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Digital Finance and Industrial Chain Resilience in China: A Spatial Network Perspective

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Abstract: Digital finance has increasingly influenced the functioning and stability of industrial systems by reshaping interregional economic linkages. Based on panel data from 31 Chinese provinces spanning the period 2012–2021, this study investigates how the development of digital finance is associated with the spatial structure of industrial chain resilience. A modified gravity model is used to construct interprovincial interaction networks, and social network analysis is applied to examine their structural characteristics and temporal evolution. The empirical results show that the spatial network related to digital finance and industrial chain resilience has become progressively more connected over time, as reflected by a gradual increase in network density. However, substantial regional heterogeneity persists in network position and influence. Provinces with relatively advanced digital finance tend to occupy more central positions and exert stronger structural influence, whereas peripheral provinces remain weakly connected and play limited roles within the network. This asymmetric network configuration constrains the overall stability of the industrial chain system and highlights the importance of coordinated development in digital finance for improving systemic resilience.

Keywords: Digital finance; Industrial chain resilience; Spatial network; Gravity model; Social network analysis

1 Introduction

In an increasingly interconnected economic environment, the stability of industrial chains has become a central concern in discussions of regional development and economic governance. Disruptions arising from technological change, market volatility, and external shocks have exposed structural vulnerabilities within industrial systems, drawing attention to the role of industrial chain resilience in maintaining system continuity and risk tolerance. Understanding how such resilience is formed and sustained has therefore become an important issue in the management and coordination of complex economic systems.

Digital finance, as a core component of the digital economy, has altered traditional patterns of financial intermediation by reshaping the ways in which capital, information, and financial services are allocated across regions. Existing studies suggest that digital finance can ease financing constraints, reduce information frictions, and broaden access to financial services, thereby influencing regional economic performance and industrial development [1, 2]. Beyond its direct financial functions, digital finance may also affect the structural configuration of industrial systems by modifying interregional linkages and resource allocation patterns. However, the mechanisms through which digital finance interacts with industrial chain resilience remain insufficiently understood, particularly from a spatial and structural perspective.

From a management and decision-making standpoint, industrial chain resilience is not only determined by the performance of individual regions, but also shaped by the network of interregional interactions in which they are embedded. Differences in the development of digital finance across regions may lead to asymmetric network positions, resulting in heterogeneous levels of influence and control within industrial systems. Such structural asymmetries can amplify regional disparities and constrain the overall stability of industrial chains. Despite growing interest in the relationship between digital finance and industrial resilience, existing research has largely focused on direct effects, with limited attention paid to the underlying network structure and its evolution over time.

To address this gap, this study adopts a spatial network perspective to examine the relationship between digital finance and industrial chain resilience in China. Using panel data from 31 provinces over the period 2012–2021, a modified gravity model is employed to construct interprovincial interaction networks, which are subsequently analyzed using social network analysis. By examining both spatial structure and temporal evolution, this study aims to reveal how regional differences in digital finance development shape the configuration of industrial chain resilience and to provide insights into the management of complex industrial systems.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the research hypotheses and methodological framework. Section 4 analyzes the spatial network characteristics and their evolution. Section 5 concludes with a discussion of the main findings and their implications.

2 Literature Review

Digital finance has been widely discussed in the literature as an outcome of the integration between financial services and digital technologies. International studies generally define digital finance as a financial system that relies on internet technologies and financial innovations to provide more efficient and accessible financial services [3]. The rapid development of digital finance has reshaped the traditional financial sector and exerted broader influences along economic and industrial chains [4]. In practice, digital finance encompasses a range of activities, including online payments, internet banking, peer-to-peer lending, digital currencies, and blockchain-based financial applications [5].

A substantial body of research indicates that digital finance can overcome geographical constraints and spatial frictions by expanding financial coverage and improving service efficiency. Its characteristics, such as wide accessibility, scalable service provision, and relatively low transaction costs, enable digital finance to better accommodate the demands of industrial upgrading and structural transformation [6]. Through digital infrastructure and data-driven platforms, digital finance facilitates information sharing, resource allocation, and service delivery, while reducing financial exclusion and lowering transaction costs [7]. These features help alleviate financing constraints faced by entrepreneurs and small firms, stimulate new business models, and expand entrepreneurial opportunities [8]. At a macro level, improvements in digital finance coverage, usage intensity, and technological sophistication have been shown to contribute to higher-quality economic development [9, 10].

The concept of resilience was initially introduced in early ecological and engineering studies and later extended to economic analysis. Scholars such as Reggiani and Rajesh applied the notion of economic resilience to explain the instability, adaptability, and complexity of economic systems, which subsequently became a foundational concept in regional and industrial studies [11, 12]. Building on this theoretical foundation, research in industrial economics gradually introduced the concepts of industrial cluster resilience and industrial chain resilience by integrating resilience theory with supply chain and industrial organization perspectives. In this context, industrial chain resilience is generally understood as the capacity of an industrial system to adjust, absorb shocks, and recover when exposed to external disturbances [13].

An industrial chain is typically viewed as an integrated production and supply system that links upstream raw material procurement, midstream manufacturing and processing, and downstream distribution and services. Accordingly, industrial chain resilience refers to the ability of this system to respond effectively to changes in the external environment, reduce potential losses, and maintain continuity and stability in production and supply processes [14]. Existing studies have identified several key factors influencing industrial chain resilience. Structural complexity has been found to enhance resilience by strengthening interconnections among internal links, thereby improving adaptability under external shocks [15]. Internal synergies within the industrial chain, including information sharing, resource complementarity, and collaborative innovation, also play an important role in mitigating risks and reinforcing resilience [16]. Technological capability is another critical factor, as higher technological levels enable industrial chains to better adapt to environmental changes and sustain performance [17]. In addition, risk management mechanisms—such as risk identification, assessment, prevention, and response—contribute to improving resilience by enhancing the capacity to cope with uncertainty and disruption [18]. Policy-related factors have also been emphasized, with studies suggesting that an appropriate policy environment, financial support, and innovation incentives can provide important safeguards for industrial chain resilience [19].

Domestic research further conceptualizes industrial resilience in terms of multiple dimensions, including shock absorption capacity, adaptive capacity, and recovery or renewal capacity [20]. From this perspective, industrial chain resilience reflects the ability of each link within the chain to withstand internal and external shocks, maintain system stability, and prevent chain disruption [21]. Some studies define it more broadly as the overall capacity of industrial chains to respond to diverse forms of disturbance [22]. Related research has also extended the concept to supply chain resilience, emphasizing the ability of supply chains to cope with and recover from both internal and external shocks [23].

Although the relationship between digital finance and industrial chain resilience has attracted increasing attention, direct investigations remain relatively limited. Most existing studies approach this relationship indirectly. Some scholars argue that digital finance can improve overall industrial chain resilience by increasing financial service penetration, improving transaction efficiency, and strengthening coordination between upstream and downstream enterprises [24]. Others find that digital finance reduces transaction and operational costs, enhances firm competitiveness, and thereby contributes to greater resilience within industrial chains [25]. Improved risk management enabled by digital finance has also been identified as a mechanism through which firms can better identify, assess, and respond to potential risks in a timely manner [26]. By expanding financing channels and offering more flexible financial services, digital finance helps alleviate financial constraints faced by enterprises, which further supports industrial chain stability [27]. As a result, digital finance influences industrial chain resilience through multiple channels, including efficiency improvement, cost reduction, enhanced risk management, and improved access to finance [28].

The growing reliance of industrial chains on information technologies has further reinforced the role of digital finance in shaping industrial resilience. Digital finance enables more efficient information exchange and processing, supporting refined management practices and data-driven decision-making across industrial systems [29]. By facilitating information sharing and inter-firm cooperation, digital finance reduces trust-related costs and improves coordination efficiency, which contributes to stronger internal synergies and resilience within industrial chains [30]. In addition, digital finance supports the development of new business models and innovative products, promoting the transformation and upgrading of traditional industries and improving their capacity to adapt to market changes [31]. Related studies on digital technologies more broadly highlight their role in stimulating firms' internal potential, optimizing supply chain processes, and strengthening supply chain resilience [32]. Empirical evidence from epidemic contexts further demonstrates that digital technologies enhance firms' responsiveness to disruptions, reduce adjustment costs, and improve supply chain robustness and memory [33, 34].

Recent studies have also explored more specialized contexts, such as green digital finance and digital infrastructure. Green digital finance has been shown to enhance the coordinated resilience of low-carbon industrial chains by lowering financing barriers for environmentally friendly industries, strengthening public environmental preferences, and accelerating information diffusion related to low-carbon development [35]. Digital infrastructure strategies implemented in pilot regions have enabled industrial chains to achieve stronger resistance to disruption and faster recovery by supporting real-time monitoring, early risk warning, and cross-regional capacity coordination [36]. Other studies examine the role of supply chain digitization through multiple mediation frameworks and find that digital transformation improves resilience and performance by enhancing process management, information integration, and product synergy [32, 37]. A variety of empirical approaches—including structural equation modeling, fuzzy-set qualitative comparative analysis, fixed-effects panel models, and case studies—have been employed to analyze the impact of digital finance and digital technologies on supply chain and industrial resilience [38–42].

Despite these advances, several limitations remain in the existing literature. First, direct analysis of the relationship between digital finance and industrial chain resilience remains relatively scarce, with most studies focusing on related but distinct concepts such as the digital economy, industrial structure resilience, or urban economic resilience. Second, limited attention has been paid to the spatial correlation and interregional spillover effects associated with digital finance in the context of industrial chain resilience. Traditional empirical methods often struggle to capture the complex relational structures among multiple regions. As a result, the underlying network characteristics and spatial interaction patterns remain insufficiently explored. To address these gaps, this study applies the quadratic assignment procedure (QAP) and social network analysis to construct and analyze a spatial correlation network of digital finance and industrial chain resilience. This approach allows for a systematic examination of the overall spatial structure, its temporal evolution, and the differentiated roles of individual regions within the network.

3 Research Hypothesis and Research Design

3.1 Research Hypotheses

3.1.1 Impact of digital finance on industrial chain resilience

Drawing on the inclusive finance mechanism proposed by Hasan et al. [1] and the digitalization framework of supply chains discussed by Ivanov et al. [25], existing studies suggest that digital finance may influence industrial chain resilience through multiple channels, including transaction cost reduction [3] and improvements in risk control capacity [26]. As a financial model that integrates digital technologies with traditional financial services, digital finance is characterized by broad accessibility, relatively low transaction costs, and operational efficiency, which distinguishes it from conventional financial systems.

From a structural perspective, digital finance can improve the alignment between capital supply and demand within industrial chains by alleviating information asymmetry and reducing coordination frictions among upstream and downstream entities. By facilitating more continuous and predictable capital flows, digital finance contributes to the stability of inter-firm linkages and operational continuity along the chain. In addition, the application of data-driven credit assessment expands the informational basis for evaluating firms' creditworthiness, allowing for more accurate risk identification and financing decisions. This, in turn, improves firms' access to external financing and supports the functioning of industrial chains under conditions of uncertainty.

Moreover, digital finance enables greater diversification of financial services through collaboration with multiple capital providers and the expansion of service delivery channels. Such diversification improves the matching efficiency between financial supply and the heterogeneous financing needs of firms within the industrial chain, thereby reducing systemic vulnerability arising from financial concentration. Taken together, these mechanisms suggest that digital finance can influence the structural configuration and operational stability of industrial chains, with potential implications for their resilience.

Based on the above analysis, the following hypothesis is proposed:

H1: Digital financial inclusion has a positive structural effect on industrial chain resilience.

3.1.2 Spatial spillover effects of digital finance on industrial chain resilience

According to Tobler's first law of geography [43], economic activities are spatially interdependent, and interactions among neighboring regions tend to be stronger than those among distant ones. Building on this principle, studies on interregional collaboration, such as that by Dubey et al. [30], indicate that economic and technological linkages often generate spillover effects across regional boundaries. In the context of digital finance, such spillovers may arise through several spatial mechanisms.

First, digital finance reduces the dependence of financial services on physical proximity, thereby weakening traditional geographical constraints and allowing financial resources to circulate more freely across regions. This diffusion process creates a radiation effect, whereby improvements in digital finance development in one region may influence surrounding regions through interconnected financial and industrial networks. Second, differences in the level of digital finance development across regions may give rise to a siphon effect. Regions with more advanced digital finance systems tend to attract capital, talent, and other production factors by offering higher returns and more efficient financial services, leading to a spatial concentration of high-quality resources. Third, an aggregation effect may emerge as neighboring firms learn from leading regions and adopt complementary strategies, particularly in research and development activities. Such interactions can stimulate innovation dynamics and contribute to the formation of regional industrial clusters.

Through these channels, digital finance may not only affect industrial chain resilience within a given region but also influence the resilience of industrial chains in neighboring regions via spatial interactions and factor mobility. On this basis, the following hypothesis is formulated:

H2: The positive effect of digital finance on industrial chain resilience exhibits spatial spillover effects.

3.2 Research Design

3.2.1 Generation of the gravity model

The gravitation model is a classical analytical framework in regional economics, originally developed by Tinbergen [44] based on the physical principle of gravitation. By linking the intensity of interaction between regions to their economic attributes and spatial distance, the model provides a parsimonious representation of cross-regional relationships. Owing to its flexibility, the gravitation model has been widely applied in studies of spatial interaction, regional connectivity, and economic linkage structures.

In the context of this study, the gravitation model is adopted to characterize interprovincial interactions associated with digital finance and industrial chain resilience. Industrial chains operate through interconnected regional systems rather than isolated units, and differences in regional financial development may lead to asymmetric interaction patterns. To capture such heterogeneity, the traditional gravitation model is modified to incorporate indicators reflecting digital finance development and industrial characteristics, thereby allowing interaction intensity to vary across provinces [45].

On this basis, a spatial interaction network is constructed to represent the structural relationships among provinces in terms of the impact of digital finance on industrial chain resilience. The specification of the modified gravitation model is presented as follows:

$$\begin{gathered} R_{ij} = K_{ij}\frac{\sqrt[3]{GC_iP_iIC_i}\,\sqrt[3]{GC_jP_jIC_j}}{D_{ij}^2} \\ K_{ij} = \frac{GC_i}{GC_i + GC_j} \end{gathered} \tag{1}$$

3.2.2 Gravitation model metrics description

R_{ij} denotes the linkage intensity between province iand province jin terms of the impact of digital finance on industrial chain resilience. K_{ij} represents the contribution weight of province ito the bilateral linkage R_{ij}, which reflects the relative level of digital finance development. GC_i and GC_j denote the digital finance indices of provinces iand j, respectively.

P_i and P_j represent the total resident population of provinces iand j. Population size is introduced to capture differences in economic scale and the diversification potential of local industrial systems. INC_i and INC_j denote the levels of industrial chain resilience in provinces iand j, respectively.

D_{ij} denotes the geographical distance between the capital cities of provinces iand j. In this study, distance is used as a proxy for spatial separation and interaction costs between regions [46].

3.2.3 Processing of the gravity matrix

Based on the modified gravitation model, a gravity matrix describing interprovincial interactions among 31 provinces in China over the period 2012–2021 is constructed. Each element of the matrix reflects the intensity of interaction between a pair of provinces with respect to the relationship between digital finance and industrial chain resilience.

To facilitate subsequent network analysis, the continuous gravity matrix is transformed into a binary adjacency matrix. Following established practice in social network analysis [47], the average value of each row in the gravity matrix is used as a threshold. For a given row, matrix elements exceeding the corresponding average value are assigned a value of 1, indicating the presence of a spatial linkage, while elements below the threshold are assigned a value of 0, indicating the absence of a linkage.

Through this procedure, a spatial interaction network is constructed to capture the structural relationships among provinces and to examine how digital finance is associated with the resilience of industrial chains within a network framework.

3.3 Measuring the Standard Elasticity of the Industrial Chain and E-Finance

3.3.1 Measurement of industrial chain resilience

Industrial chain resilience is generally understood as the capacity of an industrial system to withstand external disturbances, maintain operational continuity, and adjust its internal structure in response to changing risk conditions. Existing studies emphasize that such resilience reflects both the ability to absorb shocks and the capacity to reconfigure production and supply processes when disruptions occur [42]. From this perspective, industrial chain resilience is not limited to short-term stability, but also encompasses longer-term adaptive responses that allow the system to sustain functionality under uncertainty.

The anti-interference capacity of an industrial chain is manifested in its ability to maintain stable operations at critical moments, absorb external shocks, and coordinate adjustments across different links of the chain. At the same time, resilience also involves the capacity to explore alternative development paths when confronted with risk, which depends on the system' s ability to mobilize internal resources and respond flexibly to external changes. Prior research commonly conceptualizes industrial chain resilience along two key dimensions: innovation capability and industrial diversification [22, 48]. These dimensions capture both the adaptive potential of the system and its structural capacity to mitigate risk concentration.

With respect to innovation capability, two indicators are employed. The first is the logarithm of the ratio of research and development expenditure to enterprise operating revenue (RDS), which reflects the intensity of innovation investment. The second is the logarithm of the number of invention patent grants (INNs), which captures the output of innovative activities. Higher values of RDS and INNs indicate stronger innovation capacity within a region, reflecting a greater ability of the industrial chain to absorb disturbances and adjust production structures when faced with external shocks.

Consistent with Wei [49], industrial diversification is considered an important structural factor influencing industrial chain resilience. By dispersing production activities across multiple industries, diversification reduces concentration-related risks and contributes to greater stability of the industrial system under external shocks. In this study, industrial diversification is measured using the inverse of the Herfindahl–Hirschman Index (HHI), which is widely employed to capture the degree of industrial concentration.

Specifically, the industrial diversification index (ID) is defined as the reciprocal of the HHI , where $HHI = \sum_{i=1}^{N} S_i^2 .S_i$ denotes the share of the output value of industry i in regional GDP, and N represents the total number of industries. A higher value of ID indicates a more diversified industrial structure. The calculation is given as follows:

$$ID = \frac{1}{HHI} = \frac{1}{\sum_{i=1}^{N} S_i^2} \quad (2)$$

To construct a composite measure of industrial chain resilience, the entropy method is applied to aggregate the two dimensions of innovation capability and industrial diversification. Prior to aggregation, all indicators are standardized to eliminate differences in scale and magnitude. In this study, min–max normalization is adopted, and the standardization procedure is presented as follows:

$$X'_{ij} = \frac{X_{ij} - \text{Min}\left(X_{lj}, X_{2j}, X_{3j}, \ldots X_{nj}\right)}{\text{Max}\left(X_{lj}, X_{2j}, X_{3j}, \ldots X_{nj}\right) - \text{Min}\left(X_{lj}, X_{2j}, X_{3j}, \ldots X_{nj}\right)} \tag{3}$$

where, X_{ij} denotes the original value of indicator j for region i; $i = 1, 2, \ldots, n$ represents the regions, and j denotes the indicator. The minimum and maximum values are calculated across all regions for the same indicator j, and Eq. (3) rescales the original data to a comparable range.

The entropy method is applied to determine the information entropy and corresponding weights of each indicator. Let X_{ij} denote the standardized value of indicator j for region i. The information entropy of indicator j is calculated as follows:

$$E_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} \left(\frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \ln \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \right) \tag{4}$$

where, n denotes the number of regions. Based on the entropy values, the weight of indicator j is defined as:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{m} (1 - E_j)}$$

where, m represents the total number of indicators.

Finally, a composite index of industrial chain resilience is constructed for each region by aggregating the weighted indicators:

$$INCT_i = \sum_{j=1}^{m} W_j X_{ij} \tag{5}$$

3.3.2 Measurement of digital finance development

The level of digital finance development is measured using the Chinese Digital Inclusive Finance Index compiled by the Digital Finance Research Center of Peking University. This index is widely adopted in empirical studies in China and provides a comprehensive assessment of regional digital finance development from the perspective of inclusive and technology-enabled financial services.

The index is constructed based on three dimensions: breadth of coverage (Bre), depth of use (Dep), and degree of digitization (Dig). The breadth of coverage reflects the accessibility of digital financial services across different user groups, the depth of use captures the intensity and diversity of digital financial activities, and the degree of digitization represents the technological foundation supporting digital financial services. Together, these dimensions provide an integrated measure of regional differences in digital finance development.

3.4 Data Sources

This study takes 31 provinces in China as the research sample over the period 2012–2021, excluding Hong Kong, Macao, and Taiwan. Data on digital finance are obtained from the Digital Finance Research Center of Peking University.

Firm-level data used to construct indicators related to industrial diversification, research and development investment, and invention patent grants are sourced from the China Stock Market and Accounting Research (CSMAR) database. Population data at the provincial level are collected from the China Statistical Yearbook. All datasets are processed and aggregated at the provincial level to ensure consistency across variables and time periods.

4 Effect Analysis of Digital Finance Evolution on Industrial Chain Resilience

4.1 Quadratic Assignment Procedure (QAP) Analysis

The QAP is employed to examine whether a structural association exists between the spatial network of digital finance development and that of industrial chain resilience. Unlike conventional regression methods such as ordinary least squares, network data are characterized by interdependence among observations, which violates the assumption of sample independence. The QAP method addresses this issue by evaluating the relationship between two relational matrices through repeated random permutations, thereby generating an empirical reference distribution for statistical inference.

Specifically, QAP assesses the similarity between corresponding elements of two network matrices by comparing the observed correlation coefficient with those obtained from a large number of randomly permuted matrices. Statistical significance is determined by the position of the observed coefficient within the permutation-based distribution. This procedure allows for valid inference in the presence of network autocorrelation and avoids multicollinearity issues that commonly arise when relational data are analyzed using traditional econometric techniques [50].

The strength of the structural association between the two networks is measured by the correlation coefficient, which ranges between 0 and 1. A higher coefficient indicates a stronger correspondence between the network structures. Statistical significance is evaluated using the associated p-value, with a threshold of 0.05 indicating a statistically meaningful structural relationship.

The QAP results indicate a positive and statistically significant association between the spatial network of digital finance development and the network of industrial chain resilience. This finding suggests that regions with stronger digital finance linkages tend to exhibit corresponding patterns in industrial chain resilience within the spatial network structure, providing empirical support for Hypothesis H1.

4.2 Overall Network Characteristics

To examine the evolution of the spatial association between digital finance and industrial chain resilience, UCINET is employed to compute key structural indicators of the social network, and the corresponding results are reported in Table 1. ArcGIS is further used to visualize the spatial network structure. Four representative years, 2012, 2014, 2018, and 2021—are selected to illustrate the temporal evolution of interprovincial linkages.

Figure 1 presents the spatial network formed by both direct and indirect connections among provinces, reflecting the structural association between digital finance development and industrial chain resilience. The results indicate that interprovincial linkages become progressively denser over time, and no province remains isolated within the network. The overall structure exhibits a ring-like configuration, suggesting a core-periphery pattern that evolves gradually rather than instantaneously.

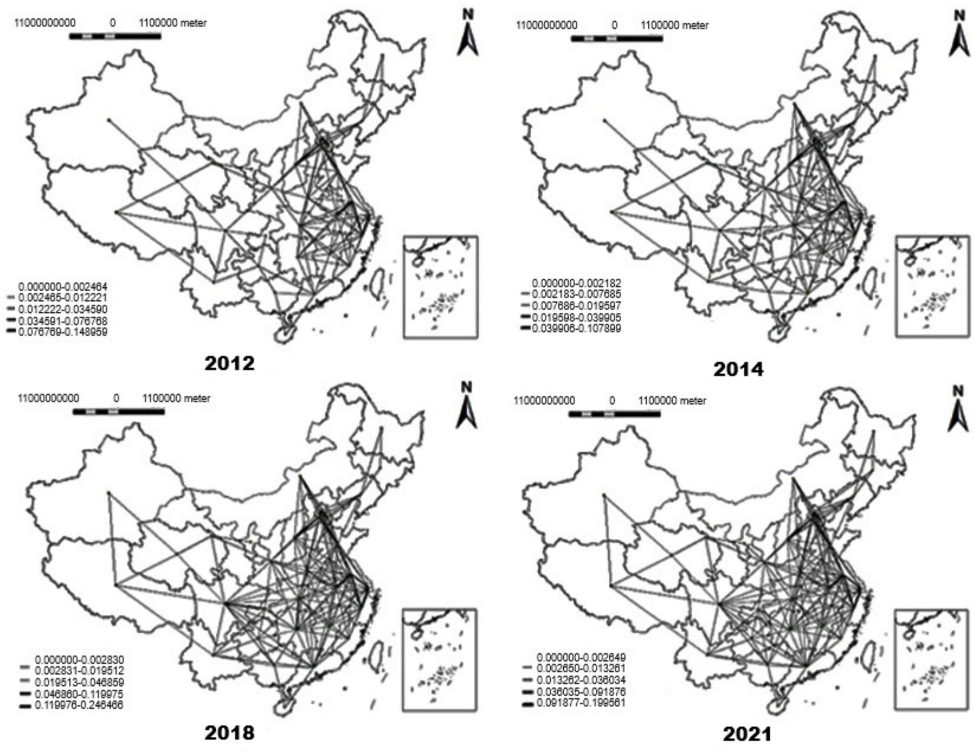

Figure 1. Evolution of the spatial network linking digital finance and industrial chain resilience

In the early stage of the sample period, provinces in the eastern and southern regions occupy central positions in the network, forming a relatively dense core. These regions are characterized by stronger digital finance development and more frequent interprovincial interactions. In contrast, provinces in the western and peripheral regions are located mainly in the outer ring, with fewer direct connections. Although spillover effects from the core regions extend toward the periphery, linkages among outer-ring provinces remain relatively limited, indicating that spatial interactions are still unevenly distributed.

Table 1 reports changes in network density and the number of effective linkages from 2012 to 2021. During the period 2012–2014, both indicators exhibit a moderate upward trend, reflecting the initial expansion of digital financial activities and interregional connections. Between 2014 and 2018, the growth of network density and effective linkages accelerates markedly, indicating a rapid strengthening of spatial interactions. This period coincides with the widespread adoption of digital financial services and deeper integration of financial activities across regions. From 2018 to 2021, the upward trend continues but at a more stable pace, suggesting a transition from rapid expansion to gradual consolidation of the network structure.

Overall, the evolution of the spatial network indicates that the association between digital finance and industrial chain resilience becomes increasingly structured over time. While the core regions maintain strong interconnections, the gradual expansion of linkages toward peripheral provinces suggests the presence of spatial spillover effects, although such effects remain uneven across regions.

Table 1. Influence of entire meshwork features on the elasticity of the digital financial evolution industry chain

Year	Network Size Analysis			Network Relevance Analysis			
	Network Density	Number of Theoretical Correlation	Number of Actual Correlation	Connect Edness	Graph Efficiency	Graph Hierarchy	Average Path
2012	0.2333	930	217	1	0.72	0.127	2.429
2013	0.2344	930	218	1	0.717	0.125	2.416
2014	0.2355	930	219	1	0.715	0.125	2.453
2015	0.2409	930	224	1	0.701	0.125	2.393
2016	0.2419	930	225	1	0.699	0.125	2.379
2017	0.2452	930	228	1	0.692	0.127	2.371
2018	0.2398	930	224	1	0.701	0.125	2.421
2019	0.2462	930	229	1	0.697	0.125	2.371
2020	0.2419	930	225	1	0.708	0.125	2.372
2021	0.2473	930	230	1	0.699	0.125	2.324

Overall, the theoretical number of possible interprovincial relationships is 930, while the maximum observed number of effective relationships is 230, corresponding to a maximum network density of 0.2473. These values indicate that, although spatial linkages among provinces have expanded, there remains substantial potential for further development of interregional connections. Throughout the period 2012–2021, network connectivity remains equal to 1, suggesting that all provinces are incorporated into a single connected structure and that no region is isolated from the spatial interaction network linking digital finance and industrial chain resilience.

Network efficiency exhibits a generally declining trend over time. This pattern reflects an increase in redundant interprovincial connections and a diversification of linkage channels within the network, which contributes to greater overall connectivity and structural stability. At the same time, the network-level degree associated with digital finance and industrial chain resilience shows a downward trend, indicating the gradual formation of a hierarchical spatial structure in which a limited number of provinces occupy relatively central positions. Nevertheless, the continuous expansion of interprovincial linkages implies that spatial barriers are progressively weakened and that constraints on spillover transmission are gradually reduced.

The average path length displays an overall downward trend, suggesting that the number of intermediate steps required for interprovincial interactions is decreasing. This reflects closer and more stable spatial associations among provinces in terms of digital finance–industry chain linkages. As reported in Table 1, network efficiency declines from 0.720 in 2012 to 0.699 in 2021, indicating a rise in redundant connections and a broadening of spillover channels across regions. Over the same period, the average path length shortens from 2.429 to 2.324, implying a reduction in spatial friction and resistance to interregional spillovers.

Taken together, these network characteristics provide empirical evidence of increasingly interconnected spatial structures and support the existence of spatial spillover effects in the relationship between digital finance and industrial chain resilience, consistent with Hypothesis H2.

4.3 Individual Network Characteristics Analysis

Using UCINET, this study examines provincial-level network positions in the spatial network linking digital finance development and industrial chain resilience. Individual network characteristics are reported in Table 3 based on 2021 data, and ArcGIS is used for visualization in Figure 2.

Figure 2 indicates a stratified network structure formed by interprovincial linkages between digital finance development and industrial chain resilience in 2021. A denser pattern of connections is observed in southeastern China, whereas network connections appear comparatively weaker in northwestern regions. Beijing and the Yangtze River Delta, together with provinces such as Zhejiang—occupy relatively central positions in the overall network, functioning as important hubs through which interprovincial linkages are organized and potentially transmitted.

To illustrate how a core province may be connected to peripheral regions through digital-finance-related linkages, Beijing provides an informative case. With the development of digital finance in Beijing, the local "finance +

technology” industrial ecosystem has gradually expanded, accompanying broader industrial upgrading processes and related changes in industrial chain organization. For example, a Beijing-based digital finance firm, Rittag Technology Co., Ltd., developed the Jinsui Agricultural and Animal Husbandry Cloud Platform for the livestock sector in Qinghai Province, which reflects an interprovincial linkage in digital-finance-enabled services. Upstream, the Internet of Things (IoT) is used to digitize live animal assets, build digital pastures, and address practical issues in supervision, valuation, and disposal of collateral linked to live-animal loans. In midstream slaughtering and processing, Rittag introduced digitally supervised warehouse technologies to support warehouse receipt pledge financing during the storage of cold fresh products. Downstream, consumers can scan a food traceability code to obtain information on the origin of cattle, processing, logistics, and channel sales. This case indicates how digital-finance-enabled infrastructures may be linked to risk points and information frictions across multiple nodes of an industrial chain, which is consistent with a network-based interpretation of resilience-related linkages.

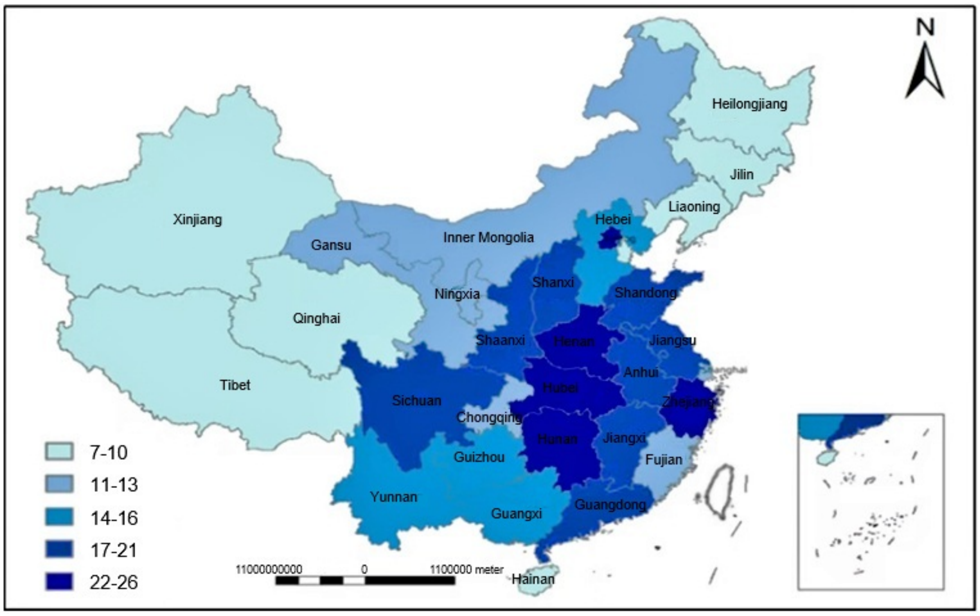

Figure 2. Network centrality diagram of the impact of digital finance on the resilience of the industrial chain in 2021

Provinces located at the periphery of the network, including Jilin, Liaoning, and Heilongjiang, are more likely to be affected by the spatial influence of core provinces such as Beijing through existing interprovincial linkages. In contrast, provinces such as Tibet, Xinjiang, and Qinghai exhibit fewer outward connection pathways in the network and therefore contribute less to the overall connectivity structure in 2021.

Table 2 reports degree centrality measures. Beijing ranks first in out-degree centrality (11.000), followed by Zhejiang (11.000) and Guangdong (10.000). These provinces are economically advanced regions where the association between digital finance and industrial chain resilience is more prominently reflected in network linkages, in both breadth and depth, and their outward ties suggest stronger potential for interprovincial diffusion through network connections. The development of digital finance in these provinces is commonly attributed to relatively stronger economic bases, talent pools, and technological capacities. In practice, these regions have pursued reforms and institutional adjustments related to digital finance, explored new service mechanisms, and strengthened linkages between finance and technology, supporting industrial digitalization and industry-finance interactions.

For instance, Beijing functions as a major national financial center, with total financial assets reported to be close to 220 trillion yuan, which provides an institutional and market foundation for digital-finance-related activities. Zhejiang is widely recognized as a pioneering region in reforms and innovation in financial services for small and micro enterprises. It emphasizes digital inclusive finance and data sharing, aiming to reduce information frictions in financing between banks and enterprises and to improve the transparency and timeliness of financial services.

Regarding in-degree centrality, the four highest-ranked provinces are Henan (17.000), Hubei (16.000), Beijing (13.000), and Jiangsu (13.000). Higher in-degree centrality indicates that a province is connected by a larger number of incoming ties and may be more exposed to interprovincial influences transmitted through the network. Henan and Hubei are located in central China, with relatively dense populations and substantial development potential. Their proximity to financially developed regions such as the Yangtze River Delta suggests that they may be more exposed to spillover transmission through interregional linkages. Jiangsu, located at the estuary of the Yangtze River, holds notable geographic and economic advantages. Jiangsu promoted the construction of a fintech industry ecosystem and application system as early as 2018, which facilitated broader adoption of fintech within the financial sector. Jiangsu has attracted digital finance enterprises, including Bank of China Jinke and Jianxin Jinke, and a number of cities have been designated as pilots for digital finance innovation.

In Jiangsu, new digital financial services have also emerged in recent years. For example, Suning Finance applies blockchain technology to support multi-party supervision, collateral registration, and collateral association. This arrangement allows upstream raw material suppliers and downstream SME financiers to ensure account consistency, addressing information silos and strengthening linkages between upstream and downstream parts of the industrial chain across regions. Such practices are aligned with the interpretation that digital-finance-related infrastructures can support risk-related information flows and coordination needs in industrial chains.

Finally, the point-out and point-in degree values among neighboring provinces within each region appear relatively close, suggesting that the relationship between digital finance and industrial chain resilience is gradually shifting from isolated provincial patterns toward more coordinated regional interaction structures.

Table 2. Individual network characteristics of the impact of digital finance development on industrial chain resilience

Region	Centrality Analysis		Small World Analysis		Structural Holes		
	Out-degree Centrality	In-degree Centrality	Clustering Coefficient	Effective Size	Efficiency	Constraint	Hierarchy
Beijing	11	13	0.441	14.521	0.678	0.202	0.082
Tianjin	4	6	0.933	3.1	0.35	0.377	0.067
Hebei	5	11	0.673	5.656	0.514	0.276	0.085
Shanxi	8	10	0.636	6.083	0.553	0.26	0.065
Inner Mongolia	8	3	0.806	3.727	0.414	0.302	0.049
Liaoning	6	4	0.762	2.95	0.421	0.403	0.086
Jilin	4	3	0.833	1.643	0.411	0.496	0.078
Heilongjiang	6	3	0.733	2.83	0.472	0.393	0.112
Shanghai	8	5	0.917	3.115	0.346	0.308	0.047
Jiangsu	7	13	0.603	7.000	0.538	0.227	0.065
Zhejiang	11	10	0.482	11.816	0.438	0.271	0.04
Anhui	7	10	0.697	5.860	0.489	0.246	0.053
Fujian	9	4	0.944	2.769	0.308	0.323	0.031
Jiangxi	9	9	0.745	4.83	0.439	0.277	0.048
Shandong	7	12	0.545	7.184	0.599	0.229	0.069
Henan	9	17	0.531	12.154	0.675	0.167	0.046
Hubei	6	16	0.55	9.364	0.585	0.213	0.061
Hunan	8	13	0.581	8.35	0.557	0.225	0.048
Guangdong	10	8	0.691	5.77	0.525	0.256	0.031
Guangxi	9	5	0.711	5.036	0.504	0.296	0.061
Hainan	7	2	0.905	2.61	0.373	0.352	0.059
Chongqing	6	6	0.714	4.083	0.51	0.296	0.07
Sichuan	8	9	0.485	7.613	0.635	0.226	0.06
Guizhou	7	8	0.778	4.433	0.493	0.298	0.046
Yunnan	8	6	0.689	5.214	0.521	0.288	0.077
Tibet	7	0	0.619	3.714	0.531	0.322	0.013
Shaanxi	7	10	0.515	7.765	0.647	0.207	0.05
Gansu	5	6	0.667	3.818	0.545	0.312	0.073
Qinghai	4	4	0.733	2.813	0.469	0.371	0.089
Ningxia	9	4	0.689	5.462	0.546	0.26	0.029
Xinjiang	10	0	0.556	6.3	0.63	0.237	0.016
Average value	7.419	7.419	0.689	5.375	0.507	0.288	0.058
Total	230	230	21.164	167.618	15.716	8.916	1.806
Variance	3.534	19.276	0.019	6.711	0.009	0.005	0
Minimum value	4	0	0.441	1.643	0.308	0.167	0.013
Maximum value	11	17	0.944	12.154	0.678	0.496	0.112

From a global perspective, the average clustering coefficient of the network is 0.689, indicating that interprovincial linkages in the digital finance-industrial chain resilience network exhibit a combination of internal and external connections, with internal linkages playing a relatively dominant role. Overall, clustering coefficients are relatively low for provinces located at the core of the network, including Beijing (0.441), Zhejiang (0.482), and Sichuan (0.485), suggesting that these provinces maintain diversified external connections rather than forming tightly closed local clusters. In contrast, provinces with higher clustering coefficients are predominantly located at the network periphery, such as Jilin (0.833), Hainan (0.905), and Fujian (0.944), where interprovincial connections tend to display strong local convergence.

Beijing exhibits the lowest clustering coefficient (0.441), reflecting its extensive external linkages that extend beyond the Beijing-Tianjin-Hebei region. As a central node in the national network, Beijing's digital finance-industrial chain linkages are characterized by a non-localized and non-centralized structure, indicating a broad spatial diffusion pattern. By contrast, Fujian records the highest clustering coefficient (0.944), suggesting that its connections are largely confined to neighboring provinces. This localized connectivity implies relatively limited outward spillover capacity within the national network.

Structural hole analysis further reveals notable differences in network positions across provinces. Provinces with more advanced digital finance development tend to occupy positions with structural hole advantages, which are associated with higher levels of information access and control within the network. Beijing exhibits the largest effective size (14.520) and the highest efficiency (0.678), followed by Henan and Zhejiang, whose values are substantially higher than those of most other provinces. Henan demonstrates a high degree of individual network openness and occupies a pronounced structural gap position, enabling it to establish extensive connections with external provinces. This network position is closely related to Henan's geographic location in the Central Plains and its large population base. In recent years, Henan has been transitioning from a large economic province toward a stronger economic structure, during which digital finance has been increasingly utilized to broaden financing channels for small and medium-sized enterprises, support production recovery, and stabilize employment. These developments are accompanied by ongoing adjustments in industrial structure and the expansion of digitally supported financial services, which are consistent with Henan's relatively favorable network position in terms of industrial chain resilience.

In contrast, Jilin Province records the smallest effective size (1.333), indicating a marginal position in the digital finance-industrial chain resilience network. Its efficiency value peaks at 0.780, suggesting that the local network is highly constrained and close to isolation, with connections largely limited to neighboring northeastern provinces. Jilin's reliance on a narrow set of interprovincial linkages restricts network mobility and reduces the efficiency of information transmission between Jilin and other regions. As a result, its participation in the broader national network remains limited, constraining the extent to which digital finance linkages are associated with industrial chain resilience in the province. Overall, marginal provinces tend to face structural disadvantages characterized by limited openness, weaker information access, and restricted external connections, which correspond to less favorable network conditions.

Zhejiang Province exhibits relatively high out-degree centrality (11.000) and in-degree centrality (10.000), indicating its prominent role in both transmitting and receiving network connections. In 2019, Zhejiang became the first province in China to introduce local regulations related to digital finance, accompanied by accelerated development in digital infrastructure and financial technologies such as blockchain. These institutional developments coincided with increased interprovincial linkages involving Zhejiang, with neighboring provinces including Anhui, Jiangsu, and Fujian displaying stronger external connections. Zhejiang' s clustering coefficient (0.482), second only to Beijing, indicates that its network connections are predominantly external rather than locally concentrated, reflecting a spatial structure characterized by openness and decentralization.

Structural hole indicators further support Zhejiang' s central network position. The province records an effective size of 11.816, an efficiency score of 0.438, and a constraint value of 0.271, suggesting relatively high network openness and a favorable balance between information access and control. Zhejiang therefore remains a core node within the national network. Alipay, headquartered in Zhejiang, represents one of the major digital finance platforms in China. Large-scale technology platforms are able to utilize data-driven mechanisms and scale effects to reduce marginal service costs, thereby extending financial services to a broad range of smaller clients and linking multiple segments of industrial chains.

An illustrative example is Ant Financial Services' entrusted farming financing model. In this arrangement, leading midstream agricultural enterprises engage in contractual transactions with upstream farmers. Ant Financial Services applies data-based credit assessment tools to evaluate the credit conditions of both farmers and leading enterprises, incorporating information on production capacity, debt status, and control relationships. Based on these assessments, banks issue loans to eligible participants. Farmers then use loan funds for agricultural production, while midstream enterprises sell finished products through downstream platforms such as Tmall to settle transactions and repay loan principal and interest. During this process, Cainiao Logistics provides integrated logistics services covering the entire chain from production to consumption, facilitating the coordination of logistics, capital flows, and information flows. This case illustrates how digital-finance-enabled infrastructures can support supply chain financing arrangements and information integration across multiple stages of an industrial chain, consistent with a network-based interpretation of industrial chain resilience.

4.4 Network Structural Analysis

4.4.1 Core-periphery analysis

Using data from 2012, 2018, and 2021, this study conducts a core-periphery analysis of the spatial network linking digital finance development and industrial chain resilience. The corresponding density results are reported in Table 3. The analysis reveals a clear differentiation between core and peripheral provinces within the network.

Table 3. Density matrix for core and peripheral areas

		Core	**Periphery**
2012	Core	0.424	0.275
	Periphery	0.100	0.158
2018	Core	0.478	0.277
	Periphery	0.097	0.173
2021	Core	0.500	0.292
	Periphery	0.112	0.179

As shown in Table 3, provinces classified in the core region are predominantly economically developed areas, including Beijing, Zhejiang, and Guangdong. Although the number of core provinces is relatively small, the density of connections within the core is substantially higher than that within the periphery. This indicates that provinces in the core region maintain relatively intensive interconnections with each other in terms of digital finance - industry chain linkages. In contrast, most peripheral provinces are characterized by comparatively lower levels of economic development and digital finance activity, and their network connections are mainly concentrated within the periphery itself.

The density of linkages between the core and peripheral regions is consistently higher than that among peripheral provinces, suggesting asymmetric interaction patterns between the two groups. Core provinces tend to occupy structurally advantageous positions, serving as key connection points linking peripheral regions to the broader network. From a network perspective, this pattern reflects a combined siphoning and radiation structure, in which core regions are more deeply embedded in the network and peripheral regions are weaklier connected.

From 2012 to 2021, the density of connections within the core region increases steadily, indicating a strengthening of inter-core linkages over time. Meanwhile, the density of connections between the core and peripheral regions also rises, suggesting that interactions across these two groups become more frequent. Although peripheral provinces exhibit slower changes in network density, the gradual increase in cross-group linkages implies that the spatial influence of core provinces within the network becomes more pronounced over time. Overall, these patterns are consistent with the spatial spillover mechanism proposed in Hypothesis H2.

Between 2012 and 2021, the correlation between the core realms of digital finance and the industry chain network markedly increased, resulting in advanced digital finance affecting the industry chain. The provinces that have lagged have experienced a slower resilience enhancement, yet the density of network links between the core and peripheral areas has increased. The intensifying impact of the core region provinces on the peripheral region provinces is becoming more pronounced.

4.4.2 K-core analysis

Based on 2021 data, a K-core analysis is conducted to further examine the internal hierarchical structure of the network linking digital finance and industrial chain resilience. The results are reported in Table 4. The network can be divided into five K-core subgroups with core values of 8, 7, 6, 5, and 4, respectively.

The K-core structure exhibits a clear pyramidal pattern. Provinces with higher K-core values form the upper layers of the network, while those with lower K-core values constitute the base. The 8-core subgroup represents the most cohesive part of the network and includes provinces with relatively advanced digital finance development, such as Zhejiang, Jiangsu, and Beijing. These provinces are embedded in dense and mutually reinforcing network connections and occupy structurally central positions.

As the K-core value decreases from 7 to 4, the number of provinces in each subgroup increases, while the internal cohesion of these subgroups weakens. In particular, the sharp reduction in the size of the 8-core subgroup compared with the 7-core subgroup indicates a pronounced differentiation in network embeddedness across provinces. This suggests that the association between digital finance and industrial chain resilience is unevenly distributed, with stronger structural integration observed in economically advanced provinces and weaker integration in less developed regions.

Overall, the K-core analysis highlights a hierarchical and stratified network structure. While provinces in the highest K-core exhibit strong internal connectivity, lower-core provinces remain more loosely connected. This configuration indicates that the spatial network linking digital finance and industrial chain resilience is still evolving, with a gradual shift from isolated provincial development toward more regionally coordinated interaction patterns.

Table 4. K-core structure of the digital finance–industrial chain resilience network (2021)

K-core	City	Quantity
8-core	Beijing, Jiangsu, Guangdong, Zhejiang, Shanghai, Hubei, Hunan, Henan	8
7-core	Anhui, Hebei, Jiangxi, Shandong, Fujian, Hubei, Hunan, Shanxi, Guangxi, Chongqing, Guizhou, Yunnan, Shaanxi, Ningxia, Henan.Beijing, Jiangsu, Guangdong, Sichuan, Hainan, Xinjiang, Zhejiang, Shanghai, Inner Mongolia	24
6-core	Anhui, Hebei, Jiangxi, Shandong, Fujian, Hubei, Hunan, Shanxi, Guangxi, Chongqing, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Henan.Beijing, Tianjin, Jiangsu, Guangdong, Sichuan, Hainan, Xinjiang, Zhejiang, Shanghai, Inner Mongolia	27
5-core	Anhui, Hebei, Jiangxi, Shandong, Fujian, Hubei, Hunan, Shanxi, Guangxi, Liaoning, Chongqing, Guizhou, Yunnan, Tibet, Heilongjiang, Shaanxi, Gansu, Qinghai, Ningxia, Henan.Beijing, Tianjin, Jiangsu, Guangdong, Sichuan, Hainan, Xinjiang, Zhejiang, Shanghai, Jilin	30
4-core	Anhui, Hebei, Jiangxi, Shandong, Fujian, Hubei, Hunan, Shanxi, Guangxi, Liaoning, Chongqing, Guizhou, Yunnan, Tibet, Heilongjiang, Shaanxi, Gansu, Qinghai, Ningxia, Henan.Beijing, Tianjin, Jiangsu, Guangdong, Sichuan, Hainan, Xinjiang, Zhejiang, Shanghai, Jilin, Inner Mongolia	31

5 Conclusions and Recommendations

5.1 Conclusion

(1) A stable spatial interaction network has been formed, with increasing connectivity but limited density

From 2012 to 2021, a spatial interaction network linking digital finance development and industrial chain resilience has gradually taken shape and remained fully connected. Network density shows an overall upward trend during the sample period, although the absolute level remains relatively low, indicating that there is still considerable room for the expansion of interprovincial linkages. The inclusion of digital finance in the draft outline of the 13th Five-Year Plan in 2014 coincides with a noticeable acceleration in network densification, suggesting a period of intensified interregional interaction.

Throughout the study period, network connectivity remains equal to 1, implying that no province is isolated and that all regions are embedded in a single national network. At the same time, average path length and network efficiency indicators indicate a gradual reduction in spatial friction and a growing number of alternative linkage paths, reflecting a more integrated but still evolving spatial structure.

(2) Provinces exhibit differentiated network positions in the digital finance-industrial chain resilience system

Differences in economic foundations, geographic location, and the level of digital finance development have led to pronounced heterogeneity in provincial network positions. Economically advanced provinces with relatively mature digital finance systems—such as Beijing and the Yangtze River Delta—are located in the core and high K-core layers of the network. These provinces display higher in-degree and out-degree centrality, lower clustering coefficients, and more pronounced structural hole characteristics, indicating stronger external connectivity and broader access to interprovincial information flows.

In contrast, provinces located at the network periphery, including Liaoning and the Qinghai-Tibet region, tend to exhibit higher clustering coefficients and more internally concentrated connections. Their network structures are relatively closed, and their participation in interprovincial linkages is limited, which corresponds to weaker integration into the national digital finance-industrial chain resilience network. This structural position is associated with slower adjustment and more constrained interaction patterns.

Overall, the spatial structure of the network reflects a clear core - periphery configuration, with uneven distribution of connectivity and interaction intensity across regions.

5.2 Policy Recommendations

(1) Improve the regulatory framework for digital finance in a coordinated and adaptive manner

Empirical results indicate that changes in digital finance regulation are associated with fluctuations in network structure. Existing research suggests that the moderating effect of financial regulation on the relationship between digital finance and industrial chain resilience may follow a non-linear pattern. As regulatory systems continue to evolve, there is a need to balance risk control with flexibility in order to support stable network interactions.

Government authorities may focus on improving the consistency, transparency, and adaptability of digital finance regulation, particularly with respect to cross-regional activities. Enhancing regulatory coordination across regions could contribute to a more predictable environment for digital finance development and reduce structural fragmentation within the industrial chain network.

(2) Support the digital transformation of industrial chain enterprises

First, accelerating the digitalization of industrial chains remains an important task. Current network indicators show uneven effective scale and efficiency across provinces, suggesting that digital finance development has not yet fully penetrated all regions. Financial institutions can leverage digital technologies to improve asset verification, transaction monitoring, and information sharing along industrial chains, thereby reducing information asymmetry and improving risk assessment processes.

Second, policy support should emphasize long-term coordination between infrastructure development and industrial upgrading. Strengthening digital infrastructure in less developed and peripheral regions may help reduce structural constraints and facilitate broader participation in interprovincial networks. Targeted support for regions with weaker digital foundations could contribute to more balanced regional interaction patterns.

5.3 Development of Digital Financial Services

(1) Promote node-based digital financial services along the industrial chain

Digital financial services can be designed to address the heterogeneous needs of different nodes within the industrial chain. In risk assessment, data-driven credit evaluation methods may help improve transaction screening and fraud detection. In transaction auditing, intelligent information systems can support more efficient verification of financial documents. In asset-based financing, real-time monitoring of movable collateral may reduce supervision costs and improve information accuracy. Together, these applications can support more stable coordination among upstream, midstream, and downstream participants.

(2) Expand interregional coverage and diversify digital financial products

Network analysis indicates that many provinces still maintain highly localized connections, with limited external linkages. Financial institutions may consider expanding the geographic scope of digital financial services and developing products that facilitate cross-regional interaction. Diversifying digital financial products and tailoring services to different industrial contexts could improve the adaptability of industrial chains to external shocks.

By broadening service coverage and strengthening interprovincial linkages, digital finance may contribute to more resilient and coordinated industrial chain structures, supporting the long-term adjustment of China' s economic system during periods of transformation.

6 Discussion

This study is subject to several limitations that warrant further investigation in future research. Addressing these issues may contribute to a more comprehensive understanding of the relationship between digital finance and industrial chain resilience.

First, although the empirical results reveal pronounced differences in network positions across provinces, the underlying causes of such imbalanced development are not examined in detail. The findings indicate that provinces such as Beijing and Zhejiang occupy more central and structurally advantageous positions in the overall network. However, the present analysis does not explicitly disentangle the relative roles of policy environments, technological infrastructure, institutional arrangements, or regional economic structures in shaping these outcomes. Future studies could incorporate region-specific policy indicators, digital infrastructure measures, or firm-level technological characteristics to explore the mechanisms through which certain provinces attain and maintain central network positions.

Second, while this study proposes policy-oriented implications based on the observed network structures, the analysis does not assess the effectiveness or feasibility of specific policy pathways. Future research could build on the proposed recommendations by adopting comparative or quasi-experimental research designs to evaluate how different regulatory approaches, digital infrastructure investments, or financial innovation strategies influence industrial chain resilience across regions. Such extensions would help translate network-based empirical findings into more operational and context-sensitive policy guidance.

Overall, these limitations point to promising directions for future research that can deepen the understanding of spatial heterogeneity, policy mechanisms, and dynamic adjustments in the digital finance–industrial chain resilience nexus.

Author Contributions

Conceptualization, X.Q.Z. and X.H.D.; methodology, X.H.D.; software, X.Q.Z.; validation, X.Q.Z.; formal analysis, X.H.D.; investigation, X.Q.Z.; resources, X.H.D.; data curation, X.Q.Z. and L.P.L.; writing—original draft preparation, X.Q.Z. and X.H.D.; writing—review and editing, X.Q.Z.; visualization, X.Q.Z.; supervision, X.H.D. and L.P.L.; project administration, X.H.D.; funding acquisition, X.H.D. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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