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A Bibliometric Analysis of Research on China's Industrial Chain Resilience: Shifts in Focus and Development Trends (2018-2025)

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Abstract

Industrial chain resilience is a key factor in ensuring stable industrial supply and promoting high-quality industrial development in complex environments. With the convergence of global shifts and domestic transformation issues since 2018, the research and practical value of industrial chain resilience has become increasingly prominent. This paper conducts a bibliometric analysis rather than an empirical study on China's industrial chains themselves. This paper selects 259 core journal articles on industrial chain resilience from the China National Knowledge Infrastructure (CNKI) database over the period 2018-2025. It conducts a visual knowledge map analysis and systematically traces the evolutionary path and core characteristics of relevant research. The findings reveal: ① The volume of industrial resilience literature exhibits a phased pattern of "fluctuating growth followed by rapid ascent," entering a peak research period after 2020 driven by sudden risk events; ② Research hotspots primarily revolve around four dimensions: the integration of industrial chains and the digital-physical convergence in manufacturing, the digital economy and industrial structure upgrading, technology-driven industrial chain resilience, and rural digital agriculture; ③ Cutting-edge topics focus on the synergistic empowerment of industrial resilience through digital technologies and data elements, the spatial effects of artificial intelligence in driving industrial structural upgrading, and the resilience of digitalization and food security. Research hotspots are summarized as four stable thematic clusters that form the field's foundational knowledge system. Research frontiers refer to emerging, policy-oriented, and spatially focused themes that have emerged since 2023, with clear temporal and logical boundaries distinguishing them from hotspots. The bibliometric analysis of this study indicates that future research should strengthen exploration in the areas of optimizing industrial chain layout, digital transformation of industrial chains, and the resilience of agricultural industrial chains.

Keywords

Industrial Chain Resilience, Citespace, Bibliometrics, Evolutionary Characteristics, Research Hotspots

1. Introduction

Industrial chain resilience refers to the ability to withstand, recover from, and adapt to risks and shocks through structural optimization, resource allocation, and coordination mechanisms within the industrial chain system (Pan et al., 2025). The Third Plenary Session of the 20th CPC Central Committee focused on strategic planning to "improve the institutional framework for enhancing the resilience and security of industrial and supply chains." This represents a significant decision by the Party, grounded in both historical and contemporary realities, positioning industrial chain resilience as a key strategic element in safeguarding national economic security. It reflects the Party's deepened understanding of the laws of economic development, national security, and the global governance landscape. The National Security Strategy (2021-2025) further emphasizes the need to enhance industrial resilience against shocks, positioning the improvement of industrial chain resilience as a key element of the national security strategy (Wu & Meng, 2025). It is evident that industrial chain resilience has become a key pillar for ensuring the security and development of the national economy. Since then, numerous scholars have conducted research on industrial chain resilience, and the volume of publications has gradually increased. However, existing research primarily focuses on macro-level strategic analysis and exhibits distinct fragmentation: research topics are relatively scattered and disjointed, often centered on specific scenarios or single dimensions, lacking long-term tracking of the field's research trajectory. Furthermore, systematic summarization and integrated analysis are rare, and a systematic research framework has yet to be established. This paper focuses on industrial chain resilience. Utilizing CiteSpace—a visualization and bibliometric analysis software developed by Professor Chen Chaomei—we conduct a bibliometric analysis of literature on industrial resilience from the China National Knowledge Infrastructure (CNKI) database. We construct a visual knowledge map to deeply analyze the current landscape, distribution of research hotspots, and evolving trends in industrial resilience research. This study not only helps fill the gap in existing research regarding the visualization and systematic synthesis of industrial resilience but also provides robust academic support for refining the theoretical framework of industrial resilience and formulating practical strategies.

2. Analysis of Annual Publication Volume and Research Development

(1) Evolution of Annual Publication Volume

Analysis of annual publication volumes reveals that research on industrial chain resilience has evolved from virtually nonexistent to explosive growth, with 2022 marking a pivotal turning point in this field. From 2018 to 2021, scholarly attention to this field was extremely low, with only one paper published in both 2018 and 2021, and no CSSCI or Peking University Core Journal articles produced in 2019 or 2020. However, in 2022, 12 related papers were published, marking the gradual entry of industrial chain resilience into the academic spotlight. This trend is closely associated with the outbreak of the Russia-Ukraine conflict, disruptions in global energy and food supply chains, and U.S. efforts to advance geographically diversified industrial chains, which have led some scholars to pay greater attention to the risk resilience of industrial chains. The period from 2022 to 2025 represents a phase of rapid growth, characterized by explosive expansion. The number of publications in 2023, 2024, and 2025 was 41, 85, and 119, respectively, with the volume doubling year after year, reflecting that "industrial chain resilience" has increasingly become a core focus in current industrial research.(Data for 2025 are collected up to October 30, 2025, and do not cover the full calendar year.) This is closely linked to the policy orientation and practical needs repeatedly emphasized by the Party Central Committee to promote "autonomy and control over key links in industrial chains." The report of the 20th National Congress of the Communist Party of China explicitly called for "focusing on enhancing the resilience and security of industrial and supply chains," which has driven the sustained rise in research interest in this field. (Figure 1)

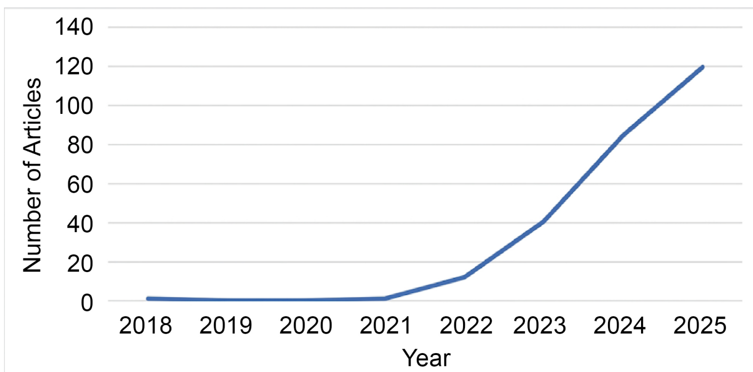

Figure 1. Line chart of annual publication volume on industrial chain resilience research, 2018-2025.

(2) The Development of Industrial Chain Resilience

From the reform and opening-up era to the early 21st century, China leveraged its advantages in labor costs and policy incentives. Through measures such as establishing special economic zones and developing processing trade, the country gradually integrated into the global division of labor, laying the industrial foundation for its status as the "world's factory." During this phase, the industrial chain was characterized by large-scale integration. Resilience was primarily manifested in the rapid organization of labor-intensive industries and their capacity for large-scale production. While the country accumulated experience in international industrial collaboration by improving basic supporting infrastructure, the overall landscape was characterized by being "big but not strong." It exhibited weak risk-resilience and a high degree of dependence on external markets and technologies.

From China's accession to the WTO in 2001 until the onset of the global financial crisis in 2008, China's manufacturing sector became deeply integrated into global production networks. Industrial support capabilities continued to strengthen, logistics efficiency improved significantly, and China's role as a hub in the global supply chain began to emerge. However, the resilience of the industrial chain during this period remained primarily factor-driven, with production concentrated in low- and medium-end manufacturing segments. Reliance on foreign sources for key core technologies and components remained high, and the sector lacked sufficient buffers to withstand fluctuations and shocks in international markets. The outbreak of the global financial crisis further exposed the structural weakness of "single-point dependence."

From the aftermath of the 2008 global financial crisis until the 18th National Congress of the Communist Party of China, China entered an exploratory phase of industrial chain transformation and upgrading. Faced with shrinking external demand and adjustments in the global industrial landscape, the state used policy guidance to encourage R&D innovation and foster independent brands. Emerging industrial chains, such as those in new energy and high-end equipment, began to take shape, and the share of private enterprises in the industrial chain continued to rise. The resilience of industrial chains shifted from scale-driven growth to quality-led development and structural optimization, gradually reducing reliance on single markets and low-end manufacturing. However, fundamental issues such as bottlenecks in core technologies and a weak industrial foundation remained unresolved, and resilience-building was still in its early stages of passively responding to risks.

Since the 18th National Congress of the Communist Party of China in 2012, the development of industrial chain resilience has gradually risen to the level of a national strategy. The building of industrial chain resilience has entered a new phase of proactive construction and systematic enhancement. In 2015, the Central Economic Work Conference proposed the "Three Reductions, One Cut, and One Supplement" initiative—promoting the "reduction of overcapacity, reduction of inventory, deleveraging, cost reduction, and addressing shortcomings"—making supply-side structural reform a key lever for enhancing resilience.

Against the backdrop of escalating Sino-U.S. trade tensions, and to navigate the complex international environment while avoiding "decoupling and supply chain disruption," the Central Committee explicitly called in 2019 for "enhancing industrial chain resilience, upgrading industrial chain standards, and fostering industrial chains with stronger innovation capacity and higher value-added through open cooperation." In 2020, the Central Committee introduced the new concept of "gradually forming a new development paradigm with the domestic economic cycle as the mainstay and the domestic and international economic cycles reinforcing each other." The Party Central Committee has repeatedly deployed measures to enhance the resilience and security of industrial and supply chains, aiming to overcome "chokepoint" challenges in key core technologies through "supplementing, consolidating, and strengthening" the chains, thereby achieving a virtuous interaction between the domestic and international economic cycles. The report of the 20th National Congress in 2022 emphasized "building a modernized economic system," explicitly identifying the modernization of industrial chains as a key pillar. Under the strategic guidance of building a new development paradigm, efforts to enhance industrial chain resilience are focused on three major objectives: "autonomy and control, security and reliability, and dynamic adaptability." Currently, leveraging the world's most comprehensive industrial system and the advantages of a massive market, China has established a resilient ecosystem where large, medium, and small enterprises develop in synergy, and domestic and international dual circulation mutually reinforce one another. This ecosystem is capable of withstanding short-term external shocks while supporting long-term industrial upgrading, thereby building a core barrier for high-quality development and national economic security.

3. Overview of Research Literature on Industrial Chain Resilience

(1) Core Publications and Literature Sources

The time span of the retrieval was set from January 1, 2018 to October 30, 2025. The retrieval was conducted in the title field using a Boolean search expression: title equals Industrial Chain Resilience or title equals Industrial Resilience. Only academic journal articles were included in the retrieval results. The source of publications was restricted to three categories of authoritative journals: Science Citation Index (SCI), Chinese Social Sciences Citation Index (CSSCI), and Peking University Core Journals. We include both industrial chain resilience and industrial resilience as keywords. Industrial chain resilience is the core concept of this study, while industrial resilience is its broader equivalent. The two terms overlap substantially in domestic research, and using both ensures comprehensive coverage and avoids missing relevant literature. After the initial retrieval was completed, the literature was filtered according to document type and publication source. Irrelevant studies were then excluded through manual screening. Duplicate documents were removed using the built-in deduplication function of CNKI, followed by a further manual cross-check to ensure accuracy. Finally, a total of 259 valid academic papers were obtained as the analytical sample of this study. The time slicing was set from 2018 to 2025 with a single year as the time slice unit. The node types included author, institution, and keyword. The threshold was determined by selecting the Top 50 items for each time slice. Pruning was applied to both sliced networks and merged networks. The clustering algorithm adopted was the Log-Likelihood Ratio (LLR). The LLR algorithm was used because it is the most widely applied method in CiteSpace and can stably and efficiently extract core themes from each cluster. Concurrently, CiteSpace 6.3.R1 software was employed to conduct a visual analysis of the sample literature, generating knowledge maps depicting author collaboration, research institutions, keyword co-occurrence, keyword clustering, and keyword timelines. This comprehensive analysis presents the current status, key research areas, and future trends in industrial chain resilience research.

(2) Author and Collaboration Network Analysis

A visual analysis of the research authors was conducted using CiteSpace software. The results showed a total of 121 author nodes (N), 58 edges (E), and a network density of 0.008. This indicates that the community of researchers studying industrial chain resilience has begun to take shape, but there is a lack of collaboration and communication among authors, and the vast majority are conducting independent research. Additionally, an analysis of publication output revealed that He Zhengchu from Xiangtan University had the highest output, with a total of 5 publications. According to Price's Law, the formula $M \approx 0.749 \times N_{max}^{1/2}$ applies, where N_{max} represents the number of papers published by the most prolific author in the field, and M represents the minimum publication output of core authors. According to the formula $M \approx 0.749 \times N_{max}^{1/2} = 0.749 \times 5^{1/2} \approx 2$, the minimum number of publications for a core author is 2. Statistical analysis of the publication output of core authors reveals that they have published a total of 75 papers, accounting for approximately 29% of the total output. This figure falls significantly short of 50% of the total output, indicating that a stable group of core authors has not yet formed in the field of industrial chain resilience research. (Figure 2)

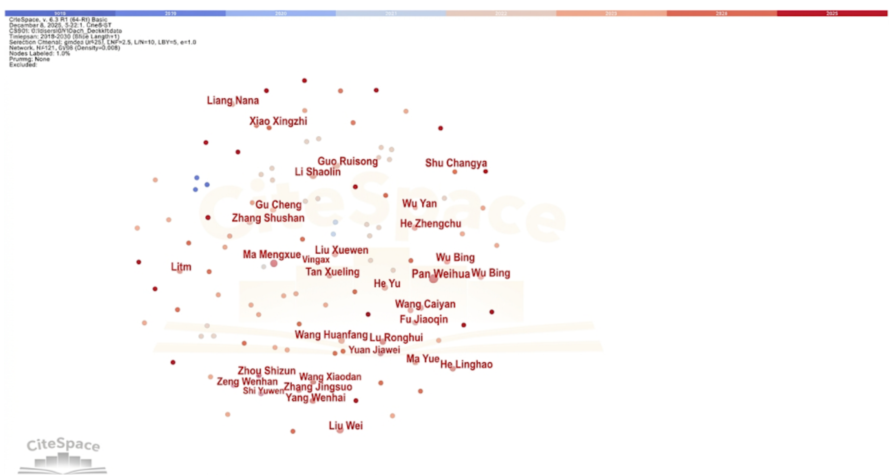

Figure 2. Core authors in industrial chain resilience research, 2018-2025.

(3) Analysis of Research Institutions and Publications

The results of the visual analysis of research institutions show that there are 106 institutional nodes (N) and 142 connecting lines (E), with a network density (Density) of 0.0075. This indicates that while there are numerous institutions in China engaged in industrial chain resilience research, the vast majority are either isolated or dispersed. Only a small number of institutions are connected by links, such as Renmin University of China, Peking University, and Wuhan University, as well as Chongqing University of Posts and Telecommunications, Guizhou Normal University, University of Electronic Science and Technology of China, and Youjiang Medical College for Nationalities. This suggests that the majority of research institutions primarily conduct independent research, with only limited collaboration and exchange. Meanwhile, the top five institutions by publication volume are Xiangtan University (5 papers), Northeast Normal University (5 papers), Three Gorges University (4 papers), Nankai University (4 papers), and Southwest University (4 papers). These five institutions span multiple regions without obvious clustering; they include both top-tier 985/211 universities and Double First-Class and provincial key universities, covering research capabilities at various levels. (Figure 3)

Figure 3. Map of core publishing institutions in industrial chain resilience research, 2018-2025.

4. Analysis of Hotspots and Trends in Industrial Chain Resilience Research

4.1. Keyword Co-Occurrence Analysis

Keywords provide a highly condensed and general overview of an article. Analyzing keyword frequency, co-occurrence, and clustering can effectively reflect the research themes of this study and is a common method for revealing hotspots, intrinsic connections, and development trends within the research field. Keyword co-occurrence is a relatively common and effective analytical method in literature analysis. Using Citespace software, we set the node to "keyword" for analysis and obtained keyword co-occurrence information, as shown in Table 1.

As shown in Table 1, aside from resilience, industrial resilience, and industrial chains (34 mentions in total)—which constitute the core research categories—high-frequency terms in related studies include the digital economy (30 mentions) and artificial intelligence (10 mentions). This reflects that research on industrial chain resilience is primarily divided into three major categories. First, research on concepts related to industrial chain resilience, such as "industrial chain" and "resilience," focuses on the foundational theories and connotations of industrial chain resilience; second, research on background domains, such as "digital economy," explores the impact and reshaping of the digital economic environment on industrial chain resilience; third, research on methods and scenarios, such as "artificial intelligence," "technological innovation," and "manufacturing," examines how technology enhances resilience in specific industrial contexts.

Table 1. Keyword frequency and centrality.

Frequency	Keyword	Centrality	Keyword
30	Digital Economy	0.2	Digital Economy
13	Resilience	0.16	Resilience
11	Industrial Resilience	0.26	Industrial Resilience
10	Industrial Chain	0.07	Industrial Chain
10	Artificial Intelligence	0.10	Artificial Intelligence
9	Technological Innovation	0.17	Technological Innovation
8	Manufacturing	0.07	Manufacturing

Using Citespace software, we can perform burstness analysis on keywords. This provides information such as the starting year of citation bursts, burstness strength, onset time, and persistence, allowing us to identify research hotspots across different time periods and their evolutionary trajectories. By selecting the "burstness" operation in the control panel, we generate a keyword burstness plot, as shown in **Figure 4**. In the keyword co-occurrence analysis, the raw results reveal five burstness values: Rural Revitalization (1.21), Technological Innovation (1.21), resilience (1.07), Rural Industries (0.91), and Transaction Costs (0.53). Through keyword burstness analysis, we can observe that the emergence of the industrial chain resilience research hotspot exhibits temporal concentration, with the surge in citations for related keywords primarily concentrated in 2022; rural industrial chain resilience, technology-enabled industrial chain resilience, and cost reduction and efficiency improvement remain current research priorities; later-stage research hotspots exhibit greater persistence, suggesting that "transaction costs" will be a sustained research direction in the field of industrial chain resilience for the foreseeable future. In this regard, relevant scholars argue that advancing agricultural and rural modernization and enhancing the resilience of agricultural industrial chains necessitates strengthening the development of digital villages; deepening the application and innovation of technology in agriculture in the new era has become a core issue in supporting rural revitalization. (**Figure 4**)

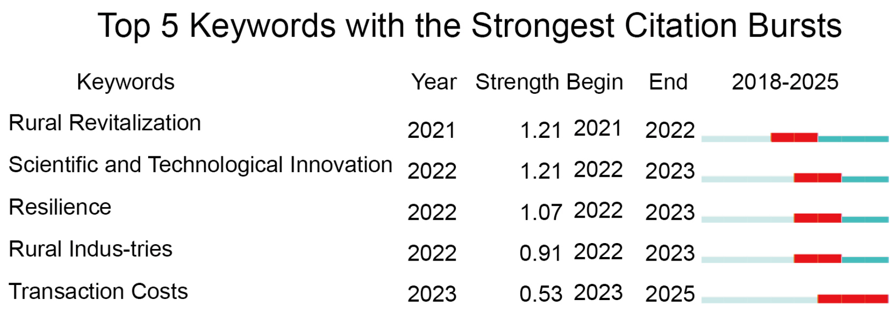

Figure 4. Frequency of keyword occurrences in industrial chain resilience.

4.2. Keyword Cluster Analysis

Since the distribution of keywords varies across different papers, it is necessary to conduct a clustering analysis after performing co-occurrence analysis of keywords in Citespace. This approach not only systematically categorizes scattered keywords but also enables researchers to better understand the specific research directions within this field. Citespace software offers three clustering algorithms: LSI, LLR, and USR. While the results from these three methods are not entirely consistent, they share some similarities. Therefore, this study adopted the more commonly used LLR method for keyword clustering analysis, with the results shown in Figure 5. The clustering results clearly reveal the specific keywords within each major cluster, while also highlighting the theoretical characteristics, problem-oriented focus, and contemporary features of "industrial chain resilience" research at this stage. The Q and S values, which are metrics used to evaluate clustering results, indicate that the keyword clustering results are significant (Q = 0.6038 > 0.3) and convincing (S = 0.8751 > 0.7).

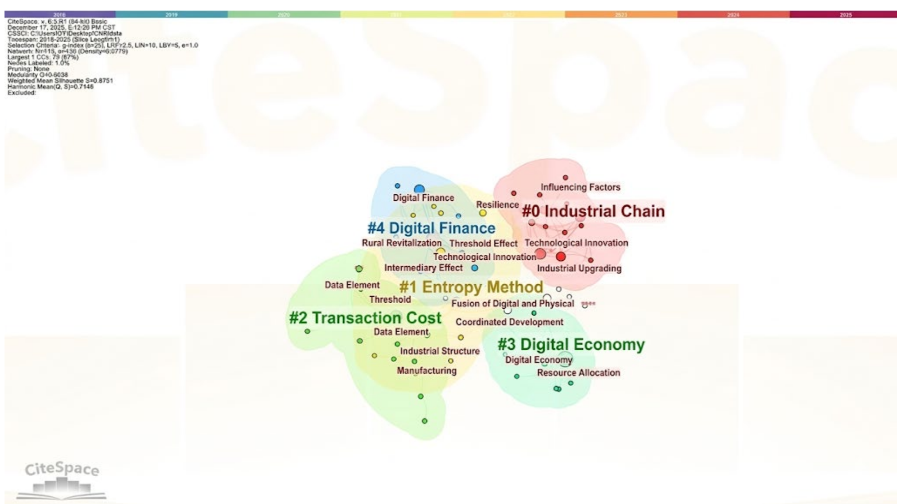

Figure 5. Keyword clustering diagram.

In the keyword clustering diagram, each "#" denotes an independent thematic cluster and represents the cluster's size; the smaller the number, the greater the number of keywords and documents the cluster contains, and the higher its proportion and importance within the research field. It is evident that "#0 Industrial Chain" is the largest core cluster, focusing on industrial resilience, industrial chain upgrading, regional chains, and technological innovation, indicating that technology-driven industrial and supply chain resilience is the core research topic in this field. Next is "#1 Entropy Method," which focuses on quantitative analysis of industrial structure and dynamic evolution, reflecting the field's characteristic use of entropy methods for empirical research. "#2 Transaction Costs" is associated with manufacturing and the integration of digital and real economies, with research on the impact of digital technologies on transaction costs in manufacturing emerging as a key subfield. "#3 Digital Economy" serves as the foundational cluster, forming the core foundation of the entire research field. Finally, the "#4 Digital Finance" cluster centers on rural revitalization and artificial intelligence, reflecting research hotspots in the integration of digital finance with rural industries and technology. As shown in **Figure 5**, the clustering regions of digital finance, the digital economy, industrial chains, and transaction costs overlap, reflecting the strong interconnections among these keywords. This indicates that digital finance and the digital economy serve as the core drivers for restructuring industrial chains and optimizing transaction costs, with a high degree of research integration across these themes. The entropy method is closely associated with themes such as industrial chains and industrial structure, reflecting the field's emphasis on using quantitative methods to study industrial development. Based on the thematic correlations illustrated in **Figure 5**, this study derives core theoretical insights. Digital finance and the digital economy constitute fundamental factor inputs, transaction cost reduction delivers efficiency improvements, and industrial chain restructuring acts as a vital structural carrier. Collectively, these elements jointly drive the theoretical mechanism of industrial chain resilience improvement.

Industrial chain resilience can be divided into two core dimensions: "industrial chain" and "resilience," which together form a unified concept aimed at enhancing the industrial chain's risk resistance and sustainable development capabilities. "Industrial chain" emphasizes a complete industrial ecosystem comprising stages such as raw material supply, manufacturing, logistics, and market sales, encompassing core elements including human resources, technology, capital, infrastructure, and market channels. "Resilience" refers to an industrial chain's capacity to withstand, recover from, reconstruct, and upgrade in the face of external shocks and internal fluctuations, including key characteristics such as shock resistance, flexibility, and adaptability.

From a practical perspective, building self-reliance and control in industrial chains and fostering their synergistic integration represent the two core pathways for enhancing industrial chain resilience. We must make breakthroughs in key core technologies to boost the resilience of industrial chains. Academic circles generally agree that the focus of building self-reliant and controllable industrial chains lies in breaking through "chokepoint" technological bottlenecks and addressing shortcomings in areas such as high-end materials, core components, and advanced processes; strengthening vertical integration across the industrial chain to cultivate a group of leading enterprises with ecosystem dominance; and improving the support system for innovation factors to build a technology innovation system that deeply integrates industry, academia, research, and application, thereby laying a solid technological foundation for enhancing industrial chain resilience. The development of industrial chain synergy and integration serves as a crucial pillar for enhancing overall resilience. The development of industrial chain synergy and integration involves key issues such as the integrated development of large, medium, and small enterprises; the complementary regional layout of industrial chains; and the deep coupling of industrial chains with innovation chains, capital chains, and talent chains. Relevant research suggests that the development of industrial chain synergy and integration is primarily manifested at three levels: first, using industrial clusters as a vehicle to build a network of division of labor and collaboration among industrial chains across regions; second, through digital transformation, breaking down data barriers across all links of the industrial chain to achieve precise matching of supply and demand and efficient allocation of resources; and third, establishing emergency coordination mechanisms for industrial chains to enhance emergency response and resource allocation capabilities under extreme conditions.

"Industrial chain vulnerability" refers to the inherent tendency of industrial chains to experience disruptions, bottlenecks, and efficiency declines when subjected to internal or external shocks. This is caused by multiple factors, including imbalances in industrial structure, excessive reliance on foreign core technologies, overly concentrated supply chain layouts, and the absence of emergency response mechanisms. At its core, it represents an imbalance between the allocation of industrial chain elements and the capacity to respond to risks. This phenomenon is particularly pronounced in sectors highly dependent on external resources or technologies, such as the supply of raw materials for new energy vehicle batteries, high-end chip manufacturing, and the production of pharmaceutical intermediates. Industrial chain vulnerability can lead to a sharp rise in corporate production costs and disruptions in production and operations. It constrains the pace of development in emerging industries, making it difficult to meet the demands of high-quality economic development and social welfare, and resulting in a dual imbalance between industrial chain supply capacity and market demand as well as security requirements. In terms of response mechanisms, targeted measures must be implemented based on the different types of industrial chain vulnerability and the characteristics of various industries to address weaknesses, build on strengths, and strengthen the industrial chain, thereby enhancing its overall resilience and development quality.

Research in this field is grounded in the digital economy and centers on industrial chain upgrading and resilience, while also extending into sub-areas such as the empowerment of the real economy through digital finance and the optimization of transaction costs in manufacturing. Quantitative research methods are widely applied in this field.

4.3. Analysis of Hot Topics

Furthermore, by analyzing keyword co-occurrence knowledge graphs, it was found that the core topics regarding industrial chain resilience between 2018 and 2025 primarily concentrated on four aspects: the digital-physical integration of industrial chains and manufacturing; the digital economy and industrial structure upgrading; technology-driven industrial chain resilience; and rural digital agriculture. Research on the digital-physical integration of industrial chains and manufacturing primarily focuses on the deep integration of the digital economy with the real economy in the manufacturing sector. It explores how digital technologies can be embedded into various stages of the industrial chain—such as production, manufacturing, and supply chains—addressing the questions of "how to integrate" and "how to implement" the digital economy within the real economy. Clarifying the path of industrial integration helps drive the transformation and upgrading of traditional manufacturing; Research on the digital economy and industrial structure upgrading is grounded in the context of the rapid development of the digital economy. It explores the driving role of digital factors in optimizing industrial structures and facilitating the transition from old to new growth drivers. It focuses on how the digital economy can guide industries toward high-end and intensive development, representing a crucial research direction for achieving high-quality industrial development; Research on the resilience of industrial chains driven by technology focuses on analyzing the mechanisms through which digital technologies and innovation capabilities enhance the stability, security, and risk-resilience of industrial chains. It concentrates on how to leverage technological empowerment to address external shocks and ensure the security and controllability of industrial and supply chains, representing a key issue for maintaining the sustained and stable operation of industries; Research on rural digital agriculture extends the application of digital technologies to the fields of rural revitalization and agricultural development. It explores application models for digital and intelligent technologies in agricultural production, operations, management, and services, and is dedicated to driving agricultural modernization and high-quality rural development through digitalization. The aforementioned four research topics are interconnected and mutually supportive. Together, they form the overall framework for industrial development research in the context of the digital economy, covering dimensions such as industrial integration, structural upgrading, security and resilience, and rural applications.

(1) Digital-Physical Integration of Industrial Chains and Manufacturing

As the core pathway for the deep integration of the digital and real economies, the convergence of the digital and real economies serves as a key driver for enhancing the resilience of manufacturing industrial chains and achieving their modernization and upgrading. Currently, academic research on the relationship between digital-physical integration and the resilience of manufacturing industrial chains has been conducted from multiple dimensions. Rich findings have been generated—ranging from mechanisms of action, pathways of influence, and characteristics of effects to empirical validation—providing important theoretical support for understanding the intrinsic logic between the two and guiding industrial practice, while also clarifying the core principles by which digital-physical integration empowers the development of manufacturing industrial chains.

From the perspective of their relationship, the role of digital-physical integration in enhancing the resilience of manufacturing industrial chains is significantly positive and multifaceted. Its core lies in reshaping the operational model of industrial chains through the comprehensive integration and permeation of digital technologies and the physical industry across production, management, and decision-making processes. The integration of artificial intelligence with digital-physical technologies represents a key direction for empowerment. It not only enhances the industrial chain's capacity for resource integration and restructuring through refined management and dynamic regulation, thereby strengthening risk resilience, but also promotes information sharing and collaborative decision-making among enterprises via intelligent supply chain platforms, thereby improving the industrial chain's flexibility and adjustment efficiency (Jiao & Liu, 2025). From the perspective of overall effects, the positive impact of digital-physical integration on industrial chain resilience exhibits distinct spatial spillover characteristics. Under an economic geography nesting matrix, it can generate maximized positive spatial spillover effects. Simultaneously, it exhibits a dual-threshold effect with industrial structure; as the levels of both improve, their enabling effects will gradually strengthen (Wu & Meng, 2025).

Mechanistically, the dual "technology-data" drive of enterprises constitutes the core internal logic through which digital-physical integration influences the resilience of manufacturing industrial chains, with the integration of digital technologies and the circulation of data elements serving as key drivers (Li & Jin, 2025). By enhancing information connectivity within industrial chains, optimizing resource allocation, and constructing networked structures, the integration of digital and real economies strengthens industrial chain resilience across two dimensions: resistance and recovery. This effect is particularly pronounced in private enterprises and technology-intensive industries. From a long-term development perspective, while the integration of the digital and real economies may temporarily increase corporate management costs, it can significantly boost total factor productivity, promote the integration of digital technology paradigms into traditional manufacturing technology systems, and facilitate the restructuring and upgrading of industrial chains. The improvement in total factor productivity, industrial agglomeration, and the level of digital transformation are precisely the key channels through which the integration of the digital and real economies empowers industrial chain resilience (Wu & Meng, 2025).

Furthermore, as the core manifestations of the integration of the digital and real economies, digital transformation and the digital economy exert their influence on the resilience of manufacturing industrial chains through multidimensional mechanisms and complex spatial characteristics. Digital transformation can significantly enhance the resilience of local manufacturing industrial chains; however, due to the influence of homogeneous development strategies across regions, it may exert certain negative spatial effects on neighboring areas, while talent aggregation and technological innovation play a mediating role between digital transformation and industrial chain resilience (Yang et al., 2025a). The positive impact of the digital economy on the resilience of manufacturing industrial chains exhibits nonlinear characteristics with increasing marginal returns. Its sub-dimensions—digital industrialization and industrial digitalization—work in concert to drive the modernization and upgrading of industrial chains by deepening the data value chain and strengthening the foundational capabilities of traditional industries, respectively. Simultaneously, they enhance resilience through industrial synergy and technological innovation effects, generating positive spatial spillover effects (Zhang et al., 2025a).

Finally, in terms of implementation pathways, the digital economy comprehensively enhances the resilience of manufacturing industrial chains across three dimensions—resistance, recovery, and transformation. Its practical implementation must center on three core tasks: "stabilizing the chain," "supplementing the chain," and "strengthening the chain" (Dong & Zhao, 2025). In practice, it is necessary to fully leverage the diverse driving forces of the digital economy's various elements to promote the phased development of industrial chain digital transformation. This involves establishing a "single-chain, multi-point, comprehensive" advancement model and building an industrial chain ecosystem led by "chain-leading" enterprises. Concurrently, tailored strategies should be formulated based on different industrial types and regional characteristics to fully unleash the empowering effects of the integration of the digital and real economies, thereby continuously enhancing the risk-resilience and sustainable development capabilities of manufacturing industrial chains.

(2) The Digital Economy and Industrial Structure Upgrading

As the core driving force of economic development in the new era, the digital economy's deep integration with industrial restructuring is emerging as a key pathway to enhancing the resilience of industrial chains. Academic circles have engaged in multidimensional discussions regarding the intrinsic relationship, mechanisms of action, and practical pathways between the two, providing important theoretical support for high-quality industrial development. In terms of causality, the digital economy, leveraging its multiple advantages in factor introduction, model innovation, and industrial cultivation, not only injects new momentum into enhancing industrial chain resilience but also strengthens the foundation of industrial development through the improvement of digital infrastructure and the cultivation of digital enterprises. Its empowering effects have been empirically validated in traditional industrial sectors such as agriculture (Song &

Zhao, 2025).In the process of industrial structural upgrading, the penetration of the digital economy has broken through the factor constraints and model shackles of traditional industrial development, driving industrial chains to transition from single-stage production coordination to high-quality development across the entire chain and in multiple dimensions.

Of course, the digital economy's empowerment of high-quality industrial chain development is not one-dimensional; rather, it is grounded in the five major development concepts of innovation, coordination, green development, openness, and sharing. It achieves multiple objectives, including enhancing the efficiency of supply and demand chains, stabilizing enterprise chains, optimizing spatial chains, and upgrading value chains. Its core logic lies in bridging the gap between efficiency and security through the enhancement of industrial chain resilience, thereby serving as a key intermediary connecting the digital economy with high-quality industrial development (Pan et al., 2025). The identification of this intermediary mechanism clarifies the intrinsic logic by which the digital economy balances the "efficiency objectives" and "security objectives" of industrial chains. It also underscores the importance of building resilience during industrial structural upgrading, providing a new analytical perspective for future research.

In terms of its mechanism of action, the digital economy relies on three major effects—data-driven traction, digital technology-driven momentum, and resource allocation-driven impetus—to empower the enhancement of industrial chain resilience through four pathways: strengthening the digital foundation, building digital enterprises, enhancing digital applications, and improving the digital environment. Its characteristics of openness, trans-spatiality, and sharing further reinforce internal linkages within the industrial chain, and under different external environments, it exhibits differentiated spatial spillover effects and risk protection effects (Li et al., 2024). However, the current process of digital economy empowerment still faces practical challenges such as low data integration efficiency, weak digital infrastructure, insufficient technological innovation capacity, and regional development imbalances, which have become significant factors constraining industrial structure upgrading and the enhancement of industrial chain resilience.

In fact, the essence of the digital economy's role in driving the optimization and upgrading of industrial structures lies in injecting new momentum into the modernization of industrial chains through the widespread application of digital industries, while the continuous expansion of industrial digitalization, in turn, promotes the deep integration of the digital economy with the real economy (Liang & Jin, 2023). In response to the constraints on the enabling role of the digital economy, academic circles have proposed focusing efforts on four key dimensions—digital infrastructure, data flow, information sharing, and talent support—to promote deep synergy among the digital chain, innovation chain, talent chain, and industrial chain. By enhancing the multiplier effect, this approach aims to achieve both qualitative improvements and reasonable quantitative growth in industrial chains. Overall, the integrated development of the digital economy and industrial structure upgrading is an inevitable choice for enhancing industrial chain resilience. Future research should further focus on regional heterogeneity and industrial differentiation to explore more targeted empowerment pathways and drive the deepening integration of the digital economy and the real economy.

(3) Technology-Driven Industrial Chain Resilience

As the core driving force of industrial development, the intrinsic link between technological innovation and industrial chain resilience has become a hot topic in industrial economics research. The academic community has conducted in-depth analyses of the mechanisms, characteristics, and practical challenges of technology-driven resilience enhancement across dimensions such as high-tech manufacturing and digital innovation, providing diverse theoretical perspectives and practical references for fostering industrial resilience. In the high-tech manufacturing sector, the positive empowering effect of technological innovation on industrial resilience has been empirically validated. Moreover, this empowerment exhibits distinct dimensional differences, with its role in enhancing resilience to shocks being significantly stronger than in other dimensions, highlighting the critical supporting role of technological innovation when industrial chains respond to external shocks (Zheng & Yang, 2022). At the same time, the development of the digital economy has further amplified the empowering effects of technological innovation. By enhancing the operational efficiency of supply chains, it has injected new momentum into the enhancement of industrial chain resilience, achieving synergistic effects between technological and digital factors.

It should be noted that the empowering effect of technological innovation on industrial chain resilience is not a direct one but is characterized by significant mediating mechanisms and threshold constraints. Industrial upgrading plays a crucial mediating role in the process by which technological innovation empowers industrial chain resilience. Technological innovation indirectly enhances industrial chain resilience by driving the optimization of industrial structure and the upgrading of industrial forms, and this mediating effect is particularly pronounced in the dimension of fracture resilience (Zheng & Yang, 2022). From the perspective of threshold effects, industrial chain resilience itself can serve as a threshold variable. When industrial resilience is at a high level, the positive promotional effects of technological innovation and industrial upgrading are further enhanced, forming a virtuous cycle of "resilience enhancement—strengthened empowerment effects." This finding clarifies the nonlinear characteristics of technology-driven industrial chain resilience enhancement.

Consequently, digital technological innovation has become a key driver for fostering industrial chain resilience. From a micro-enterprise perspective, it promotes the comprehensive enhancement of industrial chain resilience through three primary pathways: reducing transaction costs, facilitating information flow, and promoting continuous innovation (Fang et al., 2025). Digital technology innovation not only enhances enterprises' capabilities in risk identification, prevention, and resolution—thereby establishing the microfoundations for industrial chain risk management—but also optimizes the industrial chain's development landscape from both the entity and structural dimensions. It strengthens enterprises' dynamic adaptability, increases the information penetration of industrial chain networks, and effectively stabilizes supply-demand relationships while mitigating the risk of supply chain disruptions. However, the short-term cost implications of digital technology innovation must not be overlooked; the rise in operational costs in the short term will, to some extent, constrain its empowering effect on enhancing industrial chain resilience.

Turning to China, the development of resilience in the country's high-tech industrial chains exhibits a significant characteristic of overall improvement but regional imbalance. While resilience levels show a fluctuating upward trend, development gaps between regions have become a key factor constraining overall improvement (Zhang, 2025). Among these factors, regional disparities in industrial chain renewal capacity are most pronounced, and regional heterogeneity in evolutionary capacity has also become a significant contributing factor, reflecting the uneven regional development of China's high-tech industrial chains in terms of resource allocation, technological iteration, and industrial upgrading. In response to this reality, the academic community has proposed focusing on three key areas: enhancing supply chain resilience, fostering a collaborative development framework for renewal capacity, and optimizing spatial layout. By coordinating regional development and strengthening synergistic linkages, we can drive an overall improvement in the resilience of China's high-tech industrial chains. Overall, the enhancement of industrial chain resilience driven by technology is a multidimensional, nonlinear, and dynamic process. Future research should further focus on regional heterogeneity, industrial diversity, and factor synergy to explore more targeted empowerment pathways and promote the deep integration of technological innovation with the cultivation of industrial chain resilience.

(4) Rural Digital Agriculture

The deep penetration of digital technologies into the agricultural sector has driven the rapid development of rural digital agriculture, making it a core lever for fostering and enhancing the resilience of agricultural industrial chains. Academic circles have systematically analyzed the effects, mechanisms, and implementation pathways through which rural digital agriculture empowers the resilience of agricultural industrial chains, focusing on dimensions such as digital rural development and the new productive forces of digital agriculture. This has provided important theoretical support and practical guidance for the high-quality development of the agricultural industry and the revitalization of rural industries. The construction of digital villages is not a one-dimensional application of technology, but rather a comprehensive integration into the development process of the agricultural industrial chain across three dimensions: infrastructure, industry, and daily life. By restructuring the intrinsic logic of the industrial chain, it achieves a systematic enhancement of resilience. Its empowering effects are primarily realized through two transmission pathways: the enhancement of new-quality productive forces in agriculture and the optimization of industrial agglomeration levels (He et al., 2025).

In practice, the empowerment of agricultural industrial chain resilience through digital rural development exhibits multi-path configuration characteristics. The synergistic integration across different dimensions has formed differentiated resilience enhancement models. Among these, three pathways—digital infrastructure synergizing with digital industries, digital infrastructure and digital living synergizing to support digital industries, and digital infrastructure and digital industries synergizing to support digital living—have emerged as effective paradigms for enhancing agricultural industrial chain resilience in practice (He et al., 2025). Although these three configuration pathways have different focuses, they all rely on digital infrastructure as the underlying support. Through the interaction of technology, organization, and ecosystem, they drive a paradigm shift in the resilience of the agricultural industrial chain—from static to dynamic and from local to systemic—breaking through the elemental constraints and model shackles of traditional approaches to enhancing resilience.

Furthermore, the new-quality productive forces of digital agriculture, as the core achievement of rural digital agricultural development, have emerged as a new driving force for enhancing the resilience of agricultural industrial chains. Characterized by high efficiency and low energy consumption, these forces drive the upgrading of the entire agricultural industrial chain through their digital and informational attributes, thereby injecting new momentum into the cultivation of industrial chain resilience (Wu & Shang, 2025). This productive force not only applies modern digital technologies across all stages of agricultural R&D, production, and distribution—thereby eliminating bottlenecks and extending the industrial chain—but also mitigates systemic risks by fostering new agricultural sectors, business models, and technologies, thereby enhancing the agricultural industrial chain's ability to withstand external shocks at the source. The empowerment of agricultural industrial chain resilience by the new-quality productive forces of digital agriculture follows a clear mechanism of action and regulatory effects. At its core, it enhances industrial chain resilience by optimizing the allocation of innovation factors, while the construction of digital infrastructure plays a significant positive regulatory role in this empowerment process (Wu & Shang, 2025). The development of the new-quality productive forces in digital agriculture can increase the stock of innovation factors in the agricultural sector and promote the rapid flow of innovation resources, while well-developed digital infrastructure further amplifies this effect, enhancing the efficiency of factor allocation across all links of the industrial chain and forming a virtuous cycle of "productivity enhancement—optimized factor allocation—enhanced resilience."

Consequently, the deep integration of the digital economy and digital technologies positions digital agriculture as a key breakthrough for enhancing the resilience of the agricultural industrial chain. It not only enables agricultural producers to precisely align with market demand but also alleviates financial constraints on agricultural production and operations through the empowerment of digital finance (Song & Zhao, 2025). Based on the above analysis, local governments should promote the digital construction of rural areas, build an agricultural IoT monitoring system, and realize the full-chain digital traceability of food security; agricultural enterprises should develop digital agriculture and strengthen the resilience of the agricultural industrial chain. Overall, the use of rural digital agriculture to enhance the resilience of the agricultural industrial chain is a multidimensional, multi-pathway systemic endeavor. Future research and practice must further strengthen the construction of digital infrastructure, cultivate new-quality productive forces in digital agriculture, optimize the allocation mechanisms for innovation factors, and promote the synergistic integration of all dimensions of digital rural development. This will ensure that digital technology truly becomes a sustainable driving force for enhancing the resilience of the agricultural industrial chain, thereby supporting the revitalization of rural industries and the modernization of agriculture.

5. Analysis of Research Frontiers

Based on the clustering analysis results in **Figure 5**, we created a timeline visualization map of the industrial chain resilience research field (**Figure 6**), clearly illustrating the evolutionary trajectory and shifting trends of research hotspots in this field. In terms of node density and clustering relationships, the core node "Industrial Chain Resilience" has consistently remained at the center of the network. Meanwhile, the emergence of emerging nodes such as "Digital Technology" and "Artificial Intelligence," along with the increased strength of their connections, reflects that technology empowerment has become the core evolutionary direction of industrial chain resilience research.

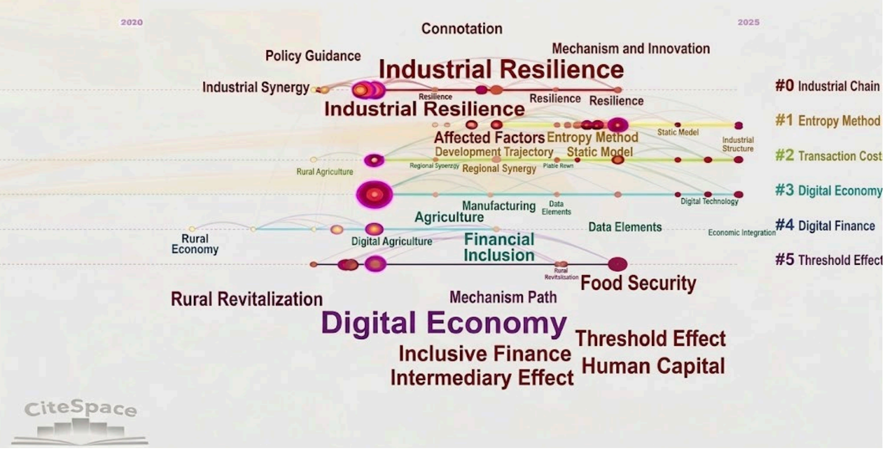

Figure 6. Timeline of keyword clustering.

Based on the clustering and association characteristics of the CiteSpace timeline map, three major frontier directions in the current industrial chain resilience research field can be identified: digitalization and food security resilience, the coordinated development of digital technology and data elements, and the spatial effects of artificial intelligence driving industrial structure upgrading.

Regarding the deep coupling of digitalization and food security resilience, the timeline map reveals that the nodes “food security” and “digital-physical integration” have exhibited significant co-occurrence since 2023, with a marked surge in connection strength. This pattern indicates explosive growth in this research area in recent years. Within the research framework of industrial chain resilience, food security has gradually evolved from a traditional issue of production capacity assurance to a comprehensive issue of end-to-end resilience enabled by digital technologies. Digitalization enhances food security resilience through dual empowerment at both the “production end” and the “distribution end.” At the production end, digital technologies such as the Internet of Things (IoT) and satellite remote sensing can precisely monitor soil moisture and crop growth, optimize agricultural production decisions, and enhance stable grain production capacity from the source; At the distribution end, blockchain and traceability technologies enable end-to-end tracking of the food supply chain, accelerating emergency response times and reducing the risk of supply chain disruptions. This “digital-physical integration” model represents cross-sectoral innovation between the digital economy and food security, offering new theoretical perspectives and practical pathways for safeguarding national food security. Existing research has theoretically demonstrated the mechanisms through which digital technologies empower the resilience of the entire grain industry chain, clarifying that the digital economy’s impact on agricultural industry chain resilience exhibits spatial spillover effects (Yang & Ma, 2025). The emergence of “digital-physical integration” nodes presented in this map further corroborates the evolutionary trend in this field from “technology application” to “deep scenario integration,” This resonates with the research conclusion in *Chinese Agricultural Resources and Regional Planning* that “digital rural development can significantly enhance the resilience of agricultural industrial chains” (He et al., 2025). Compared to earlier studies that focused on the discussion of the technical attributes of tools, current research pays greater attention to the deep coupling of digital technologies with agricultural production scenarios, which has become a core issue for the future of this field.

Second, the synergistic development of digital technology and data as a production factor has become a key issue in enhancing the resilience of industrial chains. The nodes “digital technology,” “data as a production factor,” and “transaction costs” exhibit significant clustering and correlation, and the prominence of the “synergistic development” label underscores the theoretical depth of this issue. Digital technology provides support for the circulation and value transformation of data elements, while data elements, in turn, empower technological innovation and iteration. By reducing information asymmetry, lowering transaction costs, and optimizing resource allocation, the two jointly drive the enhancement of industrial chain resilience. The core of this lies in their deep coupling, which resolves the contradictions inherent in the attributes of these elements, drives the transformation of industrial chain division of labor models, and thereby enhances the adaptive and recovery capabilities of the system within the chain. Existing research provides a solid theoretical foundation and testing framework for this mechanism: The marketization of data elements enhances industrial chain resilience through the restructuring of corporate digital capabilities, the driving force of technological diversity, the flexible adjustment of working capital, and the enhancement of reputation and trust mechanisms (Ning & Su, 2025). Data elements can promote industrial chain resilience through two channels: reducing transaction costs and strengthening industrial linkages. This research constructs a theoretical framework for the realization of factor value, providing an important reference for the synergy logic analysis in this study; Furthermore, labels in the network diagram such as the "threshold effect" and "mediation effect" resonate with existing research approaches—which use nonlinear models to validate the boundaries of technological empowerment and leverage mediation pathways to reveal transmission mechanisms—further corroborating the academic consensus and research continuity surrounding this topic.

Third, the spatial effects of AI-driven industrial structure upgrading have become a focal point in academic circles. The network analysis reveals a sustained cross-temporal association between the "AI" and "industrial structure" nodes, accompanied by core tags such as "regional disparities" and "industrial agglomeration." This indicates that the topic has transcended the framework of single-region analysis and extended into the realm of spatial economics, directly resonating with academic explorations of the spatial heterogeneity of industrial chain resilience. From a theoretical perspective, artificial intelligence drives the formation of "technological hubs" in core regions through the aggregation of factors via three major mechanisms: technological diffusion, industrial agglomeration, and the restructuring of regional division of labor. while the development of new-quality productive forces can enhance the resilience of circulation industrial chains in neighboring regions through spatial spillover effects (Wu, 2025), driving industrial upgrading in surrounding areas. This, in turn, reshapes the regional division of labor, optimizing industrial structures while improving the efficiency of regional resource allocation, thereby offering a new theoretical explanation for the regional heterogeneity of industrial chain resilience. At the same time, Yang et al. (2025b) explicitly point out that the "siphoning effect" between regions—resulting from the radiation of technology diffusion and capital flows into neighboring areas—may lead to development imbalances. Compared to existing studies that focus on testing spatial spillovers at the macro level, this map further reveals the intrinsic link between "regional disparities" and "spatial effects," refines the spatial evolution patterns of industrial chain resilience, and provides intuitive cartographic evidence for subsequent heterogeneity research.

(1) Synergistic Empowerment of Industrial Resilience by Digital Technologies and Data Factors

Against the backdrop of profound adjustments in the global industrial chain landscape and increasing external uncertainties, the synergistic integration of digital technologies and data elements is emerging as a key driver for breaking through traditional industrial development bottlenecks and enhancing industrial resilience. Their mutual empowerment has established a new support system for ensuring the autonomy and controllability of industrial chains, as well as for enhancing their risk resistance and recovery capabilities. Building on the practical experience of digital economic development, existing research has analyzed the intrinsic mechanisms through which digital technologies and data elements empower industrial resilience from multiple dimensions—ranging from macro-level industries to micro-level enterprises, from overarching logic to specific pathways, and from the roles of individual elements to the effects of integration. This has resulted in a well-structured theoretical and empirical research framework, providing a crucial reference for understanding the logic behind the construction of industrial resilience in the digital age.

From the perspective of macro-level industries and multi-stakeholder collaboration, some scholars have clarified the overall logic by which the digital economy empowers the resilience of manufacturing industrial chains. They have identified the technological advantages of digital technologies and the integrative value of data elements, demonstrating that these can drive the transformation and upgrading of the entire manufacturing chain by strengthening risk forecasting, revitalizing production factors, and optimizing the efficiency of factor allocation. At the same time, they have clarified the collaborative roles of the government, industries, and enterprises in facilitating data channels and expanding the application scenarios of digital infrastructure (Liu, 2025a), thereby establishing a macro-level analytical framework for subsequent research; Building on this foundation, the research perspective is shifted to the micro level of enterprises to further validate the core enhancing effect of data factor inputs on industrial chain resilience. It was found that this effect is not a single-dimensional phenomenon but is reinforced by the level of integration in the digital product market and is primarily achieved through two pathways: enhancing corporate digital transformation and governance levels. Additionally, the study revealed the distinctive advantages of data factors in terms of their breadth and pervasiveness (Zhao & Yang, 2025). This helps core enterprises monitor the operational status of industrial chains and mitigate the risk of disruptions, while simultaneously filling a research gap regarding the mechanisms of factor action at the micro level; Focusing on how data elements can better realize their enabling value, Ning and Su constructed an analytical framework using quasi-natural experiments established through data trading platforms. Extending their research from the perspective of the market-based allocation of data elements, they found that data marketization can integrate innovation resources across industrial chains and promote knowledge spillovers and technological synergy, thereby addressing the question of market-based pathways for data elements to efficiently empower industrial resilience (Ning & Su, 2025).

From the dual perspectives of trade costs and industrial linkages, as well as the integration effects of data as a factor of production with traditional factors such as capital and technology, data not only directly empowers industrial chain resilience by reducing trade costs and strengthening industrial linkages, but also enhances total factor productivity, drives industrial structural optimization, and facilitates value chain restructuring (Li et al., 2025). This indirectly drives the enhancement of industrial resilience through efficiency gains and structural upgrading, establishing the transmission mechanism of the data factor from micro-level enterprise efficiency to meso-level industrial structure; In the process by which the data factor exerts its influence, the supportive role of digital technology innovation serves as a critical link. Research conducted from the perspective of node enterprises further corroborates this point, noting that the self-sustaining and adaptable characteristics of digital technology innovation can synergize with the data factor to drive demand-oriented innovation by capturing market needs (Fang et al., 2025). Simultaneously, the substitution and empowerment of traditional production factors—optimizing product development, controlling the quality of intermediate goods, and stabilizing supply-demand relationships across the industrial chain—further highlight the pivotal role of digital technology innovation in factor synergy.

Scholars have further extended their research perspective to the level of industrial convergence, integrating the multifaceted relationships among digital technology, data elements, and industrial development. From the three perspectives of human capital, technological innovation, and resource allocation, they elucidate how the convergence of digitalization with manufacturing and service industries empowers industrial resilience (Zhang et al., 2025c). The accumulation of high-skilled human capital, the transformation of innovation models, and the improvement in resource allocation efficiency driven by digital transformation can further unlock the synergistic value of digital technology and data elements through capacity support, technological assurance, and ecosystem optimization.

Overall, existing research has established a comprehensive research framework spanning from macro-level synergy frameworks to micro-level mechanisms of action, from the individual roles of factors to integrated synergistic effects, and from foundational empowerment pathways to market-oriented implementation methods, clearly revealing the core logic of how digital technologies and data elements synergistically empower industrial resilience. Future research could combine multidimensional data with empirical methods to conduct in-depth analyses of the optimal pathways for factor synergy, thereby providing more precise theoretical references for policy formulation and corporate practices at the operational level.

(2) The Spatial Effects of Artificial Intelligence in Driving Industrial Structure Upgrading.

Against the backdrop of the deep integration of the digital economy and industrial transformation, artificial intelligence (AI), as a core technological driver, not only directly propels the transformation of industrial structures toward higher levels of sophistication and rationalization, but its cross-regional spatial transmission characteristics have also become a key factor in reshaping regional industrial layouts. Existing research has conducted multidimensional explorations of the spatial relationship between AI and industrial structural upgrading, yielding rich findings ranging from effect characteristics and mechanisms of action to regional heterogeneity, thereby providing important theoretical and empirical support for understanding the spatial evolution patterns of industrial structures in the era of intelligent transformation.

The spatial effects of AI-driven industrial structure upgrading are centered on technological spillovers, exhibiting dual characteristics of local empowerment and cross-regional radiation. The high penetrability and externalities of AI technologies enable them to not only drive local industrial structure upgrading but also, through the cross-regional flow of factors such as technology and knowledge, facilitate the optimization and adjustment of industrial structures in neighboring regions, thereby generating significant spatial spillover effects (Liu, 2025b). This spillover effect is transmitted through the "leading-goose" model. AI technological innovations in developed regions blur the boundaries between innovation actors across regions, promoting information sharing and factor coordination. This, in turn, enhances the sustainable development capacity of industrial chains in surrounding areas and drives the coordinated upgrading of regional industrial structures. At the same time, the spatial convergence of the AI industrial chain's resilience lays the foundation for the spatial transmission of industrial structure upgrading. The trend of gradually narrowing regional disparities in the resilience of China's AI industrial chain continuously lowers spatial barriers to technological spillovers, creating conditions for cross-regional industrial structure upgrading (Lai, 2025).

Policy empowerment and ecosystem support have become key pathways for realizing the spatial effects of AI in driving industrial structure upgrading. The establishment of National AI Innovation and Application Pilot Zones unleashes policy dividends through multiple effects. By leveraging mechanisms driven by data elements, the allocation of innovation factors, and the transmission of industrial structure upgrading, these zones significantly enhance industrial chain resilience and promote industrial structure optimization. Moreover, the empowering effects of this policy are more pronounced in regions with well-developed digital infrastructure and high market integration, confirming the reinforcing role of the policy environment on the spatial effects of AI (Zhou et al., 2025); Digital innovation ecosystems, meanwhile, provide micro-level support for the spatial effects of AI. The intermediary role of digital innovation actors and platforms, along with the regulatory function of the digital ecosystem, enables AI applications to more effectively trigger pervasive transformations in industrial patterns, driving the intelligent transformation of manufacturing and the diversification of business models (Jia & Jiang, 2025). This transformation exhibits more pronounced structural upgrading effects in regions with lower levels of industrial structure advancement, such as central and western China, thereby achieving regional compensation for the spatial effects of AI.

The spatial effects of AI in driving industrial structural upgrading exhibit significant regional heterogeneity and are deeply linked to the foundation of industrial digitization. From an industrial sector perspective, the integration of AI and digital-physical technologies exhibits distinct regional preferences in empowering the spatial transformation of the manufacturing sector. In eastern regions and areas with high levels of digital economy and urbanization, AI is better positioned to drive the transition of manufacturing toward flexible production, amplify the role of smart equipment in extending industrial chains, and thereby enhance the modernization of the manufacturing sector's industrial structure (Jiao & Liu, 2025). This heterogeneity essentially reflects differences in regional digital infrastructure, industrial endowments, and factor allocation capabilities. It also implies that the spatial effects of AI-driven industrial restructuring do not diffuse uniformly but instead exhibit a gradient pattern aligned with regional development levels.

While existing research has clarified the core characteristics and mechanisms of AI's spatial effects on industrial upgrading, there remains room for further exploration. Issues such as the quantification of transmission pathways for AI's spatial effects, spatial variations across different industrial sectors, and the precise spatial targeting of policy instruments require in-depth examination. Future research could integrate multidimensional spatial econometric models and incorporate more micro-level agents and regional factor variables to further reveal the spatial evolution patterns of AI-driven industrial restructuring, thereby providing more targeted theoretical guidance for achieving coordinated regional industrial upgrading.

(3) Digitalization and Food Security Resilience

Food security resilience serves as the core pillar for safeguarding national food security. The deep penetration of digital technologies has opened new pathways for optimizing and upgrading the agricultural industrial chain and enhancing the risk-resilience of food security. The academic community has engaged in extensive discussions regarding the mechanisms and implementation pathways through which digitalization empowers food security resilience, yielding a wealth of research findings.

The construction of digital villages serves as a key lever for digital empowerment of food security resilience. Driven by digital transformation at its core, it promotes the deep integration of digital technologies into every link of the agricultural industry chain. This not only fosters agricultural technological innovation but also effectively integrates resources across the agricultural industry chain, addressing pain points such as poor upstream-downstream connectivity and industrial fragmentation (Zhang et al., 2025b). Digital technologies empower the development of rural e-commerce and foster new agricultural business models, facilitating efficient alignment between production and consumption, thereby laying a solid foundation for stable growth and high-quality development within the food supply chain. Scholars have found that the digital economy enhances the resilience of the agricultural supply chain across multiple dimensions, serving as a key driver for strengthening food security resilience. It empowers agricultural production, the economy, innovation, and the development of green resilience through three primary pathways: green technological innovation, increased labor productivity, and the accumulation of human capital (Song & Zhao, 2025). By helping producers accurately capture market demand, leveraging intelligent monitoring and early-warning systems to enhance agricultural resilience against natural risks, and simultaneously promoting the vertical extension of the agricultural industrial chain and digital financial empowerment, it facilitates the deep processing of agricultural products and green production, thereby solidifying the industrial foundation for food security from the supply side.

From the perspective of resource allocation and industrial upgrading, the role of the digital economy in enhancing food security resilience is manifested in the efficient integration of resources and the precise improvement of production efficiency. By breaking down information barriers regarding resources such as land, water, and labor, it enables the sharing and optimal allocation of agricultural resources. It also drives the transformation of agricultural production toward precision and intelligence, breaking down information silos across the industrial chain. By extending the agricultural industrial chain, it enhances the resilience of the food supply chain from both the dimensions of resource security and industrial synergy (Yang & Ma, 2025). Furthermore, by constructing a three-dimensional embedding framework, this study reveals the underlying logic of how digital rural development empowers food security resilience. Digital rural development reconstructs the operational logic of the agricultural industrial chain across three dimensions: infrastructure, industry, and daily life (He et al., 2025). This enhances food security resilience across the entire chain—from risk identification and mitigation to adaptation—by boosting the new-quality productive forces in agriculture and the level of industrial agglomeration.

Existing research has clarified the positive enabling role of digitalization in food security resilience and distinguished the distinct pathways of digital rural development and the digital economy. However, issues such as the spatial spillover effects and regional heterogeneity of digitalization's empowerment of food security resilience remain to be further explored. Future research could focus on the mechanisms underlying the deep integration of digital technologies and food security resilience.

6. Conclusion

Based on 259 articles related to industrial chain resilience published in CSSCI and Peking University Core journals from 2018 to 2025, this paper employs the CiteSpace visualization and metaanalysis method to systematically trace the evolution, core characteristics, research hotspots, and frontier directions of China's industrial chain resilience research.clarifying the current landscape and future breakthrough pathways in this field, and providing a scientific reference for refining the theoretical framework and formulating practical strategies for industrial chain resilience.

In terms of research evolution and fundamental characteristics, research on industrial chain resilience in China has undergone a phase transition from nascent exploration to rapid development. Regarding research actors and institutions, the field has begun to take shape, with core authors and publishing institutions spanning multiple regions and levels of research capacity. However, the density of collaborative networks among authors and institutions remains low, and a stable core research community or cross-regional, cross-institutional collaborative research mechanism has yet to form, resulting in a fragmented research landscape.

In terms of research hotspots and core issues, studies on the resilience of China's industrial chains from 2018 to 2025 have taken the digital economy as their foundation. Centered on industrial chain upgrading and resilience enhancement, these studies have formed four integrated research directions, thereby establishing a comprehensive framework for industrial development research in the context of the digital economy. Research on the integration of the digital and real economies clarifies the "technology-data" driving logic, verifying its enabling effects as well as its spatial and threshold characteristics; Research on the digital economy and industrial structure upgrading clarifies the intermediary mechanisms linking efficiency and security, while identifying constraints such as weak digital infrastructure; technology-driven research confirms the enabling effects of technological innovation and identifies the intermediary mechanisms of industrial upgrading and the threshold characteristics of resilience; research on rural digital agriculture explores the three-dimensional embedding logic of digital villages and verifies the enabling pathways of new-quality productive forces. Current research combines theoretical and empirical approaches, extensively applies quantitative methods, and analyzes the patterns of resilience enhancement from multiple dimensions, providing crucial theoretical support for high-quality industrial development.

In terms of research frontiers and development trends, studies on the resilience of China's industrial chains are evolving toward greater refinement, interdisciplinarity, and scenario-based approaches. Three core frontier topics have emerged: the integration of digitalization with food security resilience; the synergistic empowerment of industrial resilience through digital technologies and data elements; and the spatial effects of artificial intelligence in driving industrial structural upgrading. The integration of digitalization with food security resilience is shifting from technological application to deep scenario-based integration, thereby strengthening the industrial foundation of food security across multiple dimensions; the synergistic integration of digital technology and data elements has become a core lever for enhancing resilience, enabling mutual empowerment and forming a comprehensive research framework; research on the spatial effects of AI-driven industrial restructuring has transcended regional limitations, clarifying the logic of technological spillovers and regional disparities, and offering new insights for coordinated regional industrial upgrading. These three frontier issues all reflect the deep integration of digital technology and industrial development, ensuring that research on industrial chain resilience closely aligns with major national strategic needs.

Nevertheless, this study entails several limitations. The sample is retrieved solely from the CNKI database without English literature, which may restrict global perspectives; the scope is limited to CSSCI and Peking University Core journals, potentially missing some high-quality publications; keyword-based retrieval may overlook a small number of thematically consistent papers; bibliometric methods capture thematic correlations rather than causal relationships; and 2025 data are incomplete as they cover only up to October 30.

Overall, domestic research on industrial resilience has yielded abundant results, clarifying the core mechanisms through which the digital economy and technological innovation empower industrial resilience, constructing a multidimensional theoretical framework, and providing crucial support for the practical development of industrial resilience. However, challenges remain, including an imperfect research collaboration system, insufficient research on industrial and regional segmentation, weak empirical exploration of cutting-edge topics, and low integration with industrial resilience practices. Moving forward, research must closely align with national strategies, build upon the integration of the digital and real economies, strengthen interdisciplinary collaboration, deepen studies on industrial and regional heterogeneity, conduct refined empirical analyses focused on cutting-edge topics, adhere to a problem- and practice-oriented approach, construct multi-level analytical frameworks in conjunction with major national strategies, explore pathways to enhance industrial resilience under the dual circulation model, and establish a theoretical system of industrial resilience with Chinese characteristics.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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