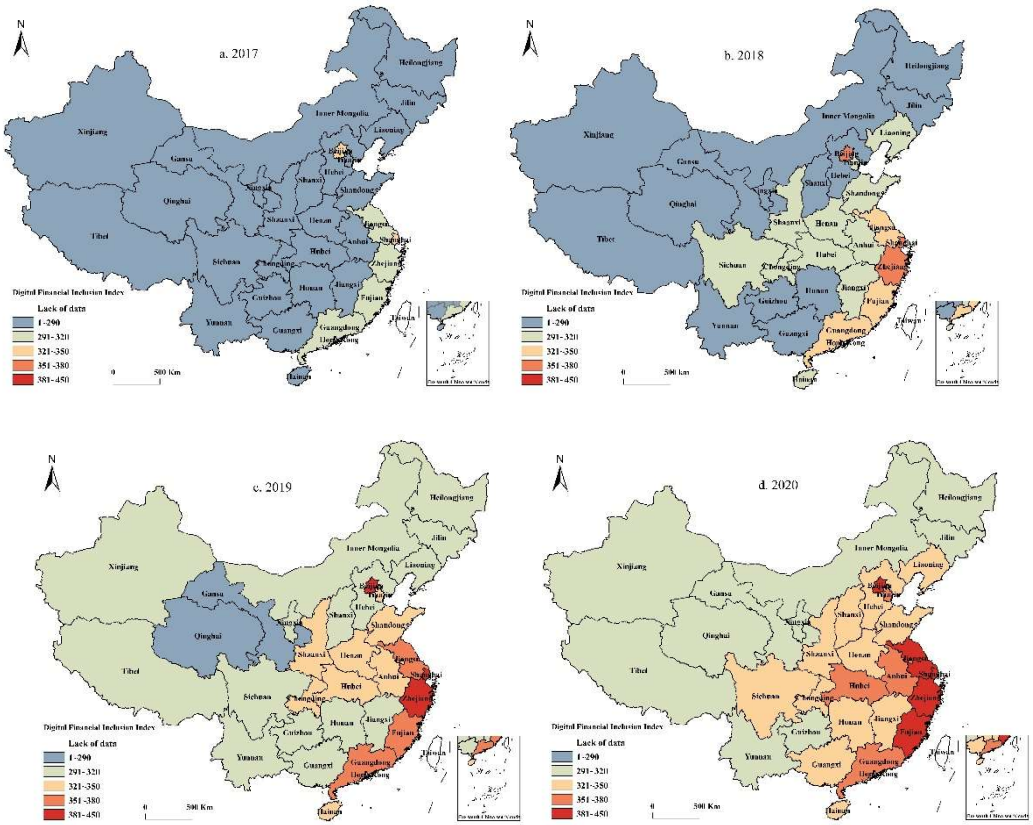

Figure 3. Spatial distribution of China's digital inclusive finance index, 2017-2020.

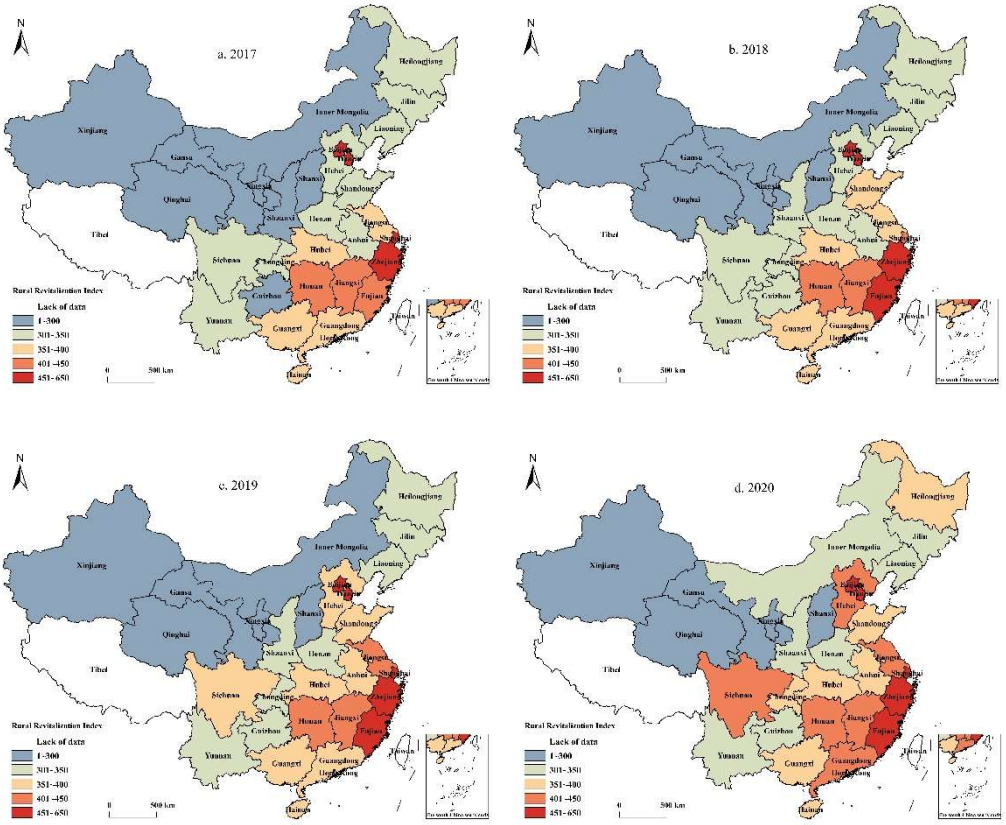

Figure 4. Spatial distribution of China's rural revitalization index, 2017-2020.

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$$\begin{bmatrix} Level & 1 & 2 & 3 & 4 \\ 1 & 0.5722 & 0.4278 & 0 & 0 \\ 2 & 0 & 0.9012 & 0.0988 & 0 \\ 3 & 0 & 0.0548 & 0.9452 & 0 \\ 4 & 0 & 0 & 0.5127 & 0.4873 \end{bmatrix}$$

and the Markov transfer probability matrix of the development level of rural revitalization

$$\begin{bmatrix} Level & 1 & 2 & 3 & 4 \\ 1 & 0.8278 & 0.1722 & 0 & 0 \\ 2 & 0 & 0.8412 & 0.1579 & 0 \\ 3 & 0 & 0 & 0.8568 & 0.1432 \\ 4 & 0 & 0 & 0.4389 & 0.5611 \end{bmatrix}$$

According to the Markov transfer probability matrix, it can be seen that the overall probability of transfer on the diagonal is significantly higher than that on the non-diagonal in terms of rural revitalization during the ten years, indicating that the mobility between the states of rural revitalization development levels is not high, and this is most obvious in the low level, low-middle level, and high-middle level. However, it is worth noting that the probability of a downward shift from high to medium-high level reaches 43.89%. Unlike rural revitalization, in digital inclusive finance, only the likelihood of transfer on the diagonal between low and medium level and medium and high level is dominant. In contrast, the probability of upward shift from low to low and medium level and downward shift from high level to a medium and high class are more significant, indicating that the mobility between the two extremes of digital inclusive finance development levels to adjacent levels is more increased. Neither digital inclusive finance nor rural revitalization development levels show a jump shift across levels. It can be seen that the evolution of the development levels of digital inclusive finance and rural revitalization is a gradual and slow adjustment process.

3.3. Spatial aggregation characteristics

To measure the aggregation of digital financial inclusion indices in each province, the global Moran statistic was calculated in this paper for 2011-2020, and the results are shown in Table 4.

Table 4. Global Moran Statistics for Digital Inclusive Finance in China, 2011-2020.

variables	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
p-value	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.002	0.002
Global Moran	0.491	0.430	0.420	0.521	0.483	0.497	0.502	0.537	0.588	0.600
Z	3.752	3.840	3.826	3.963	4.507	3.624	3.810	3.911	4.011	4.570
Sd	0.113	0.119	0.119	0.114	0.114	0.113	0.119	0.115	0.116	0.114

As shown in Table 4: Since 2011, the digital inclusive finance global Moran index has been significantly positive at the 0.05 level, indicating a significant positive spatial correlation between digital inclusive finance indices in each province of China.

The aggregation effect of the local Moran index of digital inclusive finance is explored by Geoda software to obtain different types of aggregation provinces in 2011, 2014, 2017, and 2020 in China. From Table 5, it can be concluded that: the significant high - high type of aggregation in 2011 is Qinghai, which is the hot spot, i.e., a more balanced development of digital inclusive finance. Gansu was added to the high-high type of aggregation in 2014, and Zhejiang and Shanghai in the Yangtze River Delta area were added in 2020. These areas' periphery shows high local Moran index values of digital inclusive finance. In terms

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of low-low type aggregation, only Hunan and Jiangxi present significant low-low aggregation, i.e., cold spot areas, in 2011, and Anhui and Guangdong around these two provinces do not have high digital inclusive finance index values. 2014 adds Hubei and Guangdong provinces, and Guangdong province exited low-low type aggregation in 2017, and only Guangdong remained in low-low aggregation in 2020. In terms of low-high aggregation, only Jilin and Anhui were in low-high aggregation in 2011, and these two provinces do not have high digital inclusive finance indices. Still, their neighboring provinces have high digital inclusive finance indices, and then from 2014, Anhui exits, leaving only Jilin to present significant low-high aggregation. There are no provinces in China that show effective high-low aggregation.

Table 5. Local aggregation and outliers of digital inclusive finance in China.

Year	High-High (HH)	Low-Low (LL)	Low-High (LH)	High-Low (HL)
2011	Qinghai	Hunan Jiangxi	Jilin Anhui	None
2014	Gansu Qinghai	Hubei Hunan Jiangxi Guangdong	Jilin	None
2017	Gansu Qinghai	Hubei Hunan Jiangxi	Jilin	None
2020	Gansu Qinghai Zhejiang Shanghai	Guangdong	Jilin	None

4. Exploring the Differences in the Development of Digital Inclusive Finance and the Impact of Contributing to Rural Revitalization

The Digital Inclusive Finance Index released by Peking University shows that digital inclusive finance can be divided into three dimensions: depth of use, breadth of coverage, and degree of digitization. The 19th Party Congress proposed that the path of digital inclusive finance to promote rural revitalization is mainly carried out through five aspects: driving industry, improving ecology, civilizing and educating, regulating governance, and increasing income and reducing poverty. The mechanism of digital inclusive finance contributing to rural revitalization is shown in Figure 5. In this chapter, the boosting path of digital inclusive finance contributing to rural revitalization is explored through two aspects of difference source analysis and influence factor analysis. Regarding the sources of differences, the area division standard of China by the National Bureau of Statistics divides China's provinces, cities, and autonomous areas into three major areas: the middle, east, and west. The Gini coefficient decomposition method is used to explore the differences of digital inclusive finance within the middle, east and west areas and among the three areas and to find the sources of their differences. Regarding influencing factors, two perspectives, spatial aggregation and spatial divergence are used to investigate the influencing factors of digital inclusive finance on rural revitalization. In terms of spatial aggregation, dummy variables indicating the central, eastern, and western areas are added to solve the spatial regression model to obtain each variable's influence coefficient and significance degree. A geographically weighted regression model is constructed based on the most recent 2020 data regarding spatial divergence. A 3D surface map of geographical latitude and longitude is drawn to visualize the different degrees of influence of digital inclusive finance on rural revitalization in various provinces and cities.

4.1. Analysis of the sources of differences in digital financial inclusion based on the Gini coefficient decomposition method

There is a global spatial autocorrelation and a local cold-hot effect in digital inclusive finance. To further explore the inter-area differences in digital inclusive finance and their sources, 31 areas are divided into three major areas, namely, East, Central, and West, for comparative analysis concerning the criteria for dividing areas in 2018 by the National Bureau of Statistics. As seen in Table 6, the non-stationary characteristics of digital inclusive finance development in China are significant, and the overall Gini coefficient of the country ranges from 0.046-0.248 (2011-2020).

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Specifically, the average annual decline rate of the overall difference in the development level of digital inclusive finance among provinces nationwide was 52.42% from 2011 to 2012, while the average yearly decline rate was 9.30% from 2013 to 2020. It can be seen that the overall development level of digital inclusive finance evolved at a relatively rapid pace in all provinces of the country before 2013, showing a significant decline, and grad ually tended to develop steadily in the years after that.

The intra-area differences in digital inclusive finance in China are at different levels,

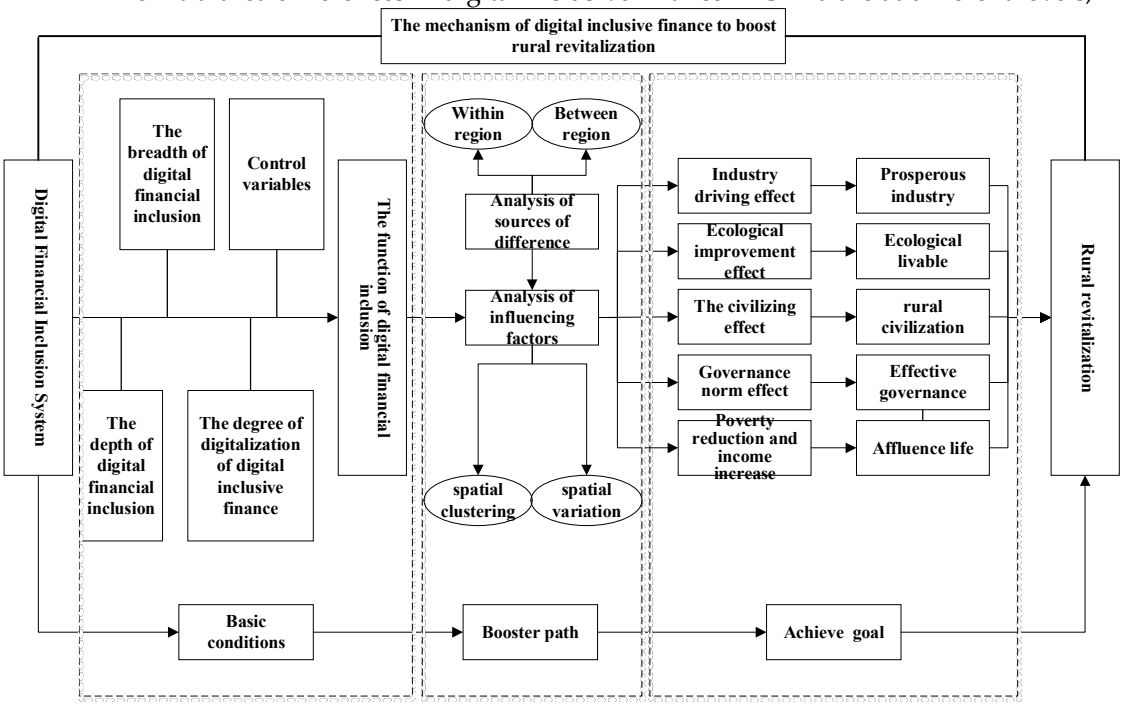

Figure 5. Mechanism of digital inclusive finance to promote rural revitalization.

and the fluctuation pattern is roughly the same as that of the whole country. Through horizontal comparison, the Gini coefficients of the central and western areas are still lower than the overall national level from 2015. Still, the intra-area differences in digital financial inclusion in the eastern part have been on par with the national differences. A longitudinal comparison shows that the Gini coefficients of the eastern, central, and western areas have decreased by 11.24%, 9.13%, and 20.40%, respectively, annually. This shows that the west area has the most significant decrease, and the difference in the development of digital inclusive finance in the western area is more significant, which may be due to the general influence of factors such as traditional finance and the level of area economic development. However, with the innovation and application of digital technology, digital finance no longer relies on traditional financial infrastructure and physical channels, and the inter-provincial gap in the western area is gradually narrowing.

Figure 6b illustrates the evolutionary trend of inter-provincial digital inclusion financial development differences between areas. Overall, the differences between areas show a general downward trend. Digital inclusive finance has the most significant difference in the East-West area, with the curve consistently higher than in the East-Central and Central-West areas. The economic development difference between the East and West areas is the most obvious. But the gap between the East-West areas has narrowed considerably. Therefore, the differences between the three major areas, East-Central, Central-West, and East-West, are gradually narrowing at the macro level. The development of digital inclusive finance between areas shows a convergence.

From Figure 7a, we can find that inter-area differences contribute the most to digital inclusion, between 0.032 and 0.180. The between-area variation fluctuates up and down

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Table 6. Area Gini coefficient of digital inclusive finance in China

Year	Overall GT	Intra-area variation			Inter-area disparities		
		East	Middle	West	East - Central	East-West	Central-West
2011	0.248	0.155	0.071	0.187	0.302	0.366	0.157
2012	0.118	0.093	0.032	0.079	0.143	0.182	0.067
2013	0.089	0.074	0.027	0.056	0.107	0.138	0.050
2014	0.069	0.064	0.024	0.040	0.084	0.105	0.038
2015	0.055	0.052	0.014	0.029	0.075	0.084	0.025
2016	0.048	0.048	0.016	0.029	0.058	0.074	0.029
2017	0.046	0.047	0.019	0.023	0.056	0.071	0.026
2018	0.052	0.051	0.027	0.024	0.064	0.080	0.031
2019	0.054	0.053	0.030	0.024	0.066	0.082	0.033
2020	0.054	0.053	0.030	0.025	0.064	0.082	0.034

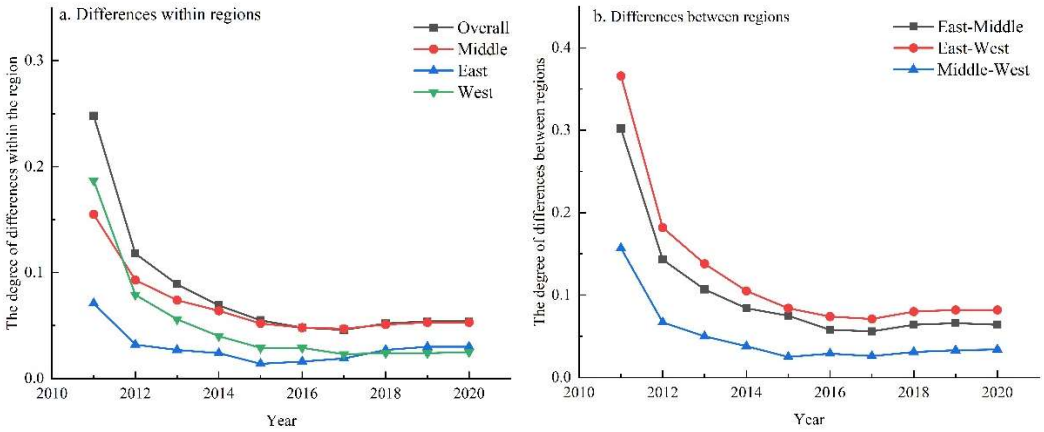

Figure 6. Area Gini coefficients.

during the study period but has an overall increasing trend. Intra-area variation has the second-highest contribution, between 0.011 and 0.052, and the contribution varies more minor over the study period, although there is an overall increasing trend. The contribution of hyper-variance density is the smallest, ranging from 0.003 to 0.016, and the contrbution rate remains between 4.65% and 8.69% from 2010 to 2020. In summary, the average annual growth of the contribution of intra-area, inter-area, and hypervariable density to the development level of digital inclusive finance is 1.2%, 0.61%, and 2.4%, respectively, which indicates that the impact of inter-area inter-provincial development on the development of digital inclusive finance is weakening. The contribution of intra-area and hy-pervariable density to the fluctuation is increasing, which means that the overlapping problems caused by intra-area and hypervariable density on the digital inclusive finance development level are gradually increasing. It reflects the existence of spatial correlation of digital inclusive finance.

4.2. Exploring the impact of digital inclusive finance on rural revitalization from the perspective of area agglomeration

From the analysis of the sources of digital inclusion financial differences above, it is clear that the contribution of inter-area differences is the largest. Therefore, we first focus on the impact of digital inclusive finance on rural revitalization from the perspective of

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area aggregation. Three significant variables are selected: breadth of coverage, depth of use, and digitalization of digital inclusive finance. In addition, the level of the rural

Table 7. Area Gini coefficient decomposition results for digital financial inclusion.

Year	Contribution			Contribution rate (%)		
	GW	*Gnb*	*Gt*	*GW*	*Gnb*	*Gt*
2011	0.052	0.180	0.016	21.015	72.622	6.363
2012	0.026	0.086	0.006	22.358	72.690	4.953
2013	0.020	0.064	0.004	22.574	72.775	4.651
2014	0.016	0.048	0.005	23.361	69.337	7.302
2015	0.012	0.038	0.005	22.265	69.046	8.689
2016	0.012	0.033	0.004	23.963	68.505	7.532
2017	0.011	0.032	0.003	23.748	70.278	5.974
2018	0.012	0.036	0.004	23.286	69.785	6.929
2019	0.013	0.038	0.004	23.328	69.238	7.434
2020	0.013	0.037	0.004	23.404	68.732	7.864

(Note: GW stands for intraarterial, Gnb stands for interareal, Gt stands for hypervariable density.)

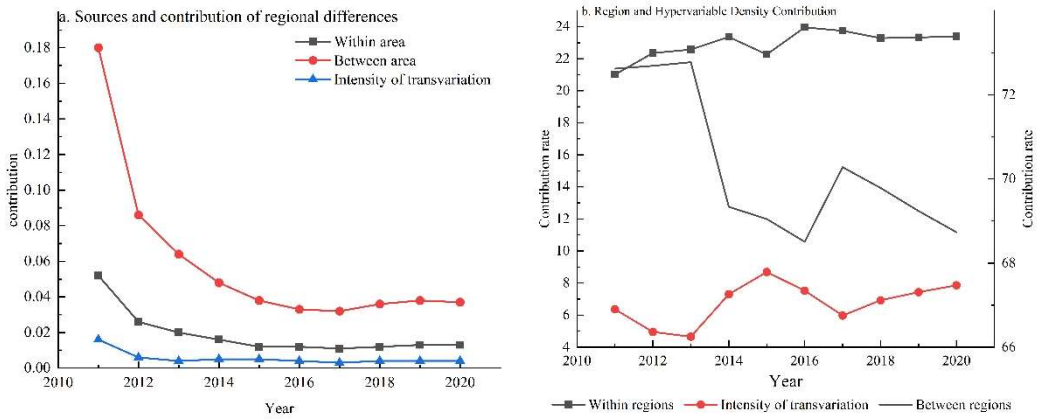

Figure 7. Sources of area differences in digital financial inclusion and their contribution.

revitalization of an area relies on the local economic development level. Areas with a high level of economic development have more financial resources to promote the process of rural revitalization, and GDP per capita is a better indicator to measure the level of economic growth. To build a beautiful countryside, it is also necessary to upgrade the country and feel the improvement of the organization and management level of the countryside from the inside out. The urbanization rate is an important indicator to measure the organization and management level of the country. Therefore, in addition to the three primary indicators of digital financial inclusion, two control variables, GDP per capita and urbanization rate [21], are the dependent variables for regression in this paper. Using 10-year panel data from 2011-2020, area dummy variables are added to establish spatial autoregressive (SAR), spatial error autoregressive (SEAR), and spatial autoregressive error autoregressive models (SARAR).

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$$\begin{cases} Y_{it} = \rho \sum_{j \neq i} w_{ij} Y_{jt} + X_{it}\beta + D_1 + D_2 + u_{it} \\ u_{it} = \lambda \sum_{j \neq i} w_{ij} u_{jt} + \varepsilon_{it} \end{cases} \quad (12)$$

When $\rho \neq 0$, $\lambda \neq 0$, the model is a SARAR model. When $\rho \neq 0$, $\lambda = 0$, the model is a SAR model. When $\rho = 0$, $\lambda \neq 0$, the model is SEAR model. D_1 and D_2 in the model are two indicative variables denoting geographical location, which in this paper represent the central and the western areas, respectively. A marginal and conditional LM test was used to determine the model's presence of random and spatially correlated effects [27-30]. The estimation results of the three models are given in Table 8, showing that the SAR model can be used to portray the influencing factors of rural revitalization.

As shown by the coefficient estimation in Table 8, the spatial autocorrelation coefficient of rural revitalization is significantly positive, reflecting the positive spatial spillover effect of rural revitalization in each province. Among the three indicators reflecting digital inclusive finance, only the depth of use significantly and positively affects the development of rural revitalization, indicating that the in-depth promotion of digital inclusive finance business in rural areas can substantially contribute to rural revitalization. The coefficient of GDP per capita is significantly positive, indicating that the level of rural revitalization relies on economic development. In terms of area effects, the level of rural revitalization in the western area is significantly lower than in the eastern area. At the same time, there is no significant difference between the central and east areas.

Table 8. Area Gini coefficient decomposition results for digital financial inclusion.

Variables	SAR	SEAR	SARAR
Constant term	-1.222***	-1.326***	-1.305***
Breadth of coverage	-0.012	-0.016	-0.016
Depth of use	0.063***	0.075***	0.073***
Degree of digitization	0.001	0.002	0.002
GDP per capita	0.470***	0.501***	0.497***
Urbanization rate	-0.001	-0.002	-0.002
Central Area	-0.061	-0.067	-0.066
Western Area	-0.198***	-0.204***	-0.204***
Spatial lag factor	0.089**	-	0.016
Spatial error correlation coefficient	-	0.120**	0.105
Random effects variance	4.229***	4.314***	4.284***
logLik	373.223	373.784	373.802

(Note: *, **, *** indicate significant at the 10%, 5%, and 1% levels, respectively.)

4.3. Exploring the impact of digital inclusive finance on rural revitalization from the perspective of spatial differentiation

As seen from the fluctuation analysis of the sources of digital inclusive finance differences in 3.1, the overall trend of intra-area difference contribution is rising, indicating that digital inclusive finance presents spatial agglomeration and spatial differentiation. To further analyze the impact of digital inclusive finance on rural revitalization from the perspective of spatial divergence [31], a spatially weighted regression (GWR) model is selected for the cross-sectional data in 2020:

$$Y_i = \beta_0(u_i, v_i) + \sum_{j=1}^{p} \beta_j(u_i, v_i) X_{ij} + \varepsilon_i$$

Where $\beta_j(u_i, v_i), (j = 0, 1, \cdots, p)$ is the spatial geolocation function. The estimation results of the GWR model are given in Table 9.

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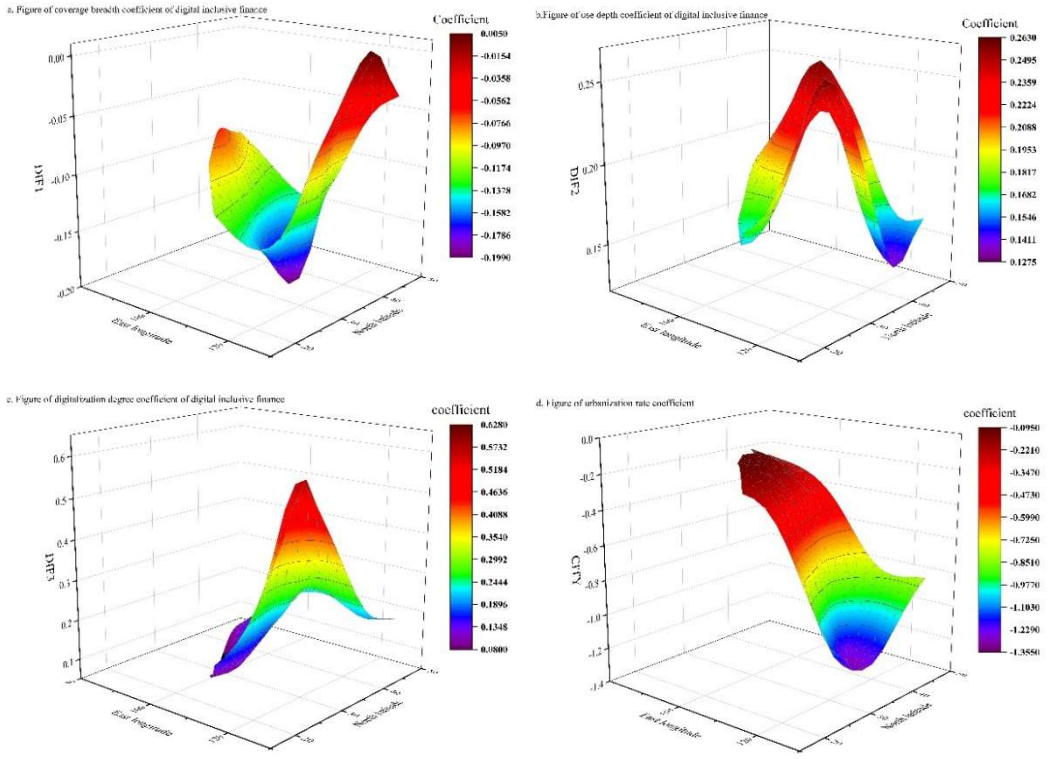
Table 9. Overall estimation results of the GWR model.

Dependent variable	Global R^2	Valid numbers	Bandwidth	*AIC* value
RURAL	0.9272	14.4534	0.1619	-125.0369

Based on the regression coefficients of the GWR model analysis, the pattern of smoothing effects of digital inclusive finance contributing to rural revitalization in various provinces and cities nationwide was obtained with the help of Origin software.

Figures 8a, 8b, and 8c show spatial heterogeneity in the development effect of digital inclusive finance. The coverage breadth of digital inclusive finance negatively impacts the degree of rural revitalization in general. The degree of effects decreases from the central part to the east-west direction, and the most negligible impact is concentrated in the eastern coastal area of China. The depth of use and the degree of digitalization of digital inclusive finance positively impact rural revitalization, and the degree of impact is the highest in the central area. In terms of depth of use, the central and eastern coastal areas have the most substantial influence, and the influence decreases in the southwest and northeast directions, reflecting that the east and significant coastal areas have established an excellent digital financial inclusion strategy and have shown apparent effects in promoting rural revitalization. In digitalization, similar to the depth of use, the highest impact is still concentrated in the central and eastern coastal cities. The difference is that the areas with the lowest impact degree of usage depth are gathered in the northeast, and the areas with the lowest impact degree of digitalization are gathered in the southwest, indicating that when digital inclusive finance promotes rural revitalization, it should be tailored to local conditions and precisely applied. The northeast area should put digital inclusive finance policies on the ground, increase the depth of its use, and improve the effectiveness of digital inclusive finance in promoting rural revitalization. The southwest area should vigorously promote the digitalization process, such as simplifying the complicated process of online processing, so as to highlight the "digital" function of digital inclusive finance and better enhance the level of rural revitalization.



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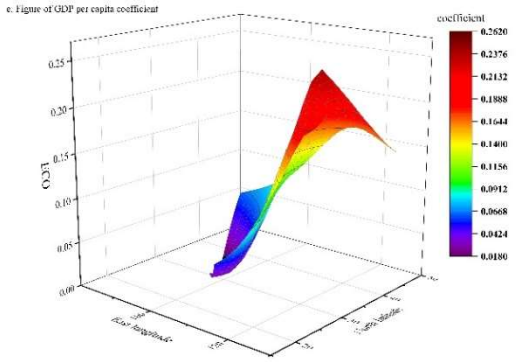

Figure 8. Pattern of the effect of digital inclusive finance to help rural revitalization

As seen in Figure 8d, the level of urbanization negatively affects the level of rural revitalization. The degree of influence shows a characteristic of increasing from west to east. It indicates that in the process of promoting urbanization construction, the level of urbanization will inhibit the level of rural revitalization, which is reflected in the eastern area with high urbanization degree, whose urbanization level influence coefficient is significantly higher than that of the western part with lower urbanization degree. From 3.2, it is clear that urbanization is ineffective in enhancing rural revitalization.

As seen from Figure 8e, it is the northern area that relies mainly on social wealth to enhance rural revitalization, and the degree of reliance shows a decreasing feature from north to south. Compared with the degree of digitalization, the higher the degree of digitalization affecting rural revitalization, the lower the degree of GDP per capita contributing to rural revitalization.

Overall, there are areas of differences in the spatial effects of rural revitalization. The eastern countryside has a higher level of digitalization, and relying on digital inclusive finance can significantly enhance the level of rural revival. Influenced by the relative lack of digitalization in the western area, vigorously promoting and applying digital businesses such as digital inclusive finance in the west can significantly enhance local rural revitalization. The reliance on digital inclusive finance in rural revival in northern cities is lacking compared to southern cities.

5. Conclusion and Discussion

5.1. Conclusion

Taking the boosting effect of digital inclusive finance on the rural revitalization as the mainline, this paper firstly analyzes the dynamic evolution of digital inclusive finance and rural revitalization development in time and space dimensions initially, takes the source of differences in digital inclusive finance as the entry point, and then studies the boosting effect of digital inclusive finance on rural revitalization from the perspective of spatial aggregation and spatial divergence. The main findings are:

(1) The level of digital inclusive finance in China has increased by about 300% in the past ten years, with the growth rate slowing down yearly. Geographically, it shows the characteristics that the eastern coastal area is higher than the central and western areas, and the difference in development level between provinces increases year by year and shows gradient characteristics, which indicates the possible emergence of multi-polar polarization phenomenon. Rural revitalization has risen by about 60% in the past ten years, and the growth rate generally shows an increasing trend. Geographically, not only does it show the high level of rural revitalization in coastal areas, but the level of rural revitalization in Sichuan, Jiangxi, and Hunan also performs brightly. Despite the strong support for China's rural revitalization strategy, the gap in rural revival among provinces is still apparent.

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(2) The evolution of the development levels of digital inclusive finance and rural revitalization is a gradual and slow adjustment process. Neither level has jumped across levels during the development process of 10 years. In digital inclusive finance, the mobility of the highest and lowest levels to the middle level is higher. In the case of rural revitalization, unlike digital inclusion finance, the mobility between the states of rural revitalization development levels is not high.

(3) The Gini coefficient of China's digital inclusive financial development shows an "L"-shaped evolutionary trend, and the differences among the three major areas gradually decrease. However, the differences in digital inclusive financial development within the western area are more significant. From the source of area differences, the influence of inter-provincial development on the development of digital inclusive finance is weakening, and the contribution of intra-area and super-variable density to the fluctuation is increasing.

(4) There is a positive spatial spillover effect on the revitalization of rural areas in each province of China. When digital inclusive finance business is promoted intensely in villages, strengthening the implementation of its depth of use can substantially contribute to rural revitalization. For every 1% increase in the depth of digital financial inclusion use, the level of rural revival can be increased by about 6.3%. And the level of rural revitalization is also closely dependent on the local economic development. For every 1% increase in the area's economic level, the level of rural revival can be increased by about 47%.

(5) Regarding the area effects of digital inclusive finance to promote rural revitalization, the impact effect in the western area is significantly lower than that in the eastern area, and there is no significant difference between the east and central areas. The depth of use and the degree of digitalization of digital inclusive finance generally show positive effects on rural revitalization, with the highest impact in the central and eastern coastal cities, decreasing toward the southwest and northeast. The areas with the lowest impact of depth of use are clustered in the northeast, and the areas with the lowest impact of digitalization are clustered in the southwest. The level of urbanization in general negatively influences the level of rural revitalization, and the degree of influence shows an increasing characteristic from west to east. GDP per capita affects the level of rural revival with decreasing factors from north to south.

5.2. Discussion

Given the differences and uneven characteristics of digital inclusive finance and rural revitalization development identified in the empirical analysis, relevant policy formulation should reflect local characteristics and differences and implement specific guidelines by category. For example, the northeastern area should put digital inclusive finance policies on the ground, increase the depth of its use, and enhance the effect of digital inclusive finance in contributing to rural revitalization. Local governments need to strengthen top-level planning and coordination, regulate the development of digital inclusive finance from top to bottom, alleviate the uneven development, and promote the coordinated development of digital finance in different areas. Better utilize digital inclusive finance to enhance rural revitalization.

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website of the Map Technical Review Center of the Ministry of Natural Resources, link at: http://www.ngcc.cn/ngcc/

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