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Unveiling the Spatial Coupling Dynamics and Coordination Mechanisms Between Digital Inclusive Finance and Rural Industrial Integration Development

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Abstract: This study examines the coupling coordination between digital inclusive finance (DIF) and rural industrial integration development (RIID) in China from 2011 to 2021, using panel data from 282 prefecture-level cities. By employing the coupling coordination model and entropy method, the research analyzes the spatiotemporal evolution and regional disparities of DIF and RIID. Key findings include the following: (1) The coupling coordination degree between DIF and RIID shows a consistent upward trend, transitioning from mild imbalance to primary coordination, though RIID lags behind DIF. (2) Significant regional disparities exist, with an “N-shaped” spatial distribution pattern from south to north, where eastern and northeastern regions exhibit higher coordination levels compared to central and western regions. (3) Regional differences are narrowing, driven primarily by inter-regional disparities, with strong spatial spillover effects observed in “high-high” and “low-low” agglomerations. (4) The overall spatial network tightness and stability have improved, with eastern regions playing a central role in the network, while northeastern and western regions remain relatively marginal. Policy recommendations include expanding DIF applications in rural industries, reducing regional disparities through resource allocation, promoting rural industrial integration in underdeveloped areas, and strengthening regional coordination to facilitate resource flow.

Keywords: digital inclusive finance; rural industrial integration development; coupling coordination



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1. Introduction

From the historical perspective of industrial structure transitions and developments across nations, rural industrial integration development (RIID) has emerged as an indispensable trend in the modernization of agriculture and rural areas globally. China currently finds itself amidst a transformative phase where digital finance is vigorously empowering RIID. An exploration into the laws governing and the spatiotemporal evolution trends of the amalgamation between digital finance and rural industries is pivotal in guiding the strategic orientation towards comprehensive rural revitalization. Historically, China has faced challenges such as a weak foundation and innovative capacity in rural industrial development, fragmentation among rural industrial entities, low levels of industrial integration, a lack of distinctive and well-planned industrial selections, financing difficulties for rural industrial endeavors, inadequate rural infrastructure, and loose industrial benefit and risk-sharing mechanisms [1]. Traditional inclusive finance and RIID have suffered from

suboptimal quality and efficiency, trapped in a cycle of “low-level integration” between finance and rural industrial growth. Digital inclusive finance (DIF) is progressively reshaping traditional financial business models [2], emerging as a novel catalyst for economic expansion and leading industrial transformation and upgrading [3]. Simultaneously, RIID has sparked significant capital investments and demands for financial services, fostering a conducive environment for the advancement of DIF [4]. Consequently, a scientific evaluation of the integration level and developmental trajectory of DIF and high-quality rural industries, alongside their spatiotemporal evolution patterns, holds immense significance in furthering the high-quality development of the rural economy and accelerating the modernization of agriculture and rural areas.

Research on the integration of DIF and RIID has mainly focused on digital technology, factor integration, and industrial development. In the rural economic system, rural finance plays a key role, and its development directly affects the economic progress of rural areas [5]. At the same time, rural finance has significantly promoted the integration of agriculture, industry, and service industries, especially in regions with mature market mechanisms and high industrial and service output values in agricultural intermediate products. The role of finance in promoting industrial integration is particularly prominent [6]. In recent years, based on deep learning and artificial intelligence technology, rural banks have further informatized, greatly promoting the development of rural finance and laying the foundation for promoting RIID in rural finance [7]. Compared with traditional inclusive finance, DIF can effectively improve the availability of farmers’ credit and agricultural total factor productivity [4,8], effectively reduce the price distortion of agricultural factors of agricultural enterprises, improve the mismatch of agricultural factors [9], drive the accumulation of capital, talents, technology and other resource factors to agricultural industry, and promote the extension of the agricultural industry chain, the improvement of farmers’ income, the expansion of agricultural multi-function, the integration of agricultural services, and the cultivation of new agricultural formats [10,11]. However, there are also regional differences due to the heterogeneity of DIF and the level of economic development, the financial support, the level of urbanization, and the degree of digitization [12]. It is still unknown whether the coupling and coordinated development between DIF and rural industrial development has a spatial agglomeration effect and a spatial network connection, and whether there is regional spatial imbalance. In the selection of coupling coordination relationship models, the coupling coordination degree model [13], the Dagum Gini coefficient method [14], the three-stage super efficiency DEA-SBM model [15], the two-way fixed effect model [16], the spatial panel data model [17], and other methods are mainly used, and most of them focus on inter-provincial-level exploration, without an in-depth analysis of the spatial network correlation between DIF and RIID from the perspective of intercity rural industrial coupling coordination. Rural industries often have certain regional and cluster development characteristics. Is there a spatial difference and regional cluster gap in the regional coupling coordination between the two? What is the root cause of the temporal and spatial evolution difference between the two? Therefore, this article deeply analyzes the coupling and coordination mechanism between DIF and RIID, and explores the spatial heterogeneity and regional spatial network correlation effects of their coupling and coordinated development from the perspective of spatiotemporal evolution.

In summary, the possible marginal contributions of this article are as follows: Firstly, it explains the coupling and coordination mechanism of DIF on RIID from both theoretical and empirical perspectives, which meets the practical needs of embedding DIF into RIID in China and provides new ideas for promoting RIID in China. Secondly, with the panel data of 282 prefecture-level cities in China from 2011 to 2021 as the sample, the paper empirically

identified the spatial-temporal evolution pattern of China's DIF for RIID, and revealed the dynamic evolution law of DIF for RIID under the spatial cluster structure of RIID. Thirdly, this study uses the modified gravity model to construct a coupled and coordinated spatial relationship between DIF and RIID, revealing the spatial network correlation characteristics between the two, and providing new ideas for exploring the DIF policy collaboration system of regional differentiated RIID.

2. Theoretical Analysis

2.1. Theoretical Connotation Analysis

The thought of RIID originated from Marx's interpretation of the law of social industrial division and development quality in capital, and put forward the endogenous economic growth theory and intensive growth theory with the quality improvement of production factors as the core [18]. It is not a simple mechanical combination among rural industries, but it strengthens the interest linkage mechanism, improve the level of RIID, and promotes the continuous cross penetration and reorganization of rural primary, secondary and tertiary industries [19], achieving the high-quality integrated development of the entire industrial chain, assisting in the transformation and upgrading of rural industrial structure and rational layout, breaking industrial boundaries through technology, promoting industrial integration and innovation, improving rural industrial efficiency and market competitiveness, fully considering the goals of increasing farmers' income and urban–rural integration development [20,21], and ultimately promoting RIID and achieving the universal sharing of achievements.

DIF provides an important driving force for promoting the digital RIID. It not only accelerates the integration of rural digital governance, data value, and digital assetization, but also leverages digital technology embedded in rural areas to exert resource allocation and innovation effects. It can not only change the traditional financial operation paradigm, but it can also actively promote the digital transformation of traditional inclusive financial services, alleviate the practical difficulties of insufficient industrial development funds and the financial exclusion of "long tail groups" [22,23], and deeply integrate data as a new production factor with traditional production factors, empowering digital application innovation in traditional rural industry scenarios such as fund financing, payment, investment, information inter-mediation, and risk prevention [24], providing strong impetus for the high-quality integration and development of digital technology embedded in rural industries. At the same time, the development of DIF in China also has regional network connectivity and spillover effects [25]. The development of DIF will not only promote the integration of rural industries in the local area, but may also provide demonstration effects for the integration of rural industries in adjacent areas. In addition, the development of the digital economy has broken through the original geographical location limitations, weakened geographical proximity, and alleviated financing constraints [26]. DIF may also promote the cross spatial allocation of financial capital, digital technology, information, and other resource elements in the process of promoting the integration of industries with high volumes, deepen the network connections between rural industries in various regions, and create spatial network structural differences in the coupling of digital finance with RIID.

2.2. Coupling Coordination Mechanism

The theory of coupled coordinated development originated in the early 1960s and was first proposed by German theoretical physicist Haken [27]. It focuses on how to coordinate multiple subsystems through common resource information and material energy exchange, transforming from disorder in time, space, and function to order. This theory emphasizes the interaction and coordination among the various components within a system, allowing

systems of different levels and structures to achieve stable development amidst changes in the external environment and to gradually move toward order. Digital economy theory argues that the rapid development of digital technologies and internet platforms has injected new momentum into economic growth. The swift flow and efficient use of information have driven the digital transformation of traditional agricultural industries. Industry integration theory highlights that in the context of the digital economy, industry boundaries are increasingly blurred, and the integration and synergy between industries have become key drivers of high-quality economic development [28]. Through industrial integration and innovation, rural industries have broken the limitations of traditional industry chains, forming a more diversified and flexible industrial ecosystem [29].

Therefore, the key to the coupling and coordination of DIF and RIID lies in cultivating new driving forces for economic development, relying on high-quality productivity to break the low-end structure of industries, and driving the integrated development of traditional industries through quality improvement. By relying on digital technology and internet platforms, through the integration and development of the value chain of each link of the rural industrial chain enabled by DIF, it can drive the cost reduction and efficiency increase in traditional rural industries, help the integration of rural industries at the innovation, coordination, green, open and sharing levels, and form a structural transformation and evolution of “cultivation of new rural industries and new business types → optimization and upgrading of rural industrial structure → RIID”. At the same time, RIID is also an important foundation and prerequisite for DIF to empower the rural real economy. By optimizing the financial development environment, driving innovation in digital financial products and services, and gathering financial resources, it can drive sustainable income growth for farmers and the modernization of agriculture and rural areas, achieve consistency and the coupling of internal goals, and help promote the high-quality development of the rural economy (Figure 1).

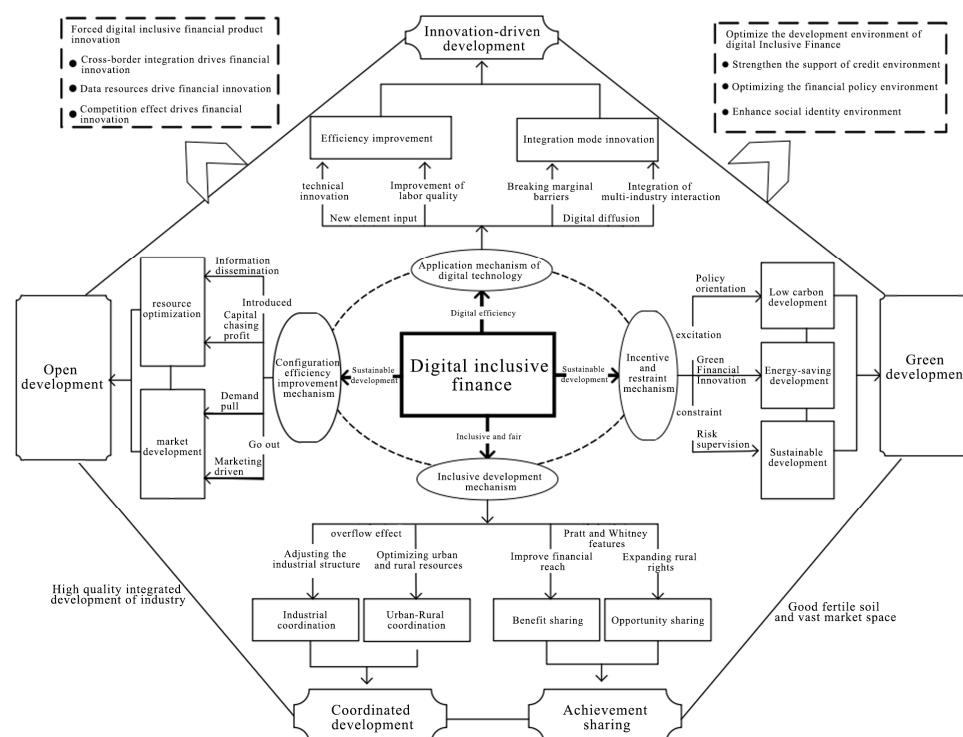


Figure 1. Coupling and coordination mechanism between DIF and RIID.

DIF empowers RIID from four aspects: innovation effects of digital technology applications, efficiency improvement effects of open competition, incentive and constraint

effects of green policies, and inclusive and mutually beneficial development effects. At the level of innovation in digital technology applications, DIF utilizes digital technology to overcome the “pain points” of traditional financial transaction processes that are cumbersome, costly, and have high barriers to entry. It complements government financial investment to alleviate financing constraints faced in low-profit and high-risk agricultural technology innovation, stimulate agricultural technology innovation vitality, and improve RIID efficiency. At the same time, with the application penetration and scenario embedding of digital technology in RIID, diversified digital financial products and services across time and industry are cultivated for the integration of rural industrial chains, helping to promote the “internal” cross integration of agricultural industries, the “vertical” extension and integration of industrial chains, the “horizontal” expansion of multifunctional integration development in agriculture, and solving the problem of information asymmetry [30]. At the level of improving the efficiency of open competition, DIF, based on the logic of open collaboration, promotes the precise matching of information between the supply and demand of resource elements such as rural land transfer and fixed assets, introduces urban social capital into rural areas, and provides new opportunities for investment in new industries and the cultivation of new business models. At the same time, DIF provides financial support for the construction of rural agricultural product brands and the expansion of agricultural product transportation channels, further promoting the “going global” of rural industries and exploring new product markets. At the level of green policy incentives and constraints, the development of DIF has policy orientation. With the support of national green policies, it promotes the transformation of old driving forces into new driving forces, drives industrial energy conservation and emission reduction, and promotes the transformation and upgrading of industrial structure towards becoming low-carbon to enhance environmental benefits [31]. At the same time, the sustainable development of DIF can alleviate the problem of high risks caused by information asymmetry faced by traditional financial institutions, empower green finance to improve quality and efficiency, promote the traceability and transparency of the green industry chain, and achieve the sustainable development of rural industries. At the level of inclusive, mutually beneficial, and coordinated development, DIF has obvious inclusive growth characteristics [32], breaking down the barriers of uneven distributions of economic opportunities in urban and rural areas, opening up new paths for rural industrial structure reform, promoting high-quality industrial integration, improving resource endowment and location environment, providing possibilities for expanding farmers’ income and employment channels, optimizing urban–rural income consumption structures, and narrowing the gap in urban–rural public service development.

DIF also provides strong financial support and technological support for the innovative application of digital scenarios in rural industries. Firstly, RIID will expand the coverage of DIF. RIID pays more attention to the endogenous development momentum of rural areas, indirectly promoting the spillover and diffusion of core elements such as knowledge, technology, and concepts, enhancing farmers’ credit needs and investment and financial awareness, and contributing to the “horizontal” extension of digital inclusive financial services and products. Secondly, RIID will deepen the use of DIF. RIID will make the boundaries between different industries increasingly blurred, and will create digital application scenarios across industries and fields, generating more diverse financial needs, directly or indirectly promoting innovation in credit, investment, and credit evaluation by financial institutions, and promoting the “vertical” extension of financial services and products. Thirdly, RIID will enhance the digitization level of DIF. The process of RIID is also a process of capital endowment accumulation [33], which will not only guide more financial resources to gather in rural areas and provide efficient and convenient financial services to

support industrial development in the gathering areas, but also provide a material basis for integrating and utilizing industrial chain data information, and improve the convenience level of financial services [34].

3. Construction of Indicator System, Research Methods, and Data Sources

3.1. Construction of Indicator System

The new development concept is the evaluation criterion for high-quality development [35]. Regarding the measurement of RIID, several valuable explorations have been undertaken in existing studies [36–38]. Huang et al. (2023) developed an industrial integration indicator system based on three dimensions: method, subject, and forma [4]. Other studies in the literature have constructed indicator systems based on the breadth and depth of RIID, reflecting both the quality of the integration and the effectiveness of the integrated development [38]. Additionally, some scholars have developed a coupling-based indicator system from the perspective of coordinated development among the three industries, employing a coupling coordination model to measure integration through separate indicators for the primary, secondary, and tertiary industries [39]. Due to differences in research objectives and subjects, no universally recognized comprehensive evaluation system has been established in existing studies. However, these evaluation indicator systems generally encompass aspects such as industry chain extension, multifunctional expansion, new technology penetration, and benefit linkage. Considering the scientific nature of the indicator system, data availability, and the comparability of the system, an indicator system is constructed from the dimensions of innovative integration, green integration, open integration, coordinated integration, and shared results of integration in rural industries [4].

- ①RIID relies on technology to improve agricultural total factor productivity, promote the rational allocation of various resources such as land and labor, and achieve innovation-driven development, measure the efficiency of industrial integration from total factor productivity, land output rate, and labor productivity, and measure the quality of industrial innovation integration from the subdivision form of industrial integration.
- ②Green and sustainable development is a prerequisite for RIID, measured from three aspects: Low carbon development, Energy saving and consumption reduction development, and sustainable development [40].
- ③The long-term development of open and integrated rural industries should adhere to the combination of bringing in and going out, and should efficiently utilize rural resource elements and market space [41]. Considering the availability of data, the actual level of foreign investment utilization in rural areas and the dependence on agricultural product imports and exports are used to approximately measure the level of rural resources and market openness.
- ④Marx's theory of industrial integration emphasizes that promoting RIID requires a focus on addressing the dynamic balance of the primary, secondary, and tertiary industries and their capital forms in the supply–demand relationship. The upgrading of industrial structures reflects the overall coordination quality of industrial structures, and the coordinated development of urban–rural income and consumption is used to measure the urban–rural coordination relationship.
- ⑤The ultimate goal of industrial integration development is to improve the living standards of farmers and achieve the sharing of rural integration achievements. The benefit sharing status is represented by the per capita income-sharing level of rural residents, while the opportunity sharing status is represented by rural public service opportunities and employment opportunities. Drawing on existing research [42], the entropy method is employed to calculate the weights of indicators. This method measures the information content of indicators through information entropy, thereby objectively reflecting the degree of influence each indicator has on the overall evaluation. Compared to subjective assignment methods, the entropy method minimizes the interference of human factors, enhancing the objectivity of the evaluation system. The specific indicator system and weighting results are presented in Table 1. In addition, based on

the DIF Index constructed by the Digital Finance Research Center of Peking University, the overall level of DIF in Chinese prefecture-level cities is measured from three aspects: coverage breadth, usage depth, and digitization degree [43].

Table 1. Evaluation index system for RIID.

Target Layer	Subsys Term	Indicator Layer	Sub Indicators	Specific Calculation Method	Direction	Weight
Level of RIID	Innovation-driven development	Innovation integration efficiency	Total factor productivity ①	Calculated according to production function	+ ③	0.0340
			Labor output rate	Value added of primary industry production/employees in the primary industry	+	0.0612
			Land productivity	Total agricultural output value/total sowing area	+	0.0570
		Innovative integration mode	Internal cross fusion	Total value of fine molecule industry	+	0.0660
			Vertical industrial chain extension	Per capita output value of agricultural product processing industry ②	+	0.0711
			Horizontal new business cultivation	Output value of agriculture, forestry, animal husbandry, and Fishery Services/rural population	+	0.1607
	Green development	Low carbon development	Fertilizer emission reduction intensity	Fertilizer use of crops/planting area of crops	-	0.0009
		Energy saving and consumption reduction development	Energy consumption per 10,000 yuan GDP	Agricultural energy/agricultural GDP	-	0.0006
		Sustainable development	Cultivated land area	Per capita cultivated land area	+	0.1238
	Coordinated development	Industrial coordination	Upgrading of industrial structure	Output value of secondary industry/output value of tertiary industry	+	0.0360
		Urban–Rural Coordination	Urban–rural income coordination	Ratio of per capita disposable income of urban and rural residents	-	0.0051
			Coordination of urban and rural consumption	Ratio of per capita consumption expenditure of urban and rural residents	-	0.0005
	Open development	Resource opening	Actual level of foreign capital utilization in rural areas	Actual utilized foreign capital/GDP	+	0.1116
		Market opening	Dependence on import and export of agricultural products	Total import and export/gdp	+	0.1502
	Achievement sharing	Benefit sharing	Income-sharing level of rural residents	Growth rate of per capita disposable income of rural residents	+	0.0030
		Opportunity sharing	Public service opportunity sharing	Per capita road area	+	0.0204
				Number of beds in medical institutions per 10,000 people	+	0.0525
				Number of ordinary primary schools per 10,000 people	+	0.0254
				Rural employment opportunity sharing	Rural employment/total rural population	+

Note: ① The agricultural output index is the total output value of agriculture, forestry, animal husbandry, and fishery, and the input index selects elements such as labor, land, machinery, chemical fertilizer, and water resources. ② Per capita agricultural product processing industry output value = (grain output + oil output + meat output)/rural population. ③ “+” represents a positive impact, while “-” represents a negative impact.

3.2. Research Methods

3.2.1. Coupled Coordination Degree Model

Based on the requirements of the coupling coordination model [44], the coupling coordination index of the high-quality integrated development of DIF and rural industries in various prefecture-level cities is measured. Specifically, the entropy method is used to

calculate the comprehensive evaluation index of the high-quality integrated development of DIF and rural industry, respectively [6], and then the coupled coordination degree model is used to measure the coupled and coordinated development level of the two. The calculation formula is as follows:

$$\text{Coupling degree: } C = \frac{2\sqrt{U_1 U_2}}{U_1 + U_2} \quad (1)$$

$$\text{Harmonization: } T = \alpha U_1 + \beta U_2 \quad (2)$$

$$\text{Coupling coordination degree: } D = \sqrt{C * T} \quad (3)$$

Among them, U_1 and U_2 represent the development level of DIF and the high-quality development level of integration of rural industries, respectively, C represents the coupling coordination degree, T represents the coordination evaluation index of the two subsystems, D represents the coupled coordination degree, α and β are the contributions of the two subsystems, and $\alpha + \beta = 1$. Considering the equal status of the two subsystems of DIF and the RIID, take $\alpha = \beta = 0.5$. Combined with the calculation results of the prefecture-level cities, they are divided into 10 levels according to the coupling and coordination level (Table 2):

Table 2. Types of industrial coupling and coordination relationships.

Interval	Coordination phase			
Coordination value	$0.6 < D \leq 0.7$	$0.7 < D \leq 0.8$	$0.8 < D \leq 0.9$	$0.9 < D \leq 1$
Basic type	Primary coordination	Intermediate coordination	Good coordination	High quality coordination
Interval	Transition phase			
Coordination value	$0.4 < D \leq 0.5$		$0.5 < D \leq 0.6$	
Basic type	Verge of maladjustment		Reluctantly coordinate	
Interval	Maladjustment stage			
Coordination value	$0 < D \leq 0.1$	$0.1 < D \leq 0.2$	$0.2 < D \leq 0.3$	$0.3 < D \leq 0.4$
Basic type	Extreme maladjustment	Severe maladjustment	Moderate maladjustment	Mild maladjustment

3.2.2. Spatial Analysis Model

Spatial auto-correlation model. The spatial effects of the coupling and coordination degree between DIF and RIID are assessed using both global and local spatial autocorrelation. Drawing on the research methods of Getis (2007) and Zhang (2022), the overall evolution of the spatial distribution of the coupling and coordination degree across different prefectural cities is first examined using the global spatial autocorrelation Moran's I index [45,46]. Subsequently, the local spatial characteristics of the development level are analyzed through the local spatial autocorrelation Moran's I scatterplot, providing insights into the spatial coordination dynamics at a more granular level.

The global Moran exponential formula is as follows:

$$\text{Moran's } I = \frac{n \sum_{i=1}^n \sum_{j=1}^n W_{ij} (D_i - \bar{D})(D_j - \bar{D})}{\sum_{i=1}^n \sum_{j=1}^n W_{ij} \sum_{i=1}^n (D_i - \bar{D})^2} \quad (4)$$

Specifically, n is the number of prefecture-level cities; D_i is the coupling and coordination degree of DIF and rural industry in i city; and W_{ij} is the spatial weight matrix.

The local Moran index formula is as follows:

$$I_i = DS_i \sum_{j=1, j \neq i}^n T_{ij} DS_j \quad (5)$$

where I_i is the local Moran's I index; DS_i and DS_j are the normalized observed values of regions i and j , respectively; T_{ij} is the normalized spatial weight.

The concept of social networks, initially proposed by Brown, has found widespread application across various fields [47]. In contrast to traditional spatial measures, social network analysis offers a more comprehensive depiction of the multidirectional linkages between regions. This study employs a modified gravity model to construct the coupled coordination degree correlation matrix of digital financial inclusion and RIID in each prefecture-level city in China [48,49]. Building upon the classical gravity model, the modified version incorporates corrective factors, such as the level of economic development, to more accurately capture the financial and industrial integration relationships between regions. The specific formula is as follows:

$$F_{ij} = \frac{DE_i}{DE_i + DE_j} \frac{\sqrt[3]{DE_i * P_i * G_i} \sqrt[3]{DE_j * P_j * G_j}}{\left(\frac{D_{ij}}{g_i - g_j}\right)^2} \quad (6)$$

Within the formula, F_{ij} is the coupling and coordination correlation strength of DIF and RIID in various prefecture-level cities in China. DE_i and DE_j represent the coupling and coordination degree of i prefecture-level cities and j , and D_{ij} means the geographical distance between i prefecture-level cities and prefecture-level cities j . The $g_i - g_j$ represents the difference between the per capita GDP of prefecture-level cities, P_i and G_i represent the total resident population and GDP, respectively, and the mean of each line of the gravity matrix is taken as the threshold of the line.

3.3. Data Source

The study took 282 prefecture-level cities in China (excluding data from Tibet, Macao, and Taiwan) from 2011 to 2021 as the study sample. Among them, the high-quality integrated development index data of rural industries came from the EPS database, the Wind database, the *China Rural Statistical Yearbook*, *China Urban Statistical Yearbook*, and the *Statistical Bulletin of National Economic and Social Development*, and some of the missing values are supplemented by the linear interpolation method. The DIF Development Index is derived from the Peking University DIF Index released by the Peking University Digital Finance Research Center. To ensure comparability between the two systems of DIF and high-quality integration of rural industries, weights are used in three aspects: digital inclusive coverage breadth, usage depth, and digitization degree. The comprehensive score of the DIF Index is calculated using the linear weighting method. In this paper, balanced panel data for 282 prefecture-level cities are finally obtained for empirical analyses, and Table 3 reports the definitions of relevant variables and descriptive statistics.

Table 3. Descriptive statistical analysis.

Variable Name	Sample Size	Standard Deviation	Mean	Maximum Values	Minimum Value
Rural industrial integration Development	3102	0.100	0.031	0.040	0.322
Digital inclusive finance	3102	0.481	0.183	0.059	0.933
Coupled coordination level	3102	0.457	0.067	0.244	0.687

4. Analysis of the Coupled Coordination Level Evolution

4.1. The Evolution Trend of Coupling and Coordination

According to the panel data related to the development of rural industries in 282 prefecture-level cities in China from 2011 to 2021, the coupling and coordination degree of DIF and RIID was calculated, respectively (Figure 2). First, the coupling and coordination level of DIF and the high-quality integrated development of rural industry in all prefecture-level cities in China is increasing year by year. The development gap between the two is narrowing, but the overall development is still in an unbalanced development state. Specifically, the average value of the digital financial inclusion index in all cities in China rose from 0.15 in 2011 to 0.73 in 2021, and the development of DIF has achieved leapfrog development. During the same period, the time sequence curve of RIID in prefecture-level cities in China also showed an upward trend on the whole, and saw an important turning point that appeared in 2017. After that, the high-quality integrated development level of rural industries showed an obvious growth trend, but the integrated development level of rural industries between cities still lags behind the digital universal benefit. The main reason for this gap in the level of financial development is that RIID requires multi-subject coordination and multi-industry interwoven penetration to promote the transformation of traditional agriculture to modern agriculture, which is a huge systematic engineering and long-term strategic task, and is still in the preliminary exploration stage.

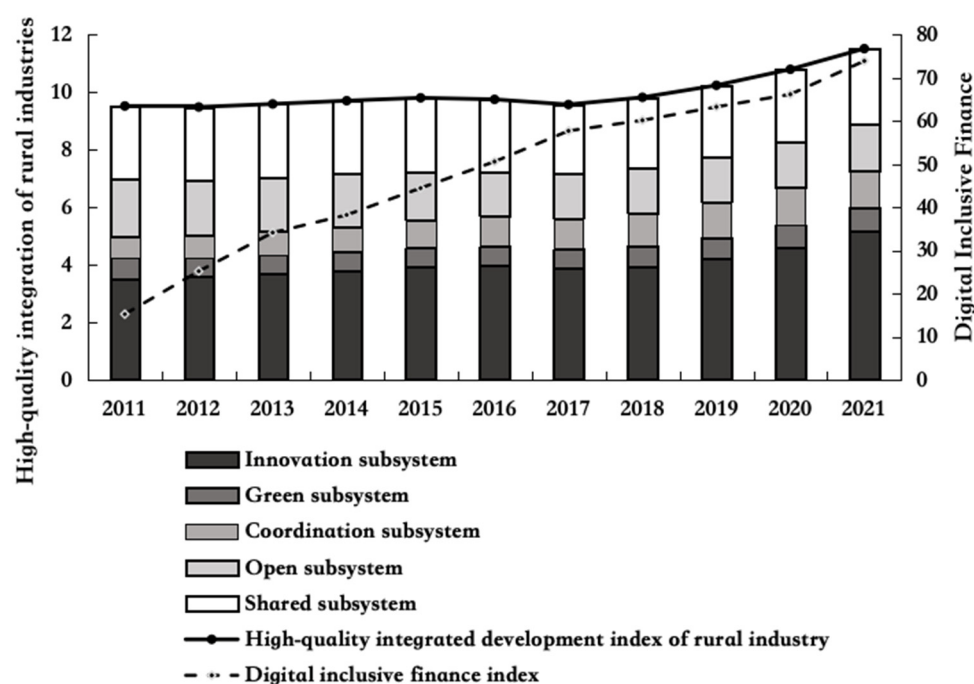


Figure 2. Coupled and coordinated evolution trend of DIF and RIID.

Second, there is also a structural imbalance among the subsystems of RIID, which is reflected in the relatively high level of innovation and the development of rural industries, while the level of green integrated development and coordinated RIID lags behind. Between 2011 and 2021, the rural industry innovation integration of the annual average in the whole period is located at the highest level, especially after 2018 when growth significantly increased, which reflects the rural industrial chain integration and agricultural extension in China in recent years, but rural industry green integration development and coordinated integration development still faces green ecological value transformation and the coordinated development of the rural industrial chain.

To more intuitively display city DIF and rural industry quality distribution characteristics of development, with the 2021 DIF Index and RIID index average score as the benchmark, the plane is divided into four quadrants of “synchronous disorder”, “industrial integration lag”, “synchronous development”, “digital financial lag”, and we found that most cities were distributed in the first quadrant and the third quadrant.

Figure 3 shows that the “synchronous development” of the first quadrant focuses on the integration of urban and rural industries in the eastern coastal provincial capitals such as Hangzhou, Beijing, Shanghai, and Xiamen, and its coordinated development level is in the leading position in the country. The second quadrant, “industrial integration lag”, region is dominated by Zhengzhou, Wenzhou, Wuxi, Hefei, and other central cities in the eastern and central regions, which shows the rapid development level of DIF and the relative lag of the high-quality integration development level of urban and rural industries. The third quadrant, “synchronous disorder type”, includes mainly Bazhong, Neijiang, Liaoyuan, Leshan, and other prefecture-level cities in central and western China, and the integration level of DIF and rural industries is lower than the national average level. The fourth quadrant, “DIF lag type”, region is dominated by resource-based cities such as Shuangyashan, Hegang, and Shuozhou. Its rural industries integrate and develop early, but the development of DIF is relatively lagging behind. The obvious reasons for such regional differences may be the differences between different urban agricultural location conditions and resource endowments, which may lead to the different driving forces and comparative advantages of digital finance embedded in RIID, and the different scale effect of rural industry agglomeration [4]. For example, Northeast China has a good foundation for agricultural development, and has inherent advantages in promoting the integration of rural industries, while the central and western regions such as Bazhong and Neijiang have weak economic foundations and the development structures of single rural industries, and most areas are still based on traditional agriculture, which is not only necessary to promote the development of digital finance, but is also needed to continuously tap the potential of digital finance to enable the digital transformation of rural industries in order to achieve high-quality integration.

4.2. Spatiotemporal Evolution Characteristics of Coupling Coordination Level

4.2.1. Overall Coupling and Coordination Degree Relationship Across the Country

From the perspective of the national overall average (Table 4), with DIF development and the high-quality integration development of coupling coordination rising year by year, from 0.3424 in 2011 to 0.5355 in 2021, and from the mild disorder state spread gradually across the primary coordination state, this shows that China’s DIF and RIID are showing a good situation of synergy and mutual promotion. From the perspective of the subdivision dimension of RIID, the coupling and coordination degree of each subsystem and DIF is increasing year by year, and the coupling and coordination degree score is in the range of 0.2–0.4, which still has large space for improvement. From the perspective of the coupling growth rate of all dimensions, the average annual growth rate of the coordinated and integrated development of DIF and rural industry is over 5%, reflecting the good results achieved by Chinas rural industry in the coordinated development of the innovation of resource endowment, promoting the flow of resource factors and optimizing the allocation.



Figure 3. Distribution levels of DIF and RIID¹.

Table 4. Coordination level of subsystem coupling between DIF and RIID.

Year	Integrated Coordinated Dispatching	Financial Support for the Integration of Industrial Innovation	Financial Support for the Integration of Industrial Green Development	Financial Support for the Coordinated Integration of Industries	Financial Support for the Open Integration of Industries	Financial Support for the Shared Integration of Industrial Sectors
2011	0.3424	0.2635	0.169	0.1806	0.2124	0.245
2012	0.3893	0.3022	0.1904	0.207	0.2397	0.2794
2013	0.4217	0.3282	0.2069	0.2263	0.2584	0.3024
2014	0.4355	0.3404	0.2134	0.2368	0.265	0.3114
2015	0.4535	0.3569	0.2218	0.2522	0.2675	0.3242
2016	0.4682	0.37	0.23	0.2656	0.2703	0.3341
2017	0.4815	0.3805	0.2372	0.2774	0.2801	0.3399
2018	0.4893	0.3861	0.2399	0.2842	0.2836	0.3457
2019	0.5005	0.397	0.2415	0.2948	0.2865	0.3521
2020	0.5128	0.4105	0.2465	0.3005	0.2889	0.3581
2021	0.5355	0.4334	0.2576	0.3074	0.3014	0.3711
mean value	0.4573	0.3608	0.2231	0.2575	0.2685	0.3239
growth rate	0.0457	0.051	0.0431	0.0546	0.0356	0.0424

4.2.2. Regional Differentiation of Coupling Coordination Level

Prefecture-level cities in China are divided into four regions, east, middle, west, and northeast, and the coupling and coordination degree of high-quality integrated development of DIF and rural industry in each region was calculated, respectively (Figure 4), and

Arcgis 10.6 software was used to show the coupling and coordinated development level of prefecture-level cities in 2011, 2015, and 2021 (Figure 5).

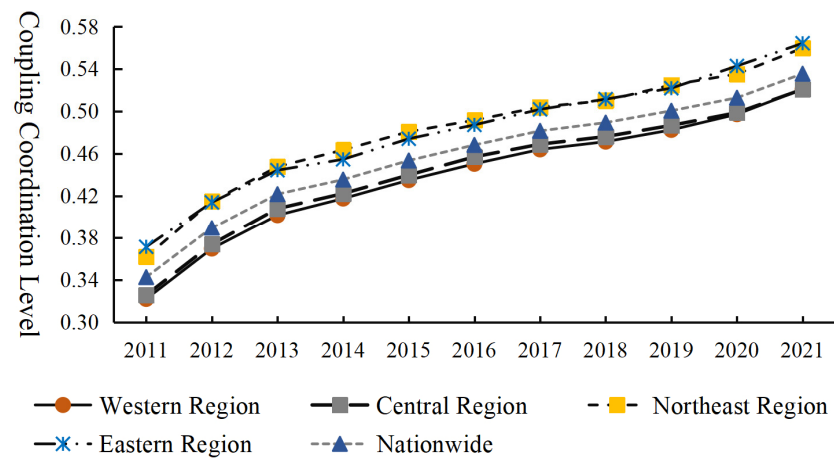


Figure 4. Spatio-temporal evolution trend of coupling coordination degree of DIF and RIID.

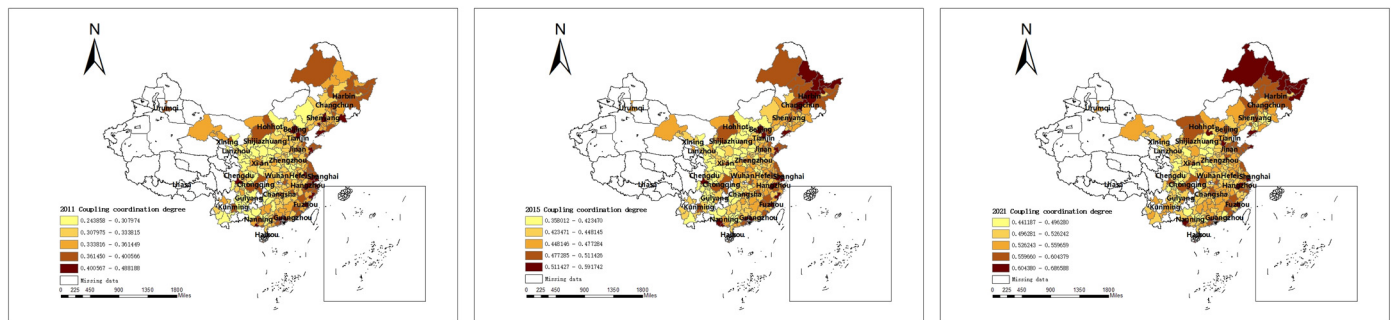


Figure 5. Regional differences in the coupling coordination of China's DIF and RIID².

First, there are significant differences in DIF and RIID between different regions in China, with higher coupling and coordination between DIF and RIID in the eastern and northeastern regions compared to the central and western regions. From 2011 to 2021, the degree of coupling and coordination between the eastern region and Northeast China is generally higher than the national average level and is in a leading position. As the leading area of China's reform and opening up, the eastern coastal areas' rural information infrastructure and industrial layout are relatively perfect, providing convenient conditions for the embedding of DIF into RIID. The northeast region presents a higher coupling coordination level, and the reason for this is that the rural industry integration level is higher, the three northeast provinces (Liaoning, Jilin, and Heilongjiang) rely on its vast rich land resources, good natural conditions, developed agricultural industry system, agricultural mechanization, and the digital application level leading the country to promote the coordinated development of the rural industry subsystem. The coupling and coordination level in the central and western regions has changed from the transition stage to the barely coordinated development stage, but there is still a gap compared with the eastern region.

Second, there is still a typical regional imbalance between the integrated development of DIF and rural industry, and the coupling degree gradually increases from west to east and forms a strip distribution along the eastern coast and the "N" spatial distribution pattern of first, then decreases, and then increases from south to north. The highly coordinated area of DIF and rural industry is dominated by rural industrial clusters in the Pearl River Delta, the Yangtze River Delta, and Harbin and Yangtze river urban agglomeration.

Third, the coupling and coordination level of high-quality integrated development of China's DIF and rural industry gradually shows the characteristics of the spatial spillover synergy of rural industry in metropolitan areas. As shown in Figure 5, the regions were coordinated in 2011, 2015, and 2021. With rapid development, the low coupling coordination area decreased year by year, and the high coupling coordination area increased year by year. With the passage of time, the coupling coordination between the east gap narrowed, "the capital urban rural industry development pole" space agglomeration function weakened, city circle rural industry gradually went from "siphon" to "spillover" development, and there was a digital agriculture development dividend gradually accelerating radiation diffusion trend to the surrounding areas. In 2021, DIF assistance to RIID in various prefecture-level cities is still mainly based on barely coordinating; its number reached 74%, the primary coordination stage above the level accounted for only 8%, and its mainly being concentrated in the eastern coastal areas and Northeast China shows that digital agriculture industry agglomeration in economic development and the resource endowment advantage area has a certain first-mover advantage.

4.2.3. Differences in the Spatial Cluster Evolution of the Coupled Coordination Degree

By comparing the spatial cluster distribution of the coupling coordination degree of the high-quality integrated development of DIF and rural industry between different urban agglomerations, we can analyze the evolution trend of the coupling cluster of the integrated development of DIF and rural industry in different urban agglomerations. From the perspective of the coupling coordination degree of various urban agglomerations in 2011, 2015, 2017, and 2021 (Table 5), the gradient ranking of RIID in different urban agglomerations has little change and has strong gradient stability. First, the coupling coordination degree of the high-quality integrated development of DIF and rural industry in urban agglomerations has evolved to the primary coordinated development direction, and has shown an upward trend at different levels. In 2011, except for the coupling coordination level of rural industries in the Pearl River Delta urban agglomeration that was on the verge of imbalance and recession, the coupling coordination degree of DIF and RIID in other urban agglomerations was mostly at or below mild imbalance. In 2015, it was on the verge of imbalance and recession, and the difference in coupling coordination degree between different urban agglomerations gradually narrowed. In 2021, it focused on the level of barely coordinated development. From the perspective of the change trend, the highest level of coupling and coordination over the years is in the Pearl River Delta urban agglomeration, and the urban agglomerations with relatively low coupling and coordination degrees are mainly Jinzhong urban agglomeration and Lanxi urban agglomeration. Although they have rich ethnic cultural resources and tourism resources, the multi-functional integrated development of rural industry is still in the initial stage of exploration, and its attraction to key elements such as agricultural technology, talent, capital, and so on is generally weak, and an effective coordination mechanism has not yet been formed for the embedded innovation of DIF [51]. Harbin Changcheng urban agglomeration and central and southern Liaoning urban agglomeration show an obvious "n" structure. In 2014, relying on the strong agricultural industry foundation and the policy dividend of revitalizing the northeast, the driving force of DIF enabling RIID gradually increased, and began to surpass that of the Yangtze River Delta urban agglomeration to rank among the top. At the same time, the growth rate of coupling and coordinated development of central and southern Liaoning urban agglomeration began to slow down, which indirectly reflects that the adjustment of rural industrial structure in the northeast needs a long amount of time. The introduction of policies has regional differences and its positive effects show a time lag.

Secondly, the coupling coordination degree of DIF and RIID presents an unbalanced state of “high in the east and low in the west” in the spatial distribution of urban agglomeration. The coupling coordination effect of DIF and RIID in the western urban agglomeration is generally lower than that in the eastern urban agglomeration. Most of the urban agglomerations with high coupling levels (Pearl River Delta urban agglomeration, Yangtze River Delta urban agglomeration, and Shandong Peninsula urban agglomeration) are located in the eastern region and are in the stage of imminent imbalance (except for Jinan). RIID in other central cities has reached the stage of being barely coordinated, while in the central and western urban agglomerations, only Wuhan in the middle reaches of the Yangtze River and Chengdu and Chongqing in the Chengdu Chongqing urban agglomeration have reached the stage of being barely coordinated. Perhaps because the eastern urban agglomeration is the first to enjoy the dividend of reform and opening up, with its first mover advantage in economic development and the geographical agglomeration advantage of capital and labor factors, the development of agricultural industry in rural areas tends to be more diversified, which is conducive to promoting the docking of DIF and embedding in the rural industrial chain network, and accelerating the development speed of the coupling and coordination level. However, the central and western urban agglomerations generally have problems such as unbalanced regional development, low levels of digital infrastructure, urban–rural integration development, and a low synergy of rural industrial development, which makes it difficult for DIF to enable RIID in urban agglomerations. However, some western urban agglomerations (such as Beibu Gulf urban agglomeration, Hubao Eyu urban agglomeration, the northern slope of Tianshan Mountain urban agglomeration, etc.) are still at the forefront of the country in terms of coupling and coordination. This is mainly due to the supporting policies such as the western development strategy in the new era and the “belt and road” initiative, as well as the prominent comparative advantages of the agricultural location of western urban agglomerations, which are more suitable for promoting the application of digital technology in the agricultural field and providing a broad industry for the integration of digital finance into basic finance, but compared with the eastern urban agglomeration, there is still a certain gap between the level of coordinated development of DIF and rural industry integration in the central and western urban agglomerations.

4.3. Analysis of the Causes of Regional Differentiation

In order to reveal the reasons for regional differentiation between the coupling coordination of China’s DIF and RIID, the Dagum Gini coefficient method is used to decompose the regional differences (Table 6) so as to explore the root causes of regional differences. The overall Gini coefficient of the coupling coordination degree of DIF and RIID in China’s four regions dropped from 0.066 in 2011 to 0.043 in 2021, with an average annual decline of 4%, indicating that the regional differences in the coupling coordination degree of DIF and RIID are gradually narrowing, and that the two are in the stage of coordinated development.

From the perspective of intra-group differences, the Gini coefficient of the coupling coordination level of the high-quality integrated development of DIF and rural industry in the east and west showed a downward trend of fluctuation, and the gap within the region was shrinking, while the northeast and central regions declined before 2018, and rose after 2019. The gap within the region has increased in recent years. Specifically, the Gini coefficient in the eastern region decreased from 0.049 in 2011 to 0.038 in 2021, with an average annual decline of 2.6%. The Gini coefficient in the western region decreased from 0.063 in 2011 to 0.031 in 2021. However, the Gini coefficient in the central region decreased from 0.038 in 2011 to 0.026 in 2018, but increased from 0.026 in 2018 to 0.038 in 2021. The regional differences showed a trend of narrowing first and then expanding. This

is mainly because Wuhan, Changsha, Nanchang, and other cities have increasingly obvious advantages in promoting the development of digital finance, scientific and technological innovation, and modern agricultural industrial systems, while other cities in the region are relatively lagging behind. From a numerical point of view, the average Gini coefficient of the northeast and eastern regions is significantly higher than that of other regions, possibly because the economic development level of cities in the eastern region such as Beijing, Shanghai, Nanjing, and Wuxi, and cities in the northeast region such as Shenyang, Dalian, and Harbin is relatively better, their modern agricultural industrial system and digital economy development are far higher than that of other cities in the region, and the regional imbalance of the coupling and coordination of high-quality integrated development of DIF and rural industry is more serious.

Table 5. Classification of coupling coordination degree between DIF and RIID among different urban agglomerations.

Location	City Clusters	Year				Compreh -Ensi ve Score	Level of RIID in Central Cities
		2011	2015	2017	2021		
Eastern urban ag- glomeration	Yangtze River Delta urban agglomeration	II	III	IV	IV	0.4819	IV (Shanghai)
	Pearl River Delta urban agglomeration	III	IV	IV	IV	0.5143	IV (Guangzhou)
	Beijing Tianjin Hebei urban agglomeration	II	III	III	IV	0.4551	IV (Beijing), IV (Tianjin)
	Shandong Peninsula urban agglomeration	II	III	IV	IV	0.4764	III (Jinan), IV (Qingdao)
	Urban agglomeration on the west coast of the Straits	II	III	IV	IV	0.4730	IV (Fuzhou), IV (Xiamen)
	Non-urban agglomeration area	II	III	III	IV	0.4530	
Northeast urban ag- glomeration	Harbin Changchun city group	II	III	IV	IV	0.4851	IV (Harbin, Changchun)
	Central and southern Liaoning urban agglomeration	II	III	III	IV	0.4686	IV (Shenyang), IV (Dalian)
	Non-urban agglomeration area	II	III	IV	IV	0.4731	
Central urban ag- glomeration	Central Shanxi urban agglomeration	II	III	III	III	0.4141	III (Taiyuan)
	Central Plains urban agglomeration	II	III	III	IV	0.4347	III (Zhengzhou)
	Urban agglomeration in the middle reaches of the Yangtze River	II	III	III	IV	0.4496	IV (Wuhan), III (Changsha)
	Non-urban agglomeration area	II	III	III	IV	0.4262	
Western urban ag- glomeration	Beibu Gulf urban agglomeration	II	III	III	IV	0.4688	III (Nanning)
	Lanxi urban agglomeration	I	III	III	IV	0.4187	III (Lanzhou, Dingxi)
	Chengdu Chongqing urban agglomeration	II	III	III	IV	0.4274	IV (Chongqing, Chengdu)
	Central Guizhou urban agglomeration	II	III	III	IV	0.4386	III (Guiyang)
	Guanzhong urban agglomeration	II	III	III	IV	0.4434	III (Xi'an)
	Ningxia urban agglomeration along the Yellow River	II	III	III	IV	0.4426	III (Yinchuan)
	Central Yunnan urban agglomeration	II	III	III	IV	0.4488	III (Kunming)
	Urban agglomeration on the northern slope of the Tianshan Mountains	II	III	IV	IV	0.4749	III (Urumqi)
	Hubao Eyu urban agglomeration	II	III	III	IV	0.4630	III (Hohhot)
	Non-urban agglomeration area	II	III	III	IV	0.4275	

Note: I, II, III, and IV refer to moderate disorder, mild disorder, imminent disorder, and barely coordinated development, respectively. The grade of the central comprehensive city is obtained from the weighted average of the coupling coordination degree of the high-quality integrated development of DIF and industry from 2011 to 2021.

From the perspective of inter-group differences, the Gini coefficient of the coupling coordination degree of DIF and RIID in each region has decreased as a whole, but it has increased slightly in some regions in recent years. Specifically, the Gini coefficient between the northeast and western regions decreased the most, from 0.087 to 0.052. The Gini coefficient between the eastern and western regions decreased the second most, from 0.075 to 0.043 (Figure 6). However, the Gini coefficient between the northeast and eastern regions showed a downward trend at first and then an upward trend. This may be because nearly half of the pilot areas of RIID in 2016 were located in the east, and only 14% of the areas were located in the northeast. The pilot areas, relying on their policy advantages, drove the continuous emergence of new forms of rural industry and new business models, spawned more diversified demand for financial services, promoted the benign interaction

between the two, and their coupling coordination also increased significantly, which made the overall regional differences between the northeast and eastern regions tend to expand.

Table 6. Regional differences and root causes of coupling coordination of DIF for RIID.

Year	Overall Gini Coefficient	Intra-regional Differences				Inter-regional Differences					Over Variable Density Contribution (%)			
		Northeast China	East	Central	West	Northeast and East	Northeast & Central	Northeast and West	East and Central	East and West	Central and West	Within the Area	Inter-regional	Hypervariable Density
2011	0.066	0.064	0.049	0.038	0.063	0.058	0.076	0.087	0.062	0.075	0.052	22.75	50.90	26.35
2012	0.054	0.040	0.055	0.028	0.048	0.049	0.057	0.068	0.060	0.071	0.041	22.34	51.24	26.42
2013	0.050	0.039	0.050	0.028	0.046	0.046	0.052	0.065	0.052	0.065	0.040	22.73	49.90	27.37
2014	0.047	0.036	0.049	0.030	0.043	0.044	0.052	0.061	0.050	0.058	0.038	23.30	47.49	29.21
2015	0.046	0.043	0.045	0.028	0.039	0.045	0.051	0.060	0.048	0.056	0.036	22.79	48.63	28.57
2016	0.042	0.041	0.041	0.028	0.038	0.041	0.046	0.055	0.043	0.052	0.035	23.20	46.39	30.41
2017	0.043	0.044	0.042	0.027	0.038	0.043	0.047	0.054	0.044	0.052	0.034	23.19	45.03	31.78
2018	0.044	0.041	0.049	0.026	0.039	0.045	0.045	0.054	0.047	0.055	0.035	22.87	44.81	32.33
2019	0.043	0.051	0.038	0.027	0.039	0.046	0.050	0.057	0.043	0.052	0.035	22.58	45.29	32.13
2020	0.042	0.052	0.037	0.028	0.038	0.046	0.051	0.055	0.042	0.049	0.035	23.03	40.85	36.12
2021	0.042	0.052	0.038	0.038	0.031	0.046	0.055	0.052	0.047	0.043	0.035	23.56	38.37	38.07

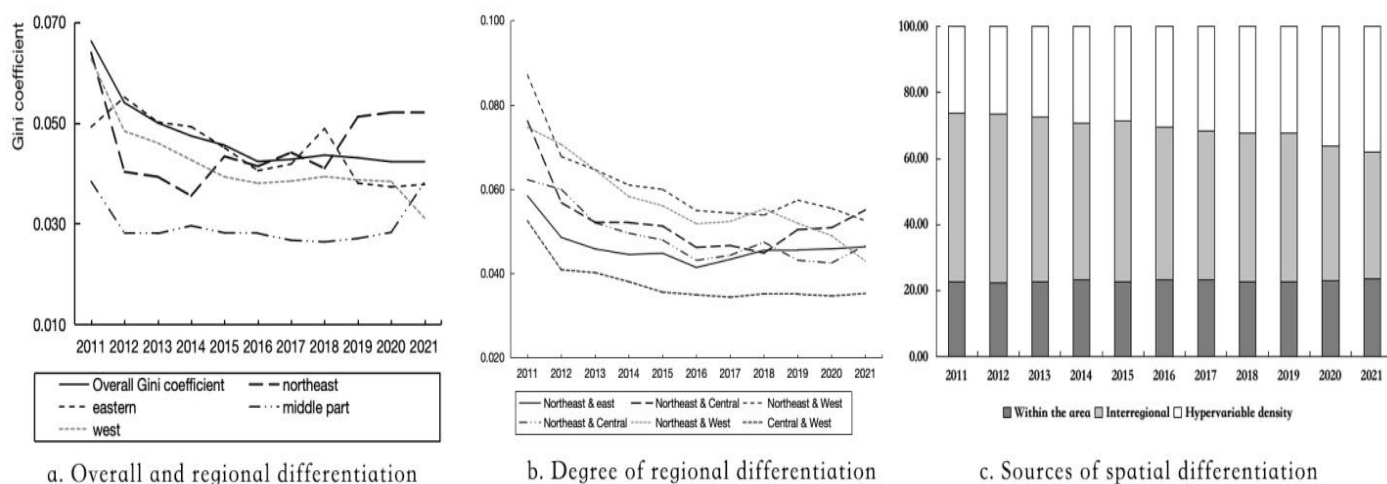


Figure 6. Variation and contribution rate of Gini coefficient of regional coupling coordination degree.

From the perspective of the sources of differences, the differences in the coupling coordination degree of DIF and RIID in different regions from 2011 to 2021 were mainly caused by regional differences, and the contribution rate of regional differences decreased from 50.9% in 2011 to 38.37% in 2021. The contribution rate of regional differences ranged from 22.75% to 23.56%, and the overall fluctuation was relatively stable. The contribution rate of super variable density increased from 26.35% in 2011 to 38.07% in 2021, showing a fluctuating upward trend, indicating that the region with a high degree of coupling and coordination also has the phenomenon of the internal differentiation of urban agglomerations, which is still expanding.

5. Spatial Coupling Correlation Analysis

5.1. Spatial Coupling Effect

In order to further explore the spatial effect of the coupling coordination degree between different intercity DIF and RIID, Moran's I index was used for spatial autocorrelation analysis. From Table 7, it can be seen that the coupling coordination degree of China's intercity DIF and RIID was significantly positive from 2011 to 2021, but the Moran's I index showed a downward trend of fluctuation, indicating that the coupling coordination between different intercity DIFs and RIIDs were not independent of each other, but had significant characteristics of spatial agglomeration. Areas with a good foundation for rural

industry development had strong radiation-driving ability, demonstrated an effect and scale advantage to drive the development of rural industry in surrounding areas, and attracted more financial resources and digital technology scenarios to be embedded in the process of rural industry integration and development in these areas [52], so as to promote the continuous coupling and coordination of DIF and rural industry integration. At the same time, DIF also has a strong spatial spillover effect in the process of enabling RIID. Through financial agglomeration and financial innovation, it can accelerate RIID, realize economies of scale and technology spillover, promote the effective flow of production factors among regions, and form a coupled and coordinated spatial agglomeration distribution pattern.

Table 7. Regional spatial Moran's I index change in DIF to promote RIID.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Moran index	0.402 ***	0.405 ***	0.374 ***	0.368 ***	0.390 ***	0.363 ***	0.380 ***	0.367 ***	0.381 ***	0.380 ***	0.346 ***
Z value	10.244	10.334	9.539	9.399	9.958	9.252	9.681	9.360	9.721	9.692	8.840

Note: *** means significant at 1% level.

Figure 7, respectively, selects four important time nodes in 2011, 2015, 2017, and 2021 to draw the spatial scatter diagram of the coupling coordination degree of the high-quality integrated development of DIF and rural industry, so as to reflect whether the coupling coordination degree of the national DIF and RIID has the evolution characteristics of temporal and spatial agglomeration in its adjacent regions. The results show that the number of regions in the first and third quadrants is significantly more than that in the second and fourth quadrants, indicating that “high-high” and “low-low” agglomeration areas are more common, and that adjacent cities will interact with each other, while the points in the third quadrant are significantly more than those in the first quadrant, and the coupling and coordinated agglomeration of high-quality integrated development of DIF and rural industry at a low level is more significant.

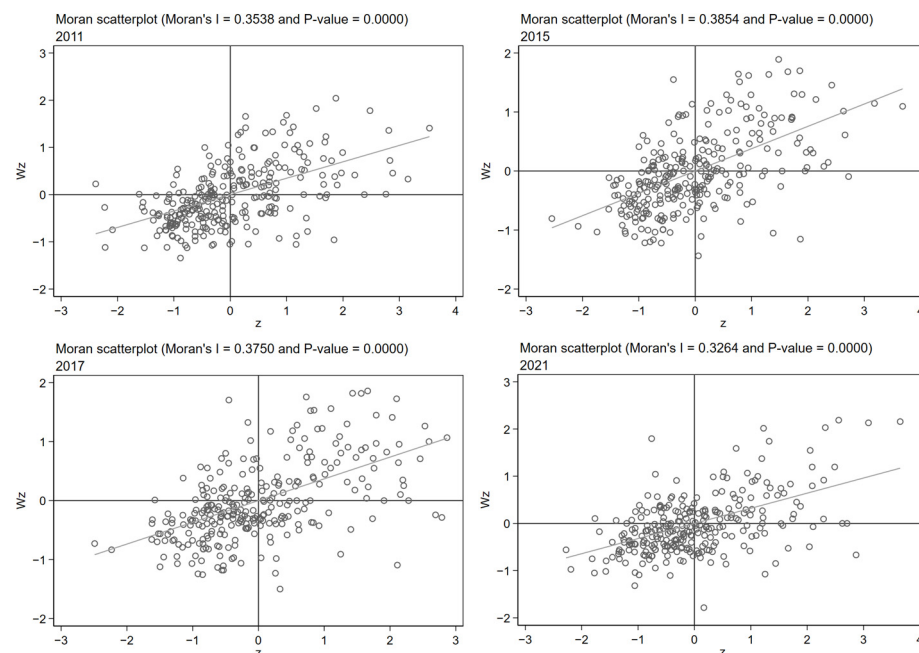


Figure 7. Spatial Moran's I scatter diagram of integrated development of DIF and rural industry.

In order to further investigate the spatial coupling correlation degree of different urban agglomerations, cities with a significance level of 5% are selected. The agglomeration

types of some regions in 2011, 2015, and 2021 are shown in Table 8. It is found that the “high–high” agglomeration areas of the four time node coupling coordination schedulings are mainly located in the Yangtze River Delta in the eastern region, the urban agglomeration on the West Bank of the Strait, and the central and southern Liaoning and Harbin Changcheng urban agglomeration in the northeast region. Among them, Xiamen, Jiaxing, Ningbo, Wenzhou, Shenyang, Harbin, and other cities have always been in the ranks of high concentration, probably because the eastern region is the leading region in the development of digital economy. The depth and degree of DIF in cities in the region are generally high, and the innovation ability of digital finance embedded in the RIID scene is relatively strong. It not only has a high level of coupling and coordination, but it also has played a good role in driving the development of surrounding cities. However, Shenyang, Harbin, Panjin, and other cities in Northeast China have effectively stimulated the integration of digital finance into rural industrial development due to the continuous release of national policy dividends such as the revitalization of Northeast China and the construction of modern agriculture. The “high–low” agglomeration areas are mainly located in the central Yunnan and Chengdu Chongqing urban agglomerations in the western region. Chongqing, Chengdu, and Kunming have always been in the high–low agglomeration ranks. These cities’ own economic development level is relatively leading, and the level of good interaction between the high-quality integrated development of DIF and rural industry is high, while the coupling development level of the surrounding prefecture-level cities is low, resulting in the phenomenon that the “siphon” effect is stronger than the “spillover” effect. Especially in recent years, the “Chengdu Chongqing economic double city circle planning outline” proposed to vigorously develop the digital economy in the economic circle, and made a top-level layout for accelerating the development of the digital economy in the Chengdu Chongqing economic circle. The advantages of “dual core” digital financial resources in Chengdu and Chongqing are more obvious, while the digital economy development in non-core cities has a time lag, which further exacerbates the imbalance and disharmony between the development of DIF and the integration of rural industries in the region.

Table 8. Distribution of intercity spatial clusters with high-quality integrated development of DIF and rural industry.

Type of Change	Regional Distribution of Rural Industrial Clusters
“H-H” agglomeration and stability zone	East: Suzhou, Wuxi, Jiaxing, Ningbo, Shaoxing, Taizhou (Yangtze River Delta urban agglomeration); Fuzhou City, Sanming City, Xiamen City, Wenzhou City (urban agglomeration on the West Bank of the Strait); Northeast China: Panjin City, Shenyang City (central and southern Liaoning city group); Daqing City, Harbin City (Harbin Great Wall City Group); Hegang City, Jixi City, Baishan City
“L-L” agglomeration and stability zone	East: Handan and Xingtai (Beijing Tianjin Hebei urban agglomeration); West: Anshun City, Zunyi City (Central Guizhou urban agglomeration); Shizuishan City and Wuzhong City (Ningxia urban agglomeration along the Yellow River); Baiyin City, Dingxi City, Lanzhou City (Lanxi urban agglomeration); Tongchuan and Weinan (Guanzhong urban agglomeration); Dazhou, Deyang, Guang’an, Leshan, Luzhou, Nanchong, Neijiang, Suining, Ya’an, Yibin, Ziyang and Zigong (Chengdu Chongqing urban agglomeration); Longnan City, Qingyang City, Tianshui City, Wuwei City, Zhangye City, Guyuan City, Ankang City, Yan’an City, Bazhong City, Guangyuan City, Panzhihua City, Baoshan City, Zhaotong City; Central China: Luohe City, Pingdingshan City, Xinxiang City, Jincheng City, Yuncheng City, Changzhi City (Central Plains urban agglomeration); Jingmen City, Jingzhou City, Xiaogan City, Loudi City, Yiyang City, Yichang City (urban agglomeration in the middle reaches of the Yangtze River); Jinzhong City, Luliang City and Yangquan City (Jinzhong urban agglomeration); Xuchang, Shiyan, Huaihua, Shaoyang, Zhangjiajie, Linfen, Xinzhou
“H-L” agglomeration and stability zone	West: Kunming (Central Yunnan urban agglomeration); Chengdu, Chongqing (Chengdu Chongqing urban agglomeration)
“L-L” agglomeration to “H-L” transition zone	East: Baoding (Beijing Tianjin Hebei urban agglomeration); Central China: Nanyang City, Jiaozuo City, Zhumadian City (Central Plains urban agglomeration); Changde City (urban agglomeration in the middle reaches of the Yangtze River); Sanmenxia City, Shouzhou City; West: Qujing and Yuxi (Central Yunnan urban agglomeration); Lijiang City, Bayannaoer City

The transition path of the coupling coordination degree of the high-quality integrated development of DIF and rural industry is mainly based on the transformation of “H-H agglomeration”, “L-L agglomeration”, and “L-L agglomeration” to “H-L agglomeration”,

and “L-H agglomeration” to “H-H agglomeration”, but there is no region of transformation from “L-L agglomeration” to “H-H agglomeration”, which reflects that there is a strong stability in the spatial agglomeration state of the coupling and coordinated development between cities, and homogeneous areas find it difficult to get rid of the shackles of the original rural industrial spatial clusters.

5.2. Spatial Coupling Network Correlation Analysis

Based on the modified gravity model, this paper uses software to explore the dynamic evolution trend of the coupling and coordination of spatial network correlation between the high-quality integrated development of DIF and rural industry in various cities [53]. It can be seen from Table 9 that the overall network density shows a fluctuating upward trend, rising from 0.1517 in 2011 to 0.1583 in 2021, and the spatial correlation of various regions is gradually close. Especially in 2015, the network density has been significantly increased, which is mainly due to the enhancement of policy support for the pilot of RIID, which provides strong policy support for encouraging the integration and development of DIF embedded in new rural industries, new business forms, and new scenes, making the number of spatial network connections for the rationalization of rural industrial structure continue to increase, and the overall network tightness has been significantly improved. However, from the perspective of the correlation coefficient, the degree of correlation between local cities is still not high on the whole, and it is still necessary to continue to strengthen the close cooperation between local cities in the coordination and efficiency of finance and rural industry. The network correlation degree from 2011 to 2021 has been 1, which indicates that the spatial coupling network correlation degree of high-quality integrated development of DIF and rural industry in various cities is high. The average network correlation efficiency from 2011 to 2021 was 0.77, indicating that the stability of the spatial network correlation degree of the coordinated development of high-quality integration of rural industries and DIF in prefecture-level cities was good.

Table 9. Spatial network correlation characteristics of coupling coordination levels of DIF and RIID.

Year	Network Density	Number of Network Connections	Network Relevance	Network Efficiency
2011	0.1517	12,020	1	0.7811
2012	0.1541	12,208	1	0.7764
2013	0.1556	12,328	1	0.7728
2014	0.1574	12,472	1	0.7700
2015	0.1604	12,713	1	0.7655
2016	0.1617	12,814	1	0.7631
2017	0.1595	12,636	1	0.7654
2018	0.1517	12,020	1	0.7786
2019	0.1534	12,154	1	0.7756
2020	0.1563	12,382	1	0.7701
2021	0.1583	12,543	1	0.7681

Using the multiple measures algorithm in UCINET 6 software, the degree centrality, proximity centrality, and intermediate centrality of the node characteristics of the coordinated development network of high-quality integration of rural industries and DIF in 2021 are calculated. The results are shown in Figure 8. The spatial distribution characteristics of degree centrality and proximity centrality are similar, and the central and eastern regions have stronger control ability than the western and northeastern regions. Specifically, at the degree centrality level, Shanghai, Wuxi, Suzhou, Nanjing, Beijing, and other regions rank relatively high. These regions have strong overall network relevance in the process

of promoting the coupling and coordination of the high-quality integrated development of DIF and rural industry, while Bayannaoer, Ulanqab, Shizuishan, Langfang, Xuancheng, Chengde, and other prefecture-level cities rank low, and their spatial network relevance with adjacent regions is weak. From the perspective of closeness to the center, only more than 50 cities, such as Shanghai, Wuxi, Suzhou, and Beijing, are above the average. These regions play a central role in the coordinated promotion of the network structure of RIID and DIF. They are less dependent on other adjacent regions and have a strong ability to gather resources. From the perspective of intermediate centrality, the low value is mostly located in the northeast and western regions, which are in a relatively marginal and weak position in the association network, while the regional differentiation among cities in the eastern region is more serious. The developed eastern regions rank high in Shanghai, Beijing, Suzhou, Nanjing, Hangzhou, and other regions, and play a “bridge” intermediary role in the spatial network association of the high-quality integration of rural industries and the coordinated development of DIF, while the eastern regions such as Binzhou in Shandong, Chengde in Hebei, and Taizhou in Zhejiang, which have a small population or small economic scale, have a relatively low level of coupling and coordination, and are in a subordinate position in the spatial network.

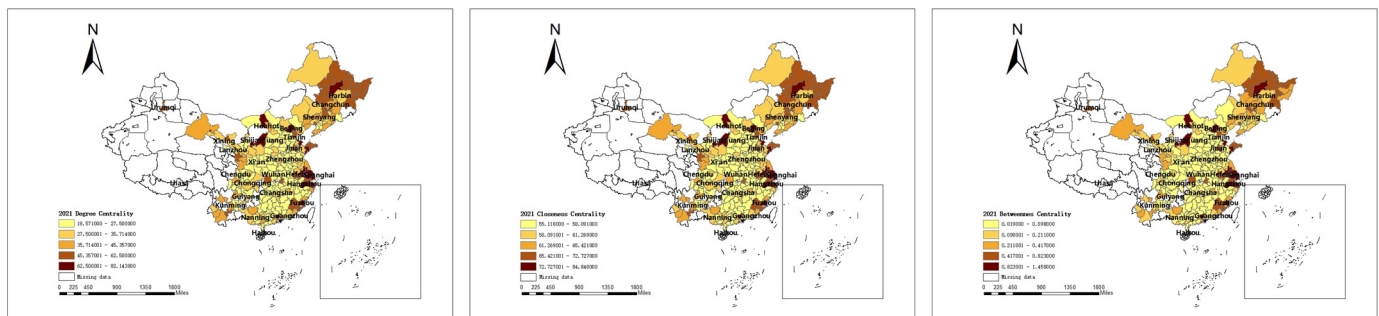


Figure 8. Network association spatial distribution of DIF and RIID³.

6. Research Conclusions and Policy Implications

6.1. Conclusions

This study uses panel data from 282 prefecture-level cities in China from 2011 to 2021 as the sample and employs coupling coordination models, spatial correlation analysis, and social network analysis to explore the characteristics of changes in the coupling coordination level of digital inclusive finance and rural industrial integration. The research findings are as follows: (1) The coupling coordination degree of DIF and RIID shows an overall upward trend, with significant gradient characteristics. However, the coupling coordination development level of each subsystem is still in a mildly imbalanced state, with certain structural differences. (2) There are regional differences in the coupling coordination development levels, with smaller differences in the western region, while internal differences in the eastern and northeastern regions have increased, mainly due to inter-regional disparities. Over time, these regional differences gradually diminish, and the spatial distribution pattern of rural industrial integration circles shifts from a “siphoning” model to a “radiation” model. (3) There are significant spatial spillover effects in the coupling coordination development levels, with high–high and low–low clustering phenomena being common, and the clustering state in each region shows strong stability. (4) In the overall spatial network correlation, the coupling network of the high-quality integration of digital inclusive finance and rural industries continuously improves in closeness and stability, but there is still considerable room for improvement in network tightness.

6.2. Policy Recommendations

Regional differences in the coupling coordination between DIF and RIID stem from several factors:

Economic Development and Infrastructure: Developed eastern metropolitan areas benefit from strong economies and advanced infrastructure, facilitating better access to digital finance and supporting rural industry transformation. In contrast, underdeveloped regions face challenges due to weaker economies and lower digitalization.

Policy Support and Resource Allocation: Developed regions receive stronger policy support and resource distribution for digital finance and rural industry projects, while underdeveloped areas face financial constraints and inefficient policy execution.

Resource Mobility and Network Effects: Urban clusters attract capital, technology, and talent, fostering innovation and supporting digital finance and rural industry integration. Underdeveloped areas lack these resources, limiting their potential for rural development through digital finance.

Policy Recommendations:

- (1) Financial institutions should expand the application of digital inclusive finance in rural industries, leveraging its potential to promote the high-quality integration of rural industries. More targeted and personalized financial services should be developed, with innovative products introduced to meet the specific needs of rural industries, thereby promoting sustainable development.
- (2) Local governments should accelerate efforts to narrow the gap in the integration of digital inclusive finance and rural industries across regions and urban agglomerations. Developed metropolitan areas should utilize their comparative advantages to direct high-quality resources to underdeveloped regions, particularly in the central and western areas, driving the penetration of digital inclusive finance and fostering more balanced regional development.
- (3) The government should continue supporting rural industry integration, especially in underdeveloped areas, by promoting the development of advantageous industrial clusters. Targeted support policies should be implemented to prevent resource over-concentration in high-coupling areas, avoiding the creation of industrial “deserts.” At the same time, ongoing reforms to rural property rights systems should be pursued to encourage business model innovation and provide support for the coordinated integration of digital finance and rural industries.
- (4) Governments, financial institutions, and enterprises should strengthen coordination and cooperation in digital finance across regions. By breaking down regional barriers and establishing cross-regional cooperation mechanisms, they can facilitate the flow of resources such as technology, talent, and capital, optimizing resource allocation and driving the development of high-quality rural industries.

6.3. Deficiencies and Future Prospects

This study also acknowledges several potential limitations: (1) **Data Limitations:** The research faces challenges due to the limited availability and inconsistency of data from various prefecture-level cities across China. The disclosure of data related to key variables is incomplete, which restricts the comprehensiveness of the measurement of rural industrial integration development indicators. (2) **Focus of the Study:** While this paper focuses on exploring the coupling coordination between DIF and RIID, it does not extensively analyze the internal and external driving factors that facilitate their coordinated development. This represents a significant area for future research to delve deeper into the mechanisms and influences that drive this coordination. (3) **Generalizability:** The study’s findings are based

on the context of DIF and RIID in China. To enhance the broader applicability of the results, further validation in other countries and regions is necessary.

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Notes

- ¹ Synchronization imbalance type: industrial integration index < 0.115, digital inclusive finance index < 0.739; Lagging type of digital Inclusive Finance: 0.115 < industrial convergence index < 0.30, digital inclusive finance index < 0.739; Synchronous development type: 0.115 < industrial integration index < 0.30, 0.739 < digital inclusive finance index < 1; Lagging Industrial Convergence: 0.115 < industrial convergence index < 0.30, 0.739 < digital inclusive finance index < 1
- ² Note: Based on the standard map GS (2024) 0650 [50] from the Standard Map Service website of the Ministry of Natural Resources.
- ³ Degree centrality measures the number of direct connections a node has, reflecting its direct influence or activity level; closeness centrality measures the average distance from a node to all other nodes, indicating its efficiency in information dissemination; betweenness centrality measures the frequency with which a node appears on the shortest paths between all pairs of nodes, highlighting its strategic importance as a “bridge” or “intermediary”.

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