WEP Warwick Evans Publishing

International Journal of Global Economics and Management
ISSN: 3005-9690 (Print), ISSN: 3005-8090 (Online) | Volume 9, Number 3, Year 2025
DOI: https://doi.org/10.62051/ijgem.v9n3.09
Journal homepage: https://ijgem.org

A Comprehensive Review of Supply Chain Resilience Research

Panpan Ma

School of Economics and Management, Chongqing Jiao tong University, Chongqing 400074, China

ABSTRACT

This article systematically describes supply chain resilience, mainly focusing on two core research areas: the resilience of supply chain logistics networks and the resilience capabilities of supply chain services. Regarding the resilience of logistics networks, scholars have achieved many results in network design optimization, disruption response mechanisms, and resilience assessment frameworks. These include considerations of initial disturbances in network design, probabilistic network graph modeling, load redistribution mechanisms, integration and application of the physical internet, and the use of models and algorithms such as mixed-integer nonlinear programming. In terms of the resilience capabilities of supply chain services, it explains that its core meaning is consistent with supply chain resilience, summarizes multi-dimensional evaluation systems (such as prediction, response, adaptation, recovery, and learning dimensions), key components (resistance and recovery capabilities), and improvement methods such as supply chain digitalization, intelligent logistics, and digital transformation, and explores the heterogeneous impacts of enterprise types, industrial chain positions, regional characteristics, and time lag effects. Through multiple research perspectives and methods, it elaborates on the overall framework and key findings of supply chain resilience research and provides references for subsequent related studies.

KEYWORDS

Supply chain management; Supply chain resilience; Logistics network resilience; Supply chain service resilience

1. INTRODUCTION

In the context of intensifying global competition and mounting market pressure, supply chains are faced with multiple internal and external uncertainties, including demand fluctuations, facility disruptions, geopolitical changes, and sudden public - health incidents. These disruptions can result in reduced supply - chain efficiency, elevated costs, service interruptions, and may even exert a substantial influence on the survival of enterprises and the stability of industries. Consequently, supply - chain resilience, as the core competence that gauges a supply chain's capacity to withstand risks, rapidly recover, and maintain stable operation, has emerged as a focal point for both the academic community and the industry.

Research on supply chain resilience encompasses multiple aspects, including network structure design, capability assessment, and improvement paths. As the core carrier of the supply chain, the logistics network directly determines the continuity and reliability of material flow. Meanwhile, as the core functional manifestation of the supply chain, supply chain services' resilience level is related to the demand satisfaction of upstream and downstream nodes as well as end customers. Recently, scholars at home and abroad have conducted extensive research in these two core areas, achieving many theoretical accomplishments. However, existing research shows differences in perspectives, methods, and conclusions, necessitating systematic classification and integration.

This paper aims to comprehensively summarize the research achievements related to supply chain resilience, with a focus on two aspects: the resilience of the supply chain logistics network and the resilience capabilities of supply chain services. It systematically reviews the research perspectives, core viewpoints, key methods, and main conclusions in each field, analyzes the current research progress and limitations, clarifies future research directions, and provides theoretical support and practical references to further deepen the research on supply chain resilience and guide enterprises in enhancing their supply chain risk resistance capabilities.

2. RESEARCH ON THE RESILIENCE OF SUPPLY CHAIN LOGISTICS NETWORKS

2.1. A Review of Research on Supply Chain Logistics Network Resilience

When a complex logistics network can maintain nearly peak performance in the face of disruptions, it is considered to be resilient. The flexibility and robustness of the logistics network are of vital importance. As customer demands continue to expand and uncertainties increase, the logistics network is facing increasingly severe tests. Any disruption or fluctuation at any node will affect the efficiency of the entire logistics network.

Peng et al. considered various possible disruptions at the initial stage of logistics network design. By optimizing the logistics network design, they ensured the continuity and efficiency of the logistics network during disruptions, thereby enhancing the resilience of the entire logistics network [1]. Lam proposed an elasticity analysis framework to analyze and design how to handle complex disruptions in the logistics network, as well as to understand the network's ability to recover to a stable state after a failure interruption. Under the resilience analysis framework, the logistics network is modeled as a probabilistic network graph, and the resilience is analyzed through the reliability of all independent connection paths between logistics entities and the connection weights [2]. Zhao et al. studied the resilience of the supply network to disruptions and provided insights for supply chain managers from the perspective of complex network topology on how to construct an elastic supply network [3].

Chen et al. described a method for quantifying and optimizing resilient strategies based on the concept of comprehensive resource allocation, rather than making hasty decisions randomly in the post-interruption stage. They first employed a typical transportation network modeling method, and then incorporated the nonlinear time-varying cargo value function into a multi-objective mixed integer nonlinear programming problem [4]. Chen et al. studied the resilience of the logistics network in the express delivery industry when nodes fail due to network interruptions, and proposed a load redistribution mechanism for evaluating and enhancing the resilience of the logistics network in the presence of cascading failures [5].

The logistics network is prone to disruption, resulting in increased delivery costs and delays. Kulkarni studied the design problem of an elastic super-connected logistics hub network. Two solutions based on integer programming were proposed, aiming to open logistics centers so as to connect a group of origin-destination pairs using multiple shortest paths and multiple paths that do not intersect the shortest edges. The research results show that the designed network has significantly improved the ability to withstand disruptions compared to the traditional lean logistics mesh network. The functional effectiveness of the enterprise logistics management information system is significantly correlated with the elasticity of the enterprise supply chain network [6]. Yang et al. extracted the application effectiveness characteristics of the logistics management information system and established dimension indicators, and established an association hypothesis with the elasticity indicators of the supply chain network [7].

Sheng et al. expounded that a supply chain is a complex adaptive system with a social multi-center sharing and governance structure. They pointed out that supply chain resilience is a capability indicator reflecting the overall behavior and function of the supply chain system's ability to adapt to the changes in the complexity of the environment [8]. Zhu et al. introduced a mixed integer nonlinear programming (MINLP) model and an improved genetic algorithm, aiming to design a reliable closed-loop supply chain that can operate effectively to reduce the risk of random facility disruptions. The effectiveness of the model and the customized algorithm was evaluated through computational experiments. The results are helpful in enhancing the resilience of the logistics network and ensuring its reliable operation even in the event of disruptions [9].

In traditional supply chain network design, enterprises define and optimize their own logistics networks, resulting in the current logistics system being a group of independent and heterogeneous logistics networks. The concept of Physical Internet (PI) aims to integrate independent logistics networks into a global, open, and interrelated system. Yang studied how the inventory model applying PI handles the disruptions of centers and factories. For this purpose, a single-product inventory problem with uncertain demand and random supply disruptions was investigated. An optimization model based on simulation was proposed to determine inventory control decisions [10].

2.2. Summary of Research on the Resilience of Supply Chain Logistics Networks

The resilience of the logistics network is a key characteristic that enables it to maintain high performance in the face of disruptions. To ensure continuity and efficiency, researchers emphasize considering various disruption scenarios at the initial stage of logistics network design and enhancing the network's resilience through optimized design. Different studies approach the issue from multiple perspectives, including resilience analysis frameworks, resilience analysis, resilience indicators, and network growth models, to gain a deeper understanding and build resilient supply networks. The research also focuses on methods such as complex network topology, resource allocation strategies, and load redistribution mechanisms to improve the logistics network's response capability in the event of disruptions. Additionally, the application effect of enterprise logistics management information systems is significantly negatively correlated with the resilience of the supply chain network, highlighting the impact of information systems on network resilience.

3. RESEARCH ON SUPPLY CHAIN SERVICE RESILIENCE CAPABILITY

3.1. A Review of Research on Supply Chain Service Resilience Capability

The concept of "Supply Chain Resilience" was defined by Hohenstein et al. as the supply chain's ability to prepare for unforeseen risk events, respond promptly and recover rapidly from potential disruptions, and revert to the initial state or attain growth by transitioning to a new and more favorable state [11]. Concerning "Supply Chain Service Resilience", it can be considered a near - synonym of "Supply Chain Resilience". This is because the essence of the supply chain lies in providing "delivery services" to end - customers or upstream and downstream nodes, which encompasses a series of service activities such as material supply, logistics distribution, inventory assurance, and order response. Therefore, the term "service" in "Supply Chain Service Resilience" explicitly emphasizes the core function of the supply chain, rather than serving as an additional restrictive condition. Both concepts center on the anti - interference capacity of the supply chain system.

Numerous scholars have provided various depictions of the resilience capabilities of supply chains. For instance, Fan et al. constructed a supply chain resilience evaluation index system from five dimensions: prediction, response, adaptation, recovery, and learning, and conducted quantitative analysis by combining the ISM model with the entropy weight - TOPSIS method. Empirical evidence shows that the overall resilience of the automotive supply chain is at a medium level or above, but during the pandemic, it exposed shortcomings such as insufficient predictive ability. In the postpandemic era, it is necessary to strengthen risk management, promote digital development, and facilitate collaborative cooperation among supply chain partners to restructure the supply chain crisis response system and enhance the ability to deal with "black swan events" [12]. Yu et al. based on the "preparation, response, and recovery" three dimensions, constructed a supply chain resilience capability - performance indicator framework (SCPM), and conducted a structural review of 11 types of SCRE performance indicators and their corresponding capabilities [13]. Shi et al. used the 2018 supply chain innovation and application pilot policy as a natural experiment, based on the data of Shanghai and Shenzhen A-share listed companies from 2013 to 2020, constructed a triple difference model, and analyzed it using the instrumental variable method and parallel trend test, etc. Some scholars have described supply chain resilience capabilities indirectly [14]. Aslam et al. studied the impact of supply chain duality on supply chain resilience, defining supply chain duality as the ability to simultaneously apply supply chain adaptability and consistency. The study further discussed the role of supply chain sensitivity in the relationship between the two and proposed the hypothesis that when market uncertainty is high, the correlation between supply chain duality and supply chain resilience will be stronger, providing an important research perspective for understanding the path and contextual conditions for enhancing supply chain resilience [15]. Melnyk et al. pointed out that supply chain resilience capabilities consist of two key and complementary components: (1) resistance capability, which is the ability of the system to minimize the impact of disruptions by completely avoiding or minimizing the time between the occurrence and start of disruptions and recovering from them; (2) recovery capability, which is the ability of the system to find a return path to a functional stable state once a disruption occurs [16].

Some scholars have also conducted research on how to enhance supply chain resilience. Zhang et al. utilized the data of A-share listed companies from 2012 to 2021 and the data of prefecture-level cities and A-share listed companies from 2010 to 2020 to examine the influence of supply chain digitization and smart logistics on supply chain resilience. The research verified that the former can strengthen the latter through information, product competitiveness, and internal control channels. This effect is more pronounced in mature enterprises, those located downstream of the industrial chain, and regions with a favorable business environment. Furthermore, the impact of supply chain digitization on resilience exhibits a time lag, and the enhancement of resilience is accompanied by a decline in management efficiency. Smart logistics can significantly improve the resilience and recovery capacity of the supply chain. The mechanism involves expanding the market strategic layout of enterprises, reducing transaction costs, and enhancing supply chain efficiency. Heterogeneity analysis indicates that this effect is more prominent in regions with a low market position, enterprises downstream of the industrial chain, regions with convenient transportation, and areas with a high intensity of smart logistics spatial connection [17, 18]. Wu et al. discovered that digital transformation can reduce the concentration of the upstream and downstream of the supply chain as well as the overall concentration, and promote diversified allocation. This effect is achieved by reducing the coordination cost of supply and demand and the transportation inventory cost. In scenarios such as regions with a low degree of marketization, highly competitive industries, and under high systemic risks, this effect is more significant [19].

3.2. Research Summary on Supply Chain Service Resilience Capability

In the study of the resilience of supply - chain services, scholars have developed an evaluation index system from multiple dimensions, namely prediction, response, and recovery. They have carried out research via quasi - natural experiments and framework construction, precisely identifying the key elements, including resistance and recovery capabilities. Additionally, they have investigated factors such as supply - chain duality, market uncertainty, and contextual conditions. The research indicates that the digitalization of supply chains and intelligent logistics can enhance the resilience of supply - chain services through different mechanisms. This effect varies across different enterprise types, positions in the industrial chain, and regions. Furthermore, the impact of digitalization on resilience has a time lag, and the improvement in resilience may be accompanied by a decline in management efficiency.

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