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A Review and Outlook on Research into How Digital Transformation Enhances Supply Chain Resilience

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Abstract

Global industrial chains continue to face successive shocks from geopolitical conflicts, trade protectionism, and various unforeseen risks. Supply chain resilience is no longer confined to a management issue at the corporate operational level; it has risen to become a core strategic priority for national industrial security. The iterative implementation of digital technologies-such as the Internet of Things, big data, artificial intelligence, and blockchain-provides new analytical perspectives and practical pathways for building risk-resilient supply chain systems.This paper systematically traces the evolution of the concept of supply chain resilience, clarifying the logical progression of academic understanding from static post-disaster recovery to dynamic adaptation across the entire lifecycle. By integrating foundational theories such as dynamic capabilities, organizational information processing, and complex co-evolution, it identifies four mainstream pathways through which digital technologies empower supply chain resilience: information sharing, collaborative optimization, resource coordination, and risk prevention and control.At the same time, this paper dissects the underlying causes of the significant heterogeneity in the effects of digital empowerment from three dimensions: regional institutional environments, industrial network structures, and internal corporate characteristics. Although existing literature has accumulated a wealth of research findings, there remain research gaps, including insufficient analysis of the interaction among multiple mechanisms, a scarcity of dynamic time-series studies, weak empirical evidence regarding specific industry segments and network structures, and a lack of critical discussion on the potential risks of digitalization.Accordingly, future research could establish a dynamic, integrated analytical framework that synthesizes multiple theories to distinguish the differentiated empowerment pathways of various digital technologies; advance cross-industry, multi-tier network comparative empirical studies to refine standardized measurement systems and hybrid research paradigms; and dialectically examine the dual impacts of digital transformation, balancing its benefits with the risks it entails.

Keywords

Digital Transformation; Supply Chain Resilience; Empowerment Mechanisms.

1. Introduction

The global situation changes all the time. Political tensions between countries happen often. Trade protection policies grow in number. Sudden risks appear. Long-term risks appear. These risks put steady pressure on global supply chains. The smooth running of these chains is affected. Their old weaknesses are exposed. Supply chain networks are highly connected. A break at one point can spread risk to earlier stages. It can spread risk to later stages. A chain reaction starts. Real economies suffer a lasting negative effect. Supply chain resilience became a key issue for researchers. It became a key issue for policymakers. Supply chain resilience means the full ability of an industrial chain system. The system can foresee risks. It can adjust to outside shocks. It can make quick repairs. It can improve its structure in a shock. National

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strategic plans now include stronger supply chain resilience. They include stronger supply chain security. This shows the real research value of the topic.

Several digital tools are used widely. Their use grows across many industries. These tools include big data, artificial intelligence, the Internet of Things, blockchain. A full change of the industrial system is driven by these tools. Digitalisation is no longer a simple tool upgrade. It involves a full redesign of the whole value chain. Company structures are redesigned. Business operations are redesigned. Profit models are redesigned. Value distribution is redesigned. These changes offer new solutions. The new solutions address supply chain weaknesses. Some supply chains are changed by digital tools. Information transparency can be improved by these supply chains. Decision-making efficiency can be improved by them. Collaboration across organisations can be strengthened by them. Traditional supply chains show less resilience to outside shocks. These changed supply chains show greater resilience. They recover faster from unexpected events.

The number of studies on digitalisation and supply chain resilience grew over the past ten years. Researchers discussed many aspects of the topic. They covered concept definitions. They covered theory development. They covered empirical tests. A full shared analysis is still missing. The analysis should cover the inner transmission ways of digitalisation. The analysis should cover its boundary limits. The analysis should cover its industrial use paths. Current studies fall into three groups. The first group looks at the strategic value of digitalisation from a big view. These studies focus on supply chain security. The second group uses company case studies at a small level. These studies often focus on blockchain. They also focus on single digital tools. The third group tests the link between digitalisation and supply chain resilience. These tests use theories. These theories include dynamic capabilities. They include network coordination. Current research gives many different views. Most studies check the positive gains of digitalisation. The risks of digital change are less discussed. These risks include data safety problems. They include platform control by few large companies. They include too much dependence on technology.

This paper gives a systematic review of past literature. It gives a research view for the future on digital support for supply chain resilience. The concept history of supply chain resilience is traced first. The main parts of digital change are defined. The basic theories of this field are described. Existing main findings are then reviewed in three areas. These areas are transmission ways, mixed conditions, empirical methods. Research gaps are found from this review. Research weak points are found. Four key future research directions are proposed. This paper tries to improve the theory analysis frame of this field. A balance is tried between the good effects of digitalisation and its possible risks. A closer fit is promoted between academic results and real supply chain needs.

2. Evolution of Core Concepts and Theoretical Foundations

2.1. The Evolutionary Trajectory of the Concept of Supply Chain Resilience

The main approach to research on supply chain resilience has shifted from passive post-disaster recovery to proactive dynamic adjustment. Much of the early research drew on analytical methods from the field of engineering systems, focusing primarily on the extent to which a system recovers after suffering a shock; its overall analytical perspective tended to be rather static[1]. Christopher and Peck proposed a pioneering definition of resilience, defining supply chain resilience as the ability of a supply chain to return to its original operational state-or even to achieve a superior operational level-following a disruption; they also introduced the '4R' analytical framework, comprising robustness, redundancy, agility and contingency planning. This framework has long dominated early academic research, leading most discussions to focus on post-disaster recovery capabilities.

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As global industrial chains face increasing shocks, a static perspective focused solely on the 'post-shock recovery' phase is proving increasingly limited in its explanatory power. The academic community is gradually recognising that resilience cannot be confined merely to remedial measures taken after a shock; risk anticipation, real-time adaptation during an event, and systemic transformation following a shock have all been incorporated into the analytical framework, thereby expanding the conceptual framework into a multidimensional and dynamic perspective. Relevant research indicates that resilience encompasses three progressive capabilities: sustained operations, adaptation to the external environment, and the completion of systemic transformation, placing proactive change and supply chain evolution at the core of the analysis[2]. Domestic research has also contributed to the exploration of this dynamic perspective. Some studies regard supply chain resilience as a composite and comprehensive capability; in addition to withstanding shocks and rapidly restoring supply chain links, these studies emphasise achieving long-term development and optimisation through proactive restructuring[3]; other studies, meanwhile, decompose supply chain resilience into two attributes-dynamic responsiveness and risk resilience-highlighting the core characteristic of supply chain self-adaptation in uncertain environments[4]. A comprehensive analysis of the existing literature indicates that a basic consensus has emerged within the academic community: supply chain resilience has evolved into a dynamic capability system encompassing four dimensions-prevention, adaptation, recovery and transformation[5,6]. The focus of research has shifted from 'survival' during crises to continuous learning and iterative upgrading throughout the entire risk cycle, marking a transition from a survival-oriented approach to an optimisation-oriented one.

2.2. The Core Logic of Digital Transformation and the Digital Technology Support System

Digital transformation is not merely a matter of combining various technological tools, but rather a fundamental and systematic reorganisation of supply chain strategy, processes and organisational structures[7]. Numerous studies emphasise that digitalisation goes beyond a one-sided perspective that views it merely as a tool, highlighting that digital technologies can fundamentally reshape the operational logic of supply chains. This hierarchical transformation logic can be further subdivided into two stages: 'empowerment' and 'capabilisation'[8]. The initial stage of the transition is the foundational empowerment stage, during which existing operational processes are optimised and operational efficiency is directly improved through the use of the Internet of Things (IoT) and data analytics technologies. In contrast, deep digitalisation enters the empowerment stage, enabling the creation of entirely new business models within the industrial chain. This classification provides a clear analytical framework for explaining the role that digitalisation plays in strengthening the resilience of supply chains.

By building a technological ecosystem in which various digital technologies complement one another, generate synergies, and continuously evolve, it is possible to revolutionize the operational models across all stages of the supply chain. The Internet of Things (IoT) and digital twin technologies establish real-time interaction channels between the physical supply chain and virtual models, providing a platform for simulation and scenario analysis, thereby supporting risk modeling and process optimization[9]; Big data analytics can extract market and risk information from vast amounts of operational data, thereby supporting flexible, dual-track business decision-making[10]; blockchain technology, based on distributed ledgers and smart contracts, builds a trusted transaction system with end-to-end traceability, effectively eliminating trust barriers in inter-enterprise collaboration[11]; Artificial intelligence endows systems with autonomous learning and dynamic decision-making capabilities, significantly enhancing the supply chain's responsiveness in complex environments[12]; Cloud computing provides elastic computing power and storage resources. As the foundational infrastructure

ISSN: 2688-9323

supporting the implementation of various digital technologies, it helps reduce deployment costs.

2.3. Diverse Theoretical Foundations for Digital Empowerment of Supply Chain Resilience

Research on how digitalization enhances supply chain resilience draws on multidisciplinary theories, each of which offers a distinct explanatory framework.

The theory of dynamic capabilities focuses on the behavioral logic by which firms integrate, build, and reorganize internal and external resources to adapt to environmental changes[13]; digital transformation is a key pathway for firms to cultivate dynamic capabilities. Existing empirical evidence indicates that digitization enhances supply chain resilience in the face of shocks by driving co-creation of value within the industrial chain and expanding firms' dynamic capabilities, and it fully explains the underlying logic of how supply chains flexibly adjust their operations through digital technologies[14]. Organizational Information Processing Theory posits that organizational performance depends on the degree of alignment between information processing capabilities and the information demands of the external environment [15]. Digital technologies can comprehensively broaden the channels for information acquisition, transmission, and sharing. Relevant empirical studies based on this theory demonstrate that digital transformation can improve the efficiency of information capture and collaborative processing, thereby enhancing the flexibility and adaptability of supply chains in meeting information demands within highly uncertain environments[16]. Complex systems theory defines the supply chain as a complex adaptive system and posits that its resilience stems from the system's endogenous capacity to cope with complexity and uncertainty[17]. Digital tools such as digital twins and simulations can enhance the supply chain's ability to manage complex risks by reducing the system's cognitive complexity, thereby improving its resilience. The resource-oriented and relationship-oriented perspectives constitute complementary analytical frameworks. The resource-oriented perspective views data, algorithms, and digital platforms as scarce, non-replicable, and heterogeneous digital resources that serve as the core source for enterprises to establish long-term competitive advantages[18]; whereas the relationship-oriented perspective emphasizes how digital technologies optimize collaborative relationships among organizations. For example, blockchain can enhance supply chain resilience at the network level by reducing transaction costs and strengthening mutual trust among participants[19].

Most empirical studies now use only one theory framework. Sometimes two theory frameworks are used. These frameworks build their analysis models. A deep look at one transmission path is allowed by this approach. The full multilevel logic of capacity building is not captured well by this approach. The complex logic of capacity building is not captured well by this approach. Such analyses are often broken into pieces. A full theory is not yet developed. The full theory should include technology. It should include organisation. It should include industrial networks. It should include the outside environment. Future research should push for the joining of multiple theory frameworks. A complete analysis framework should be built by future research.

3. Key Research Findings on How Digital Transformation Empowers Supply Chain Resilience

Scholars have outlined specific measures for enhancing supply chain resilience through digital transformation at multiple levels; these measures can be summarized as the following four core mechanisms:

ISSN: 2688-9323

Information level improvement is the most basic way to strengthen digital abilities. IoT sensors are connected. RFID technology is connected. Internal company information systems are connected. End-to-end information is synced in real time across the whole supply chain. Materials information is synced. Orders information is synced. Inventory information is synced. Information gaps between supply and demand are removed by this. The risk of supply-demand imbalance is lowered by this. The imbalance is caused by the "flywheel effect." Big data mining builds on this base. AI algorithms build on this base. Demand is forecasted by these tools. Early risk warnings are given by these tools. Large amounts of live operation data are used by these tools. The supply chain gets stronger situation awareness from this. The supply chain gets stronger changing decision ability from this. Smart scheduling of production capacity is enabled. Smart scheduling of logistics is enabled. Digital twin technology creates virtual simulation scenes. Supply chain operations are tested in these scenes. Different outside shocks are tested. Processes are improved by this. Industry research data shows one point. Good information flows are the base of resilient supply chains. Smart processing systems are the base too. This point is proven by the data[20].

Digitalization not only reshapes collaborative relationships among enterprises but also collectively enhances the symbiotic ecosystem of the industrial chain in terms of collaboration efficiency and mutual trust. Lightweight digital tools, such as cloud computing, can reduce communication costs associated with data integration and resource allocation among enterprises. By flexibly shifting the allocation of production capacity and warehousing resources between centralized and distributed models, they improve the responsiveness of supply chains during market fluctuations[21]. Based on technical characteristics such as immutability and end-to-end traceability, blockchain establishes a trustworthy transactional foundation for long-term, cross-regional, and multi-stakeholder cooperation. It enhances the stability of long-term contract fulfillment and strengthens companies' willingness to jointly mitigate risks. The information exchange facilitated by digitalization continuously promotes precise matching between supply and demand, guiding companies to shift from short-term, one-off transactions toward long-term cooperation and symbiosis[22].

Digital technologies can break down resource barriers across the industrial chain, enabling the identification, dynamic coordination, and optimal allocation of factors, thereby strengthening the resilience of the chain at the resource supply level.The "Five-Chain Integration" analytical framework provides a systematic explanation of this pathway. Digitalization permeates the five major chains-information, logistics, capital, innovation, and talent-by using the information chain to strengthen the data foundation, the logistics chain to stabilize circulation, the capital chain to broaden financing channels, the innovation chain to address technological gaps, and the talent chain to provide intellectual support. The synergistic interaction among these multiple chains enhances the efficiency of resource allocation across the entire industrial chain [23].From the perspective of industrial networks, digital technology drives the synergistic spatial and functional clustering of industries, continuously spurs technological iteration, extends the shock-absorption buffer of industrial chains, and improves overall resource utilization efficiency[24]. Relevant empirical findings also corroborate that digitalization continuously reduces transaction costs and activates innovation factors, providing structural support for enhancing industrial chain resilience[25].

Digitalization permeates the entire process-from risk prediction to emergency response and post-disaster recovery-directly enhancing supply chain resilience. During the preemptive identification phase, big data can capture various potential risk signals, while simulation models can quantitatively assess the scope of impact and scale of losses caused by disruptions such as supply shortages and logistics bottlenecks[26]. During the acute phase of a risk event, real-time data-driven emergency decision-making systems can be used to rapidly adjust production plans and reroute supply chains. Enhanced information processing capabilities

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directly improve operational flexibility and shorten emergency response times; after the impact has been mitigated, digital systems preserve a complete record of the entire response process, accumulating lessons learned for future risk prevention and control. Digital tools can mitigate the ripple effects of risks throughout the supply chain, thereby limiting the scope of their impact[27].

The extent to which digitalization enhances supply chain resilience is neither fixed nor uniform; it is influenced by numerous constraining factors, including the external environment, a firm's position within the network, and internal corporate characteristics.

The level of development of regional digital infrastructure and regional industrial support policies can influence the effectiveness of digital transformation; in regions with well-developed support systems, the improvement in firms' digitalization levels is more pronounced [28]. A firm's position within the industrial chain network also plays an important moderating role. When firms in core positions undergo digital transformation, they not only generate positive spillover effects but also help small and medium-sized enterprises (SMEs) in upstream and downstream stages improve their risk resilience[29,30]; however, digital transformation may also widen the gap among network participants, as peripheral firms lacking financial and technical capabilities are prone to falling into the digital divide, which may ultimately lead to a relative decline in their risk resilience[31]. Existing empirical research on environmental dynamics has not reached a consensus. Some studies suggest that the degree of environmental volatility has no significant impact on the relationship between big data and corporate agility; other empirical findings, however, indicate that the positive impact of digital technologies on resilience is more pronounced under conditions of lower uncertainty. A firm's ownership structure and asset composition are important moderating variables. Most existing empirical studies indicate that for larger private firms with flexible mechanisms and sufficient financial resources, investments in digital technologies have a more pronounced effect on enhancing resilience[32,33]. A firm's life cycle and industry sector also exert differing influences; cutting-edge technology firms in the mature stage generate a greater promotional effect due to higher alignment between their business processes and digital technologies[34]. Furthermore, a firm's research and development (R&D) expenditures and internal control standards also play a constraining role. Firms with ample R&D resources are better equipped to absorb and transform digital technologies[35]; conversely, firms with relatively high internal coordination costs have more limited scope for improving resilience through digitalization by reducing governance costs.

At present, a diverse set of empirical tools has emerged in this field. Panel regression and structural equation modeling are the mainstream choices for large-sample micro-level empirical analysis, primarily used to test mediating and moderating mechanisms .Simulation modeling methods are suitable for simulating the transmission pathways of risk shocks and quantifying the implementation effects of different resilience strategies. Existing research has utilized the anyLogistix simulation software to model supply chain fluctuations under pandemic shocks, validating the method's practical value .Qualitative comparative analysis (QCA/fQCA) is gradually gaining wider application. This method focuses on identifying the multiple combinations of conditions that lead to high or low resilience . Building on this, some studies have combined QCA with network analysis methods to visually present the phased evolutionary characteristics of the effects of digital empowerment.

4. Theoretical Shortcomings and Research Gaps in Existing Studies

While there is a relatively rich body of literature on digital empowerment of supply chain resilience, several shortcomings remain in terms of research depth, scope, and empirical rigor. These are primarily reflected in insufficient discussion of the interactions among multiple

ISSN: 2688-9323

mechanisms, a lack of dynamic evolutionary analysis, limited research on specific sub-industries and scenarios, and superficial analysis of supply chain network structures.

Most existing studies focus on a single empowerment pathway in isolation, with relatively little discussion of the complementary, substitutive, or mutually reinforcing relationships among different mechanisms. Taking the “Five-Chain Integration” analytical framework proposed by Wang Huiyan et al.as an example, while the study outlines multiple pathways for digital empowerment, it fails to further explain the intrinsic interconnections among various mechanisms-such as whether the transparency resulting from information sharing can simultaneously improve financing efficiency along the supply chain.In actual industrial operations, various digital transformation initiatives are often implemented simultaneously and intertwined; however, at the theoretical level, the sequence of action and conditions for the application of multiple mechanisms have not yet been clarified. Questions such as whether certain foundational digitalization steps constitute prerequisites for innovation synergy, and whether multiple pathways can be implemented in parallel or serve as substitutes for one another in different scenarios, still lack systematic analysis.

Existing empirical studies largely rely on cross-sectional data to conduct static correlation tests, and the phased nature of digital transformation and the gradual process of cultivating supply chain resilience have not been fully discussed .Digital transformation is divided into two stages: foundational empowerment and in-depth enablement. Similarly, resilience-building evolves continuously from passive risk mitigation to proactive industrial transformation. However, existing literature rarely tracks and analyzes how these two dynamic processes adapt to and shape one another. At the same time, most studies treat digital transformation as a single, broad variable, failing to distinguish the differentiated pathways of action among various technologies such as the Internet of Things (IoT), blockchain, and artificial intelligence (AI). There remains significant room for further discussion from the perspective of technological heterogeneity.

There is also a significant gap in analysis at the industry level; most existing empirical samples are concentrated in the manufacturing sector, while discussions of niche sectors with unique operational logics-such as retail, cross-border e-commerce, healthcare, and agriculture-related supply chains-are scarce.Although case studies such as Yang Yaoxu on the retail industry and Shi Kuiran and Sun Yi on SHEIN demonstrate industry-specific characteristics, comparative analyses spanning multiple industries and supported by large samples remain relatively scarce[36].

Research on the structural level of supply chain networks remains in its infancy. Most studies treat firms as independent analytical units or simplify the supply-demand relationship between upstream and downstream firms into a binary linear model, thereby overlooking the complex network topology of real industrial chains.Structural attributes such as network density, node centrality, and the strength of collaborative relationships can systematically alter the implementation outcomes of various digitalization mechanisms. Existing research has paid only limited attention to the differences between core and peripheral firms and has not thoroughly dissected the underlying logic by which various network characteristics moderate the effects of digital empowerment.

In addition, four notable research gaps remain in this field.First, analysis of the digital divide is insufficiently in-depth. Existing literature has only confirmed that disparities in enterprises’ digital capabilities weaken the risk resilience of the entire supply chain[37], but has not broken down the specific manifestations of the digital divide across different dimensions-such as technological equipment, data applications, talent reserves, and capital investment-nor has it distinguished whether the divide stems from resource constraints, short-term corporate strategies, or spontaneous market choices;Similarly, there is a lack of comprehensive, systematic analysis regarding pathways to bridge the gap, such as fiscal subsidies, industry-wide standards, industrial empowerment by leading enterprises, and collaboration through

ISSN: 2688-9323

industry alliances.Second, no unified standards have yet been established for measuring core variables. As mentioned earlier, the measurement methods for the two key indicators-digital transformation and supply chain resilience-remain fragmented. Different studies employ proxy variables and measurement frameworks that vary significantly, which hinders cross-comparisons between research findings and impedes the ongoing development of theoretical consensus within the field. There is an urgent need for the academic community to construct a standardized measurement system that accounts for multidimensional connotations and ensures stable reliability and validity.Third, research methodologies are structurally monotonous, with quantitative panel and structural equation modeling-based empirical studies dominating the field, while high-quality comparative multi-case studies and mixed-methods approaches combining quantitative and qualitative data remain insufficient.Case studies can elucidate the mechanisms underlying the process of digital empowerment, while mixed-methods approaches can balance generalizable patterns from large samples with the deep-seated logic of individual enterprises. However, existing case studies primarily focus on single enterprises , lacking in-depth analyses that draw on multiple case comparisons to distill general theories.Fourth, research aligning with domestic macro-strategies lags behind. Top-level strategies such as “new-quality productive forces” and the “dual circulation” of domestic and international markets provide entirely new analytical contexts for research on industrial chain resilience. While a small number of existing studies have explored these topics from the perspective of new-quality productive forces , no resilience analysis and evaluation framework has yet been established that aligns with local industrial realities and is tailored to the dual-circulation framework. Theoretical responses regarding the differences in digital empowerment pathways under domestic and international circulation scenarios, and how to leverage digital tools to consolidate the leading position of domestic industrial chains, remain relatively limited. While some literature discusses the interactive relationship between social capital and digitalization, it has not thoroughly explored the impact of digital technologies on traditional trust models within industrial chains or the logic behind their restructuring.

5. Outlook for Future Research

Existing research has several limits. Future studies can move forward in a few areas. Theory framework development is one area. Deep study of specific parts is another area. New research methods are another area. Local theory building is another area. These areas can improve the theory frame for digital empowerment of supply chain resilience. These areas can improve the practical guidance value of the research for industry use.

At the theoretical level, existing single-perspective theories struggle to explain the intrinsic logic of the interaction among multiple mechanisms. Future research could integrate various theories-such as dynamic capabilities, organizational information processing, and complex networks-to establish a unified, comprehensive analytical framework. This would allow for empirical testing of the complementary and balancing relationships among multiple pathways, including information sharing, value co-creation, and resource coordination.For example, by examining the progressive logic linking information transparency and value co-creation, researchers can clarify how information flow provides the foundation for cross-entity collaboration, while long-term collaborative efforts, in turn, drive the continuous improvement of information-sharing systems.At the same time, existing cross-sectional static analyses struggle to capture temporal changes in variables, leaving significant room for expansion in longitudinal tracking studies. By leveraging long-term panel data, continuous corporate surveys, and longitudinal case tracking, researchers can map the entire process of the co-evolution of digitalization and supply chain resilience.The focus should be on examining the dynamic adjustments in the priorities for fostering resilience at different stages of corporate

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digital transformation, while also identifying the underlying mechanisms behind the phased shifts in the evolutionary trajectories of both resilience and digital transformation in response to major external shocks, such as geopolitical conflicts and public health crises.

There remains a wealth of content to be explored across three specific dimensions: digital technologies, industry scenarios, and network structures. First, we should delineate the distinct boundaries of the roles played by different digital tools, compare the industrial chain scenarios for which technologies such as blockchain, artificial intelligence, and digital twins are best suited, and, by integrating them with specific sectors such as fresh produce cold chain, high-end equipment manufacturing, and cross-border logistics, establish a logic of "matching scenarios with technologies, and technologies supporting resilience."Second, we will broaden the scope of industry research by conducting specialized analyses of distinctive sectors such as retail and fast-moving consumer goods (FMCG), medical and emergency supplies, service-oriented supply chains, and green circular industrial chains. Grounded in the dual circulation pattern of domestic and international markets, we will compare the distinct characteristics of digital transformation and risk mitigation models for supply chains serving the domestic market versus those oriented toward overseas exports.Third, we will deepen empirical research on network topology by introducing tools such as social network analysis and multi-agent simulation modeling to examine the moderating effects of attributes-including network density, node centrality, and network connectivity-on the diffusion of digital dividends. We will also dissect the transmission channels of digital spillovers from leading enterprises and analyze how these spillover effects alter the shock-resilience of the entire industrial chain.

Research methods and the development of a domestic theoretical framework are also key areas for expansion. Given the current overreliance on quantitative research, future studies should promote mixed-methods designs combining qualitative and quantitative approaches. This could involve using quantitative methods for preliminary screening followed by in-depth case analysis, or starting with theoretical frameworks and case studies before validating them with large-sample data. By selecting enterprises across different industries, sizes, and levels of digital maturity for comparative analysis, researchers can derive theoretical conclusions that balance general principles with the specific characteristics of each scenario.Additionally, it is necessary to establish a resilience evaluation system tailored to the realities of China's industrial landscape. This framework should align closely with top-level strategies such as "new-quality productive forces," "industrial chain modernization," and the "nationwide unified market," incorporating evaluation dimensions such as technological autonomy, green and low-carbon development, operational efficiency, and industrial chain security to form a localized analytical paradigm that meets the practical needs of domestic industrial development. Furthermore, existing research tends to focus on the positive benefits of digitalization while insufficiently addressing the risks associated with it. Future studies should incorporate negative impacts-such as data breaches, vendor lock-in, and platform monopolies-into a comprehensive analytical framework. This will enable the quantification of how various digital risks undermine supply chain resilience, thereby establishing a complete analytical logic that balances benefits and risks.

6. Conclusion

This paper systematically reviews existing literature on how digital transformation enhances supply chain resilience and integrates and evaluates core research conclusions in the field. Existing research has largely clarified the underlying logic by which digital transformation improves a supply chain's shock resistance through four pathways: information sharing, cross-entity collaboration, comprehensive resource allocation, and full-cycle risk prevention and control. At the same time, it confirms that the quality-enhancing effects of digital

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transformation are constrained by multiple factors, such as a company's own conditions and the external industrial environment, and that there is no single, uniform level of effectiveness. As relevant empirical research continues to advance, research methods in this field are becoming increasingly diverse; however, a unified consensus on the measurement standards for the two core indicators-digital transformation and supply chain resilience-has yet to be established, which remains a practical challenge constraining the cross-comparison of research findings.

A review of the literature also reveals numerous limitations in existing research. Most studies analyze individual empowerment pathways in isolation, lacking dynamic analyses of multi-mechanism interactions; discussions on heterogeneity remain superficial, with a scarcity of in-depth empirical studies on specific industrial segments, supply chain network topologies, and digital divergence; and research methodologies and variable measurement frameworks still require integration and refinement;more crucially, most existing studies focus on the positive gains brought by digitalization, while discussions of the various costs, potential risks, and even the negative effects of excessive digitalization associated with the implementation of digital technologies are limited, resulting in a lack of a dialectical analytical perspective.

Given the limitations of existing research, future studies could be conducted in the following four main areas. First, promote the development of comprehensive theoretical concepts and establish a dynamic analytical framework capable of reflecting the evolution of interactions among multiple mechanisms; Second, conduct detailed empirical research on specific topics such as particular sectors, industrial chain networks, and the digital divide to explore specific aspects in depth; Third, enhance the quality of empirical research by employing mixed-methods approaches that combine qualitative and quantitative methods, as well as by standardizing measurement systems for key variables; Fourth, adopt a dialectical analytical approach to objectively assess the dual impacts of digitalization and examine industrial supply chain management decisions aimed at ensuring a balance between benefits and risks; deepening theoretical and empirical research in these areas will not only help standardize and integrate academic discourse in this field but also provide a theoretical basis-combining practical feasibility with risk early warning-for building domestic and even global industrial supply chain security systems in the face of uncertainty.

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