Research Status and Hotspots on Supply Chain Resilience - Visual analysis based on VOSviewer

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Abstract Supply chain resilience is the ability of enterprises to withstand, adapt to, and recover, aimed at responding to uncertain disturbances or sudden major events in the external environment. It is crucial for enterprises to maintain operational continuity. This article searches for foreign literature on the topic of "Supply Chain Resilience" in the Web of Science database, and uses VOSviewer analysis software to visually analyze foreign literature from 2010 to 2023, summarizing the current research status in the field of supply chain Resilience. And divide the research period into two time periods, 2010-2019 and 2020-2023(6), and use VOSviewer software to create keyword contribution graphs for each time period to explore the research hotspots in the field of supply chain resilience. Research has found that the number of literature on the topic of "supply chain Resilience" in foreign countries has increased significantly, with a broader research perspective, and new research hotspots using the keyword "COVID-19" have emerged. This article helps scholars understand the current research status and hotspots in the academic field of supply chain Resilience, and expand the research direction of supply chain resilience.

Keywords Supply chain resilience; Visual analysis; VOSviewer; Research hotspots

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Research Background

Supply chains are the backbone of the economy, and the increase in sudden public events in recent years has increased the frequency of supply chain disruptions. Resilience is critical to the design and management of viable value creation networks. Supply chain resilience is the ability of a firm to maintain, execute, and recover from plan execution, as well as the ability to realize the plan¹. The theory of supply chain resilience explains how complex networks maintain continuity, survive and recover

during disruptions and severe crises. Designing and managing supply chains that are not only effective but also resilient can help a firm's supply chain to continue to operate and meet demand in the face of severe disruptions. Despite supply chain disruptions, resilient supply chains are able to deliver goods and services to markets and society in an uninterrupted manner. Supply chain resilience is not a relatively new term, and the positive effects of supply chain resilience on firms' response to supply chain crises have been documented in literature and practice over the past 20 years. With the frequent changes in the external environment and the development of science and technology, the perspectives of supply chain resilience research have become more diverse. Understanding the history of the development of the academic field of supply chain resilience, exploring the subject terms in the field of supply chain resilience, and grasping the research hotspots can help scholars find the direction of their research, make scholars aware of the latest research dynamics, and lay further foundations for the research of supply chain resilience.

In recent years, more and more scholars have begun to use bibliometric methods to analyze research trends in academic fields. The method of bibliometrics has been proposed and used in the 20th century, and information visualization is an important research method of bibliometrics, which can clearly display the research of an academic field through visual mapping. Knowledge graph analysis software, which integrates the theories of mathematics, graphics, and information visualization techniques with bibliometric analysis, co-occurrence analysis, and other methods, can reveal the development stage, research hotspots, and future trends of a certain field². Among them, VOSviewer is a bibliometric analysis software widely used by scholars, which can be used to analyze the "co-occurrence" of keywords, subject terms, authors and other information, especially in the clustering technology has a unique advantage³. Therefore, based on the VOSviewer analysis software, this paper analyzes the foreign literature in the field of supply chain resilience from 2010 to 2023, explores the important literature and researchers, and divides the research period into two time periods: 2010-2019 and 2020-2023 (the time ends on June 30, 2023), and compares and analyzes the keyword co-occurrence mapping in the two time periods, and analyzes the keyword co-occurrence in the two time periods through comparison. mapping, to analyze the research status and hotspots of supply chain resilience in foreign countries through comparison, and to provide reference basis for future research direction.

The paper is organized as follows: the second part is the research methodology and data sources, which describes the process of data collection and screening; the third part is the important literature and key researchers; the fourth part is the comparison of the research hotspots in the two time periods of 2010-2019 and 2020-2023(6), which reveals the research hotspots in the field of supply chain resilience; the fifth part summarizes the core topics of the field of supply chain research; and the sixth part is the conclusion, which sums up the content of the article and proposes a future outlook.

Research methods and data sources

Research methods

With the expansion of literature production, simple literature reading can no longer enable research scholars to grasp the research hotspots and development trends in related fields. Nowadays, more and more scholars begin to use bibliometric methods to analyze the development history, frontier dynamics and overall knowledge architecture of a certain subject area, and a series of literature analysis tools emerge, such as CiteSpace, NetExpress, VOSviewer, etc. VOSviewer is a scientometric and visualization tool jointly developed by Nees Jan van Eck and Ludo Waltman of Leiden University in the Netherlands. Nees Jan van Eck and Ludo Waltman of Leiden University in the Netherlands. Nees Jan van Eck and Ludo Waltman of Leiden University in scientific research.VOSviewer is a visualization tool⁴, which is widely used by many scholars in scientific research.VOSviewer is a visualization tool based on the VOC visualization technology specifically for the literature knowledge unit, which is simple to operate, rich in graphical presentation and easy to interpret the analysis results. Compared with other bibliometric software, VOSviewer has the

advantages of strong graphical visualization effect, strong versatility and adaptability with java, suitable for large-scale data, cross-platform use and so on. This paper focuses on "supply chain Resilience", using VOSviewer software to visualize and analyze the literature of two time periods, 2010-2019 and 2020-2023(6), and analyze the research status and trend of supply chain Resilience through comparison.

Research methods

In order to understand the current research status of supply chain resilience, this paper takes Web of Science Core Collection as the data source of sample literature, and the specific search process is as follows: the search scope is "Web of Science Core Collection", the Collections are "All", the search term is "supply chain resilience", and the time span is "2010-01-01 to 2019-12-31". All", the search term is "supply chain resilience", and the time span "2010-01-01 to 2019-12-31" and "2020-12-31" are selected respectively. The search term "supply chain resilience" was used in the time span of "2010-01-01 to 2019-12-31" and "2020-01-01 to 2019-12-31" and "2020-01-01 to 2019-12-31".

Data organization

In order to ensure the quality and reasonableness of the literature, and to further improve the credibility and reasonableness of the research results, this paper screens the English literature. The specific screening process is as follows: refine the literature into "Article", eliminate "Proceeding Paper", "Early Access", "Review Article" and "Editorial Material", "Review Article" and "Editorial Material", etc. The literature was searched separately, of which 659 articles were attributed to 2010-2019, and 2115 articles were attributed to 2020-2023(6). Iterature with inconsistent conditions was manually excluded to ensure the validity of the data, and a total of 1,772 articles were obtained after screening, of which 363 were attributed to the time period 2010-2019 and 1,409 were attributed to the time period 2020-2022.



Figure 1. Number of core literature from 2010 to 2019 and from 2020 to 2023(6).

Figure 1 shows the amount of core literature on supply chain resilience for the two time periods. As can be seen from Figure 1, the literature on supply chain resilience in 2020-2023 is much more than that in 2010-2019, which is more than three times as much as the latter. This indicates that scholars have been paying more and more attention to supply chain Resilience in recent years, and supply chain Resilience has become a key topic for scholars.

Key Documents and Key Researchers



Number of publications

Figure 2. Number of publications on supply chain resilience in the Web of Science database from 2010 to 2023(6).

By counting the number of publications, it is possible to visualize the degree of interest in a topic and predict future research trends. Figure 2 shows the number of literature publications on the topic of supply chain resilience in the Web of Science database from 2010-2023, from which it can be seen that there is a general upward trend in the number of publications on supply chain resilience research. Among them, the articles in this field have risen substantially since 2020, and the publication volume in 2020 is 40 times that of ten years ago, and the publication volume in 2020-2023(6) accounts for about 79.51% of the total volume of this visualization sample, which indicates that this research topic is increasingly attracting the attention of researchers. In addition, in terms of growth, the number of publications in 2020-2022 shows a huge increase, indicating that supply chain resilience has become a hot research area in the past two years.

Highly cited literature

The number of citations of a paper can reflect the recognition of the paper by other scholars to a certain extent, which can reflect the academic value of the literature and the academic status of the authors. In this paper, the citation frequency of the literature about supply chain resilience in Web of Science database is counted, and the top 10 cited documents are selected and listed in Table 1. From Table 1, we can see that scholar Ivanov has high influence in foreign countries, and his two research results published in 2020 are the first and the second in the number of citations, and the scholar Ivanov accounted for 4 of the top 10 cited literature. Ivanov takes the example of the coronavirus COVID-19 and AnyLogistix simulation and optimization software to demonstrate how a simulation-based approach can be used to examine and predict the impact of pandemic outbreaks on supply chain performance and opens up some new research on the impact of COVID-19 on global supply chain resilience⁵. In addition, Ivanov expanded the supply chain resilience perspective to survivability with the example of COVID-19, arguing that an intertwined network of supply chains ensures the delivery of goods and services to the society and the market ⁶. In 2019, Ivanov investigated the impact of digitalization and Industry 4.0 on the analysis of chain reactions and disruption risk control in supply chains, and also examined a framework for supply chain risk analysis, analyzing the prospects and future shifts in the transition to an information-physical resilient supply chain⁷. In 2020 Ivanov introduced the concept of a viable supply chain, developing a VSC model, arguing that the VSC model can help decision makers to design supply chains that can respond adaptively to positive changes (i.e., the agility perspective) and are able to absorb negative disruptions, recover and survive during short-term disruptions and long-term disruptions, and explains the value of the model for social and economic transformation in terms of resilience and sustainability, and also discusses the relationship between resilience and viability, and technically through the perspective of dynamical systems theory VSC model was explained⁸. In other highly cited literature, Pettit et al.'s paper published in 2010 introduced a new supply chain resilience framework to help firms cope with changes in the external environment. Their findings suggest that supply chain resilience can be assessed in terms of both vulnerability and capacity, while the resilient zone is defined as the ideal balance between vulnerability and capacity, and the zone where the company can deliver the most profit in the long run⁹. In addition, other highly cited literature illustrates the significance of supply chain resilience for firms in the context of financial crisis, contingent resources, and firm development.

Tuble if builds of highly cited iterature in the sample (top 10).				
Title	citations	author	Year	
Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak	759	Ivanov, D.	2020	
Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case	735	Ivanov, D.	2020	
A comparative literature analysis of definitions for green and sustainable supply chain management	755	Ahi, P and Searcy, C	2013	
The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics	695	Ivanov, D., Dolgui, A., Sokolov, B.	2019	
Food supply chains during the COVID-19 pandemic	608	Hobbs, JE.	2020	
Ensuring supply chain resilience: Development of a conceptual framework	606	Pettit, TJ., Fiksel, J., Croxton, KL.	2010	
Supply chain resilience in the global financial crisis: an empirical study	572	Juttner, U., Maklan, S.	2011	
A contingent resource-based perspective of supply chain resilience and robustness	569	Brandon-Jones, E., Squire, B., Autry, CW., et al.	2014	
Firm's resilience to supply chain disruptions: Scale development and empirical examination	548	Ambulkar, S., Blackhurst, J., Grawe, S.	2015	
Viable supply chain model: integrating agility, resilience and sustainability perspectives-lessons from and thinking beyond the COVID-19 pandemic	524	Ivanov, D.	2020	

Table 1. Statistics of highly cited literature in the sample (top 10).

Important researchers

Co-authors refer to two authors whose research results are used by another author at the same time, and the frequency of co-citation can indicate the degree of an author's contribution to this academic field, as well as the "proximity" of the academic relationship with other authors in the field. In this paper, we use VOSviewer to create a co-citation graph to analyze the important researchers in the field of supply chain resilience in foreign countries. The larger the circular node in the co-citation graph, the higher the importance of the author; the shorter the distance between two nodes in the graph, the closer the academic relationship between two scholars.

Figure 3 shows the co-citation map of the authors of the literature, from which it can be seen that Ivanov, Dougui, Kazancoglu, Luthra, Paul, and Ozbiltekin-pala have a high co-citation frequency. Among them, author Ivanov has the highest co-citation frequency, and this analysis is consistent with the highest paper citations. It can also be seen from the figure that the academically more closely related to scholar Ivanov are scholars Pishvaee and Blackhurst.In addition, a comparison of Figure 2 with Table 1 reveals that the results of high author co-citations and high cited papers do not coincide to some extent. For example, scholar Paul is ranked fifth in the author co-citation mapping, but this author's name is not in the top 10 of the highly cited literature. It can be seen that high author co-citation alone does not indicate a scholar's academic contribution in his or her field, and other dimensions, such as high literature citations, should be taken into account in order to comprehensively evaluate a scholar's academic contribution.



Figure 3. Co-citation mapping of authors of sample literature.



Publishing country analysis



Figure 4. Country Co-Citation Atlas of Sample Literature.

Table 2. Statistics on the number of publications in high publishing countries in the sample (top 10).

Country	Number of publications	Citations	Total link strength
USA	382	17489	395
China	309	5258	309
UK	274	10136	449
India	219	5808	290
Australia	142	4479	239
Germany	123	8910	155
France	123	7795	255
Iran	110	3141	88
Italy	87	2376	148
Canada	75	3391	131

In order to explore the countries that contribute more to the research field of supply chain resilience, this paper analyzes the contribution of the countries that are the source of the sample literature through the Vosviewer software, and the mapping is shown in Figure 4. Table 2 shows the top 10 countries in the sample in terms of the number of publications from the publishing countries, and from Figure 4 and Table 2, it can be seen that the United States has the largest number of publications on supply chain resilience, which is 382, accounting for 21.56% of the total number of publications in the sample. They are followed by China (309), UK (274) and India (219) respectively, all with more than 200 articles. In terms of the number of citations, U.S. scholars continue to lead all countries in terms of research citations at 17,489, followed by the U.K. (10,136) and Germany (8,910).

Comparison of research hotspots in different time periods

A research hotspot is a research topic that has received the most attention from scholars in a particular area of study over a certain period of time. An excellent paper is one that is innovative and current with research hotspots as its cornerstone. While keywords condense and distill the essence of an academic

paper, their frequency of occurrence can be used to identify research hotspots in a particular academic field; therefore, this study uses VOSviewer to visualize and analyze keywords in supply chain resilience literature. In addition, as shown in Figure 1, the literature on supply chain resilience has increased significantly from 2020-2021, and in order to explore the reasons for this, this paper takes 2020 as the time point and divides the research time period into 2010-2019 and 2020-2023.

Different colored nodes in the VOSviewer keyword co-occurrence visualization graph represent different clusters, the size of each node reflects the centrality of the keyword, and the connecting line between two nodes indicates the co-occurrence relationship between keywords. The larger centrality indicates the higher importance of the node in the whole co-occurrence network, and keywords with greater centrality are considered to reflect the research direction of a particular academic field.



Research hotspots from 2010 to 2019

Figure 5. Visualization of keyword co-occurrence in supply chain Resilience literature from 2010 to 2019.

Figure 5 shows the visualization of supply chain management keyword co-occurrence from 2010 to 2019. According to the graph, the three largest clusters in the co-occurrence network are: clusters with supply chain resistance as the main keyword, mainly including supply chain disruptions, supply chain risk, supply chain vulnerability, and other keywords; Clustering with supply chain as the main keyword, mainly including keywords such as climate change, community resilience, sustainable development, etc; Clustering with supply chain management as the main keyword includes keywords such as risk management, automatic industry, and supply risk. Therefore, clustering with supply chain resilience, supply chain resilience from 2010 to 2019. The other keywords with higher frequency of occurrence are listed in Table 3.

1 0 0	(top 10).	•
Keywords	Frequency	Total link strength
supply chain resilience	90	637
risk managment	43	337

Table 3. Statistics on the frequency of keyword appearances in sample literature from 2019 to 2020

41	225			
35	252			
management				
23	171			
20	164			
15	129			
14	117			
13	111			
10	100			
	41 35 23 20 15 14 13 10			

Research hotspots from 2020 to 2022



Figure 6. Visualization of co-occurrence of supply chain Resilience keywords from 2020 to 2023(6).

Figure 6 shows a visualization of keyword co-occurrence in supply chain management literature from 2020 to 2023(6). According to the figure, the three larger clusters are: those with supply chain resistance as the main keyword, mainly including circular economy, digital transformation, blockchain technology, and other keywords; Clustering with COVID-19 as the main keyword, mainly including keywords such as risk management, supply chain risk, ripple effect, etc; Clustering with supply chain as the main keyword mainly includes keywords such as climate change, sustainable development, and environmental performance. Therefore, clustering with supply chain resilience, COVID-19, and supply chain as the main keywords is a hot research topic in the field of supply chain resilience from 2020 to 2022. The other keywords with higher frequency of occurrence are listed in Table 4.

(top 10).			
Keywords	Frequency	Total link	
		strength	
supply chain resilience	385	3131	
covid-19	298	2330	
supply chain	175	1307	
risk-managment	110	1066	

Table 4. Statistics on the frequency of keyword appearances in sample literature from 2020 to 2022

supply chain management	106	904
dynamic capabilities	98	979
scale development	88	879
firm performance	69	703
big data analytics	55	598
supply chain management	55	508

Comparative analysis of research hotspots in two time periods

By comparing the keyword co-occurrence networks for the two time periods 2010-2019 and 2020-2023(6), the similarities and differences in the keywords of the largest clusters corresponding to the two time periods can be seen. On the three largest clusters, both have clusters with supply chain resilience and supply chain as the main keywords. The difference is that in 2020-20223, there are clusters with covid-19 as the main keyword, and the frequency of this keyword is second only to the retrieved topic supply chain resilience. observing Figure 4, it can be seen that there are also keywords such as food supply chain, food security, climate change, etc. in the clusters with covid-19 as the main keyword. security, climate change, etc. In addition, keywords such as artificial intelligence, big data analytics, network design also appear in the keyword co-occurrence visualization map. For the keyword supply chain management, the frequency of occurrence is also high in the literature for 2020-2023, which is ranked at the fifth position, so this keyword is not the main difference between the two time periods.

Table 5 shows the top 10 most cited literature on the topic of supply chain resilience in both time periods to further analyze the research hotspots in different time periods. From Table 5, COVID-19 is mentioned in the titles of the top four most cited literatures for the years 2020-2022. Among them, the authors of the 1st, 2nd, 4th, and 5th ranked citations are all Ivanov, reflecting his outstanding contributions to this field. In addition to presenting a simulation approach and intertwined supply chain networks to cope with the impact of COVID-19 on supply chains, Ivanov, who is also based on the COVID-19 pandemic context in the fifth most cited literature, theorizes the concept of digital supply chain twins, pointing out that the combination of digital supply chain twin modeling and data-driven approaches can help supply chains cope with the shock and contribute to the recovery after the pandemic¹⁰. In summary, it can be seen that sudden public events such as COVID-19 are academic hotspots in the foreign academic field of supply chain resilience.

Periods	Title	Frequency	
2010-2019	A comparative literature analysis of definitions for green and sustainable supply chain management		
	The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics		
	Ensuring supply chain resilience: Developing of a conceptual framework		
	Supply chain resilience in the global financial crisis: an empirical study		
	A contingent resource-based perspective of supply chain resilience and robustness		
2020-2023(6)	Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak		
	Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case		
	Food supply chains during the COVID-19 pandemic	608	
	Viable supply chain model: integrating agility, resilience and	524	

Table 5. Statistics of highly cited literature in the sample for both time periods (top 10).

sustainability perspectives-lessons from and thinking beyond the COVID-19 pandemic A digital supply chain twin for managing the disruption risks and 460

resilience in the era of Industry 4.0 In the context of the times, COVID-19, also known as novel coronavirus pneumonia, is an acute respiratory infection that has been sweeping the globe since the early 2020's. COVID-19 is a "borderless" term, and its spread has put the lives, health, and safety of people in many countries and

regions of the world at serious risk. In addition to pandemics, extreme weather and natural disasters brought about by climate change have had an impact on the stability of supply chains, with disruptions being commonplace. Consumer demand for commodities surges in the short term under sudden-onset public health events, and panic buying of food, medicines, and necessities by consumers occurs in many countries. It has been suggested that there is a two-way relationship between supply chains and panic buying, with panic buying leading to shortages of goods, and shortages leading to panic buying, with inevitable disruptions in the supply chain, the duration of which depends on preparedness. There is a higher risk of disruption in the supply of basic items such as food and water, which can lead to an even more chaotic situation¹¹. During the COVID-19 epidemic, supply models in many Western countries were challenged.

Supply disruptions caused by sudden public health events, including epidemics, have negatively impacted the upstream and downstream supply chains of companies. According to foreign media reports, 94% of Fortune 1000 companies faced supply chain disruptions due to the epidemic¹². Some scholars have discussed the subsequent impact of supply chain disruptions - Ripple effet, pointing out that Ripple effet originates from supply chain disruptions, which are not limited to a certain part of the supply chain but spread downward, affecting the performance of the whole supply chain¹³. In addition, it has been argued that "supply chain disruptions and the associated operational and financial risks are the most pressing issues facing companies competing in today's global marketplace"¹⁴.

In this era, the daily production and operation activities of enterprises face more uncertainty, and enterprises pay more attention to supply chain management. Among them, supply chain resilience has received more and more attention from enterprises and scholars. Supply chain resilience refers to the ability of an enterprise to withstand, adapt to, and recover from disruptions in order to satisfy customer demand, ensure performance goals, and sustain operations in a fragile environment¹⁵. Supply chain resilience is widely recognized by scholars as an ability to cope with unforeseen events and an important manifestation of an enterprise's core competitiveness. Designing resilient supply chains can help companies maintain continuity of operations in changing environments and become the key to survival in the event of a disaster or crisis. It can also be seen from the highly cited literature and keyword co-occurrence mapping that the development of supply chain digital technology has become an enabler to achieve supply chain stability, sustainability and resilience, and advanced technologies such as artificial intelligence, big data, and cloud computing improve the ability of enterprises to maintain the continuity of operations and reduce the loss of relevance.

Sudden public health events such as COVID-19 and climate change are topics of close interest to people all over the world, however, supply chain resilience design mechanisms are not yet mature enough, which is an urgent problem to be solved and a challenge for scientific research. Therefore, influenced by the sudden public event of COVID-19 pandemic, supply chain resilience has become a hot area of research for scholars since 2020. In the face of the new Crown pneumonia epidemic, no one can do it alone. A group of scholars with passion and research spirit have flocked into the field of supply chain resilience research to contribute academic value.

Core issue of supply chain resilience

Based on the keyword clustering and combined with the research hotspots and research topics, it can be found that the current scholars on the supply chain resilience related research mainly focus on the following aspects:

Definition of Supply Chain Resilience

Supply chain resilience is a relatively new topic, and scholars at home and abroad have already conducted relatively rich research on supply chain resilience. Existing studies mainly focus on the definition, capability and strategy of supply chain resilience. Based on the process perspective, supply chain disruption can be divided into three stages: before, during and after disruption, and initially scholars' attention to supply chain resilience research focused on the first two stages. Some scholars proposed that resilience is the ability of a supply chain to maintain, restart and resume operation after a disruption¹⁶. Melnyk et al¹⁷ considered supply chain resilience as the ability of a supply chain to withstand disruptions or to resume operations after a disruption. Subsequently some scholars extended the definition of resilience to the process of preparing for a supply chain disruption and not just limited to the two phases during and after the disruption.Ponis S T and Koronis E¹⁸ studied that supply chain resilience is a proactive approach to responding to disruptions and retaining control of the supply chain by designing the supply chain network to proactively anticipate the occurrence of disruptive events. Chowdhury M M H and Quaddus M¹⁹ defined it as the improvement of supply chain readiness, rapid response, and recovery capabilities by developing and designing the supply chain to minimize losses from supply chain disruptions. Supply chain resilience has been proposed as an adaptive capability of the supply chain designed to cope with uncertain disruptions or sudden major events occurring in the external environment²⁰. Ponomarov S Y and Holcomb M C²¹ also defined it in terms of adaptive capability, suggesting that supply chain resilience is designed to prepare for the unforeseen, respond to disruptions, and recover from the disruptions in order to maintain the continuity of operations.

Capacity for supply chain resilience

Supply chain resilience consists of three main capacities: (1) absorptive capacity (2) adaptive capacity (3) resilience. Absorptive capacity is the ability of the supply chain system to absorb or withstand disturbances and to minimize the likelihood of disruptions at lower levels of effort. Adaptive capacity is the ability to handle disruptions without affecting the normal operation of the supply chain system²². Resilience corresponds to the stage after a supply chain disruption and is the ability of the supply chain to return to a normal state within a certain period of time after a disruption²³. Ivanov D¹ viewed each of the three capacity can be measured by the readiness of the disruption prior to the occurrence of the disruption, Adaptive capacity is the ability of the supply chain to mitigate the disruptions during disruptions and recoveries, and Resilience capacity is the ability to return the supply chain's facilities, processes and employees to their original state.

Strategies to improve supply chain resilience

Since the beginning of the 21st century, scholars have studied the strategies to improve supply chain resilience. Strategies for supply chain resilience can be categorized into two types: (1) proactive strategies; (2) reactive strategies. From the process perspective, proactive strategies correspond to the pre-disruption stage of the supply chain and reactive strategies correspond to the post-disruption stage. Snyder L V et al²⁴. pointed out that proactive strategies refer to the protection of the supply chain when designing the supply chain.Knemeyer A M et al.²⁵ argued that reactive strategies refer to the strategies, the main ones are sourcing localization/regionalization, digital connectivity, supply chain automation, and supply chain collaboration²⁶. Among them, it has been noted that the application of Industry 4.0 systems helps to improve the supply chain resilience of a sample of companies in industries, including manufacturing, in terms of cost reduction, quality or speed improvement²⁷⁻²⁸. In addition, Ivanov D^[1] pointed out that the LCN supply chain framework is an effective way to manage supply chain resilience, and its main idea is to maintain an active, efficient and flexible "ready to change" supply chain state instead of pre-designing some static and costly "ready to absorb" reactive methods. "Belhadi A^[26] and others

pointed out that reactive strategies include developing business continuity plans, improving inventory and stockpiling capabilities, supply chain collaboration, big data-driven, and so on. Among them, Lücker Florian et al²⁹ found that the use of inventory and reserve capacity reduces the negative impacts caused by supply chain disruptions.

In addition to countermeasures, quantitative modeling of supply chain resilience is also a way to improve supply chain resilience by modeling and analyzing the supply chain in order to design resilient supply chain networks. Ivanov D^[1] categorized the modeling methods for supply chain resilience analysis according to the network, process and control levels. From the network level, methods include Bayesian networks, Markov chains, Petri nets, statistical analysis, etc.; methods from the process perspective include stochastic optimization, robust optimization, linear or mixed integer programming; system dynamics, discrete event simulation, and optimal control belong to the control level.

Conclusion

This article uses bibliometric methods and VOSviewer analysis software to visually analyze 1772 foreign literature from the Web of Science database. The research period is divided into 2010-2019 and 2020-2022 (6) years, with a total of 363 and 1409 articles belonging to the two time periods, respectively. Firstly, explain the current research status in the field of supply chain resilience from the perspectives of publication volume, cited contributions, and important authors; Secondly, this article uses VOSviewer analysis software to visualize the co-occurrence of keywords in two time periods, presenting important clusters and their included keywords in the co-occurrence network. Then, by observing the co-occurrence graph of keywords, it compares and analyzes the research hotspots in the field of supply chain resilience; Finally, three core issues in the field of supply chain resilience research were summarized.

The results show that (1) the literature on supply chain resilience in 2020-2023 is much more than that in 2010-2019; (2) the number of publications in foreign literature in 2010-2023 is on an upward trend, and the number of publications in 2020-2022 shows a huge increase, and the number of publications in 2020-2023(6) accounts for about 79.51% of the total number of visualization samples, which indicates that supply chain resilience has received extensive attention from scholars in the past two years and become an emerging hot field; (3) the key researcher in the academic field of supply chain resilience is Ivanov, whose many highly cited papers are concentrated in the time period of 2020-2022, and most of the topic words are centered around "COVID-19"; (4) the second time period is similar to the first time period in terms of keywords, and the second time period is similar to the first time period in terms of keywords. The main difference between the keywords of the second time period and the first time period is that clusters with COVID-19 as the main keyword emerge in the second time period, accompanied by keywords such as climate change. The reason is that the beginning of the second time period in 2020 coincided with the epidemic of new crown pneumonia, and the increase of sudden public health events, including the epidemic, and supply chain resilience can help enterprises maintain normal production and operation, which led to the academic exploration of supply chain resilience by scholars. (5) In the context of COVID-19 era, how to make supply chain resilience is an emerging research hotspot. As human beings continue to understand COVID-19, it is believed that scholars' research on supply chain resilience will be more in-depth and more diversified in perspectives; (6) The research topics in the existing literature are mainly centered on the definition of supply chain resilience, capabilities, and strategies to improve supply chain resilience.

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