Article

COVID-19 and Supply Chain Management: A Review with Bibliometric

Kedwadee Sombultawee [1], Pattama Lenuwat [2], Natdanai Aleenajitpong [3,*] and Sakun Boon-itt [4]

[1] Department of Marketing, Thammasat Business School, Thammasat University, Bangkok 10200, Thailand; kedwadee@tbs.tu.ac.th

[2] Thammasat Business School, Thammasat University, Bangkok 10200, Thailand; pattama-len61@tbs.tu.ac.th

[3] College of Innovation Management, Rajamangala University of Technology Rattanakosin, Nakhon Pathom 73170, Thailand

[4] Department of Operations Management, Thammasat Business School, Thammasat University, Bangkok 10200, Thailand; sboonitt@tu.ac.th

[*] Correspondence: natdanai.ale@outlook.rmutr.ac.th

Abstract: The supply chain and its management are the hidden engines that drive the economy. The COVID-19 pandemic has precipitated an unprecedented sustained challenge to supply chain management around the world, which has highlighted the importance of research on the effects of COVID-19 on supply chain management. Most of the scholarly articles were mainly focused on content analysis to discuss aspects of the research related to COVID-19 and supply chain management. The literature reviews with the bibliometric method involving supply chain management in the COVID-19 context are still scarce. In this paper, we undertook a bibliometric analysis of the research on COVID-19 and supply chain management, finding a total of 257 papers published in 2020 and 2021 to determine the thematic direction of the related flourish of research. The analysis used a combination of bibliographic and network analysis to capture the direction the research has been taking. The study identified the most highly productive authors, prominent journals, and geographic centers of publications about this phenomenon. It also examined networks related to co-authorship, countries of collaboration, co-citations and highly cited authors, and co-wording. The examination identified four thematic clusters, comprised of the impact of the COVID-19 pandemic on supply chains, the improvement of supply chain resilience for viability, technology and innovation for supply chain sustainability, and supply chain risk management in response to COVID-19. These findings support the need for further investigation into supply chain management, the impact of the COVID-19 pandemic on supply chains, and, more broadly, supply chain resilience.

Keywords: review; bibliometric; supply chain management; COVID-19

1. Introduction

Supply chains are a critical aspect of how the economy works, but they are not often highly visible. These networks of buyers and suppliers are ultimately tasked with delivering raw materials, intermediate goods, and, eventually, end products to consumers and businesses around the world. For the most part, supply chains operate efficiently in the background, out of the sight of end consumers. However, this quiet efficiency began to break down during the COVID-19 pandemic, as cascading supply chain problems resulting from widespread labor shortages began to take hold. Lockdowns, including closing businesses and remote working, in countries around the world, have hindered the flow of raw materials, people, and finished products in the supply chain. The COVID-19 pandemic highlighted unseen vulnerabilities, and many firms have suffered capacity shortages and losses [1]. According to the Institute of Shipping Economics and Logistics (ISL), the container throughput index, which is used to measure the volume of goods moving through shipping ports each day, fell from 113.3 in January 2020 to 107.7 in September 2020,

down 9.5% [2]. In addition, The United Nations Organization (UN) estimated that global demand and distribution through global supply chains decreased sharply, by nearly 15%, in 2020 due to the COVID-19 pandemic [3]. The COVID-19 pandemic has therefore had a significant negative impact on the operational performance of the entire supply chain. Suddenly, supply chains became visible in the forefront of commerce, but not in a positive way, as both consumers and businesses suffered intermittent shortages of basic goods. Academics responded to the growing concern surrounding supply chains by producing a large and still growing, volume of research on the impacts of COVID-19 on the world's supply chains.

There are several key reasons for the impacts of COVID-19 on supply chain performance, such as the sensitivity of the supply chain to its inability to respond swiftly enough to rapidly changing demands. The spread of COVID-19 has also significantly increased demand in many areas of the economy due to these unexpected disruptions. This has created widespread shortages and put pressure on the related supply chains. Disruptions at one, or a few, agencies can affect almost all of the supply chain [4]. Nearly every supply chain has faced a multitude of problems due to the COVID-19 pandemic, such as supply disruptions [5], production disruptions [6], or changes in demand [7]. Consequently, there is a vital need to design flexible supply chains that are able to effectively cope with the disruptions rising from the COVID-19 pandemic [8]. This means that improving firms' resilience and ability to absorb the shockwaves from these negative disturbances is crucial to their survival during the crisis. Some of the initiatives involved the area of improving supply chain resilience and, at some point, the concept shifted toward supply chain viability, which focuses more on adaptability, rather than recovery [8–12]. Similarly, some studies focused on supply chain resilience, a time-delayed COVID-19 propagation model, and artificial intelligence (AI) technologies [10,13], while some outlined the lessons learned from COVID-19, including disruptions in agriculture and food supply chains, supply chain risk, and the associated effects of COVID-19 [14–16].

An increasing number of scholars have been conducting research related to systematic literature reviews looking at the impacts of the COVID-19 pandemic on supply chain management from many perspectives, such as supply chain sustainability, supply chain disruption, and recovery plans [6,17–20]. For example, Industry 4.0 supports holistic pre-disruption resilience measures to enable more effective proactive risk management in the face of COVID-19 [20], as well as the four broad recurring themes which were revealed in the published work investigating the impacts of the COVID-19 pandemic, including resilience strategies, technology for resilience strategies, and supply chain sustainability [18]. Most of the articles that were reviewed mainly focused only on content analysis to discuss aspects of the research which were related to COVID-19 and supply chain management. However, literature reviews exploring supply chain management in the context of the COVID-19 pandemic using the bibliometric method are still scarce [21]. In particular, many of the studies have not addressed a wider and more holistic perspective that evaluates COVID-19's effect on the supply chain and what is known about it overall. The literature is still emerging and fragmented, making it challenging to understand from these previously published reviews what is happening in academic practice.

To the best of our knowledge, very few studies about this issue exist that have been conducted primarily using bibliometric and network analysis to clarify the current state of COVID-19 related supply chain management research. The studies which do exist tend to either use a graphical framework to understand the current state-of-the-art of pandemic supply chain management [22] or use network analysis to illustrate graphical maps of a co-citation analysis of pandemic supply chain research [23]. In contrast, the bibliometric method can be employed to systematically analyze the knowledge structures to present a comprehensive overview and visualization [24], so it is good to use both graphical framework and network analysis in order to comprehensively uncover and understand the trends and relationships. This study employed a bibliometric method and network analysis to synthesize the studies from different viewpoints which are related

to the current status regarding publications, co-occurrence networks of citations, and authorship tendencies, while proposing the directions for new research based on a co-word network analysis, specifically with regard to supply chain management and COVID-19. Our research fills in the critical gap between the trends related to the COVID-19 pandemic and their effects on supply chain management. A bibliometric method is a holistic approach that provides better insights than a traditional literature review. This method has been used by researchers in various disciplines [25], and it enables scholars to capture the direction of intensive and unique research, such as with regard to supply chains during COVID-19, in a timely manner as they rapidly grow from day by day. Through this method, the amount and intensity of research on a topic are clearly quantified, so the degree of subjectivity is reduced when research direction has to be justified afterward. In brief, a bibliometric analysis provides a way to bring coherence to the vast array of literature on COVID-19 and its impact on the supply chain that has emerged within the first one and a half years of the pandemic. This can provide information for researchers to focus and target their research more effectively moving forward. The sequence of the structure in this paper begins with the description of research design and methodology in the Materials and Methods section, followed by Results and Discussion, and ends with Conclusions and Recommendations.

2. Materials and Methods

2.1. Research Design

As depicted in Figure 1, we initially searched the Scopus database using the keywords 'supply chain' and 'COVID-19' or 'pandemic' for papers published from January 2020 to July 2021, which was the early phase of the pandemic, so as to reflect the unprecedented occurrence that resulted in exceptional reactions before firms could become more adaptable to the crisis. This timeframe, however, covers a longer period than the prior bibliometric research in a similar vein [23,24] which encompassed only until 2020 and 2019.
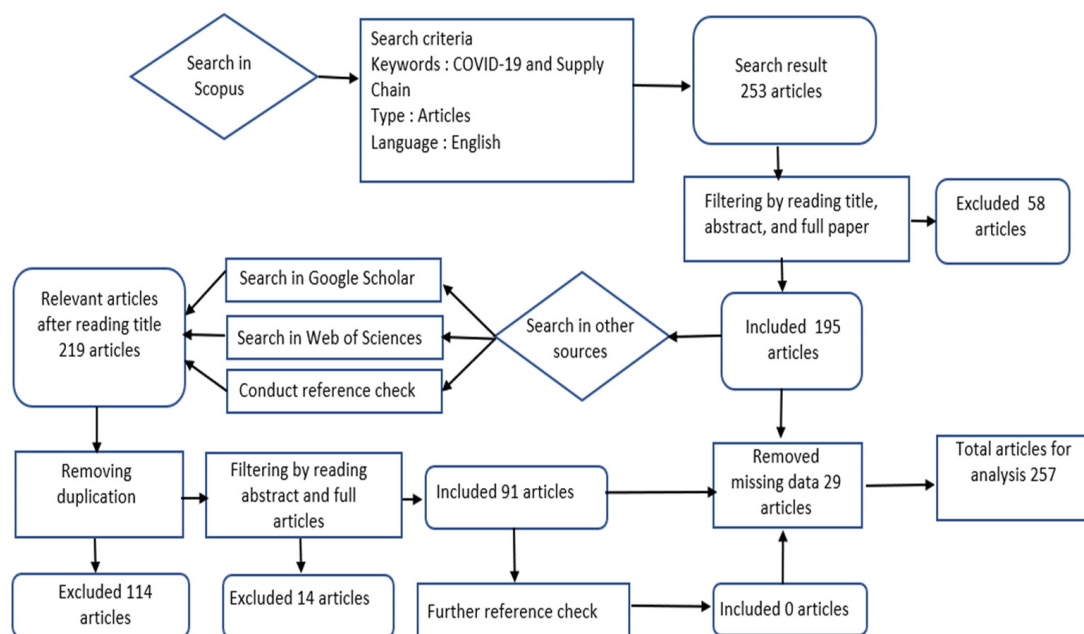
Figure 1. Data screening process for the bibliometric study.

The keyword search was set to include titles, abstracts, and key words in order to retrieve all relevant publications. The initial search yielded nearly 1700 papers but narrowing the results to only the business research area and only English articles yielded 253 articles. We then excluded irrelevant results by reviewing titles, abstracts, and full papers; this process excluded 58 articles, leaving 195 papers from the Scopus database. The inclusion criteria were: (i) articles focused on the supply chain in relation to the COVID-19

pandemic and (ii) the inclusion of both 'supply chain' and 'COVID-19' in the body text. The exclusion criterion was if keywords only appeared in the reference lists without being discussed in the body of the text.

To enhance the search results, we also searched the Google Scholar and Web of Science (WoS) databases. The process identified an additional 219 articles, but 114 of these were removed because they were duplicates of other articles found in the Scopus search. We then read, in full, the remaining 105 articles, of which we included 91 for further consideration and excluded 14 based on the previously mentioned exclusion criterion. Finally, we checked the references of the additional 91 articles, and no further articles were identified. The entire process yielded a total of 286 articles, but 29 articles were missing the authors' information, or some fields in the database were misplaced, so this left us with only 257 articles for further analysis.

2.2. Bibliometric Study

2.2.1. Performance Analysis

Based on 257 articles, we extracted the data and comprehensively investigated the information contained in each article, including the title, journal, and the study's country of origin for further descriptive data analysis. The analysis provided information related to publications and citations, including who the productive authors were, cited articles published about supply chains and COVID-19, and the articles' geographical distributions. The results allowed us to ascertain the extent of the academic contributions to various aspects of supply chain management relative to the COVID-19 pandemic, such as authorship, journal of publication, and countries of origin.

2.2.2. Network Analysis

The bibliographic network was analyzed using the VOSviewer (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands), which is a free network analysis software package for bibliographic studies [26]. The database file from Scopus (Comma-Separated Values format, CSV) was put into the program to generate a graph of the network connections and to analyze other relevant bibliometrics, including the number of documents and citations. The network is connected by links and nodes. The nodes represent the participants in the network and they could be based on the authors' names, articles' countries of origin, or keywords. The sizes of the labels and the circles are determined by the weight of the nodes. The higher the weight of a node, the larger the label and the circle for that node. The links between two nodes represent the repeated number of lines that connect the nodes to each other. The greater the number of lines connecting them, the stronger the relationship between the nodes. Another indicator of the level of the relationship is represented by the distance between two nodes. The shorter the distance, the stronger the relationship of the collaboration is in terms of journals, words, or references between the two nodes. The different colors of the nodes denote which cluster the node is classified into. The investigation of this analysis mainly comprised authorship, citations, and country of origin, and reveals the cooperation of authors and the connections of the words used.

2.2.3. Co-Authorship Network

This network analysis represents the connections of collaborative writing among authors, which further helps indicate current interests in the study of supply chain management and COVID-19 among different groups of scholars. The larger the circle, the more collaborative writing is found in the network. A shorter distance between nodes indicates how often authors work together to write a publication. The thickness of the line linking the nodes represents the strength, showing the frequency of repetitive collaborative writing. There was a total of 58 authors who met the threshold of authoring at least two documents.

2.2.4. Country Collaboration Network

The cooperation network between countries represents collaborative writing on supply chains and COVID-19 among institutions from each country. The larger the size of the circle, the more collaborative writing one country has with others within the network. The closer the two countries are, the more often they have co-authored articles. The final analysis showed there were 30 countries in the network meeting the threshold of producing at least three publications.

2.2.5. Co-Citation Network

This represents the frequency of authors citing others, and vice versa. The objective of this analysis was to examine the group of highly influential authors and their connections with others in the network based on the number of citations found. The larger the circle, the more frequently the papers of an author were cited. Additionally, the closer two circles are, the more frequently there were co-citations. We included 54 authors with a minimum of six citations per author.

2.2.6. Co-Word Network

To perform a co-word analysis, we combined the datasets and converted them into a Microsoft Word file for data cleaning and pre-processing. We manually removed the coding errors in the sources, affiliations, and cited references for further analysis. Text-mining techniques were applied to this analysis using the titles, abstracts, and keywords of the articles [26]. When multiple keywords occurred together in the same articles, they were identified as co-word links. The relationships between the keywords were determined based on the number of articles in which the keywords occurred together [26]. The co-word network could lead us to explore the ongoing research interests of the authors and be somewhat able to anticipate their future themes and directions. The larger the size of the circle, the greater the number of occurrences a word had. The closer two words are, the more often they occurred together. We identified 36 keywords in total, with each one having at least four occurrences.

3. Results

3.1. Productive Authors

Table 1 represents a ranking of the top five most productive authors. The most productive author was Ivanov, D. from Germany, with the highest number of both publications (11) and average citations per publication (73.3). The remaining productive authors, ranked in descending order, were Kumar, A. from India, Paul, S.K. from Australia, Ali, S.M. from Bangladesh, and Dolgui, A. from France. The average number of citations per publication varied widely, having a range of 5.6 to 73.3. Two of the previously mentioned authors, Ivanov, D. from Germany and Dolgui, A. from France, had the highest average number of citations per publication and usually collaborated with each other. The area of study of the most productive author was supply chain viability and was focused on adaptation to survive and thrive. The rest of the most productive authors focused on mitigating risk (Kumar, A.), managing impacts, and supply chain recovery (Paul, S.K.).

3.2. Publication Performance

Table 2 represents a ranking of cited articles. The most frequently cited article in the field of supply chains and COVID-19 was entitled 'Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2)', with more than 300 citations. The major findings describe how the timing of the closing and opening of facilities in different echelons might become a major factor that determines the impacts of the epidemic outbreak on supply chain performance. The three most cited articles investigating this issue were published by Ivanov, D., who are excelling in the resilience and viability of supply chains. The main focuses and findings of the top-cited articles reveal that most of the papers highlighted the impact of COVID-19

on the fields of global supply chains, healthcare supply chains, food supply chains, digital supply chains, viable supply chain models, and supply chain decisions. This analysis could uncover where the common interests, basic concepts, and theories related to supply chains and COVID-19 were actually grounded during the COVID-19 pandemic from January 2020 up until our cut-off date, July 2021. The results for publication performance are aligned with the results for the most productive authors, since Ivanov, D. is the first-ranked author for both the most publications and the highest number of citations.

Table 1. Top five most productive authors publishing on supply chains and COVID-19.

No. *	Author Name	Country of Author	Number of Publications	Average Citations per Publication	Number of Publications as First Author
1	Ivanov, D.	Germany	11	73.3	9
2	Kumar, A.	India	5	5.6	2
2	Paul, S.K.	Australia	5	17.0	2
4	Ali, S.M.	Bangladesh	4	8.3	0
4	Dolgui, A.	France	4	71.0	0

* Equally productive authors have the same ranking number.

Table 2. Top ten most commonly cited articles on supply chains and COVID-19.

| No.	Title (Year)	Author(s)	Citations	References
1	Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case (2020)	Ivanov, D.	320	[27]
2	Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak (2020)	Ivanov, D. and Dolgui, A.	188	[28]
3	Viable supply chain model: integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic (2020)	Ivanov, D.	118	[29]
4	Global supply-chain effects of COVID-19 control measures (2020)	Guan, D.; Wang, D.; Hallegatte, S.; Davis, S.J.; Huo, J.; Li, S.; et al.	90	[30]
5	A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19) (2020)	Govindan, K.; Mina, H.; Alavi, B.	87	[21]
6	A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0 (2021)	Ivanov, D. and Dolgui, A.	64	[31]
7	Research opportunities for a more resilient post-COVID-19 supply chain—closing the gap between research findings and industry practice (2020)	Remko, V.H.	57	[32]
8	Impact of COVID-19 on logistics systems and disruptions in food supply chain (2021)	Singh, S.; Kumar, R.; Panchal, R.; Tiwari, M.K.	47	[5]
9	Coronavirus (COVID-19/SARS-CoV-2) and supply chain resilience: A research note (2020)	Ivanov, D. and Das, A.	43	[11]
10	COVID-19's impact on supply chain decisions: Strategic insights from NASDAQ 100 firms using Twitter data (2020)	Sharma, A.; Adhikary, A.; Borah, S.B.	41	[7]

3.3. Geographical Distribution

From these data, we summarized the number of papers published on supply chain and COVID-19 from January 2020 to July 2021 based on their country of origin. The intensity of the color represents the number of documents produced by each country. The darker the color, the greater the number of documents. According to Table 3 and Figure 2, the flow of work from the US was obviously the most intense (65 documents, 25.3%), while, surprisingly, India was second (43 documents, 16.7%), followed by the UK (38 documents, 14.8%), and China (35 documents, 13.6%). The US accounted for about a quarter of all the documents in the sample. For the rest, the number of papers contributed on supply chains and COVID-19 comprised fewer than 20 documents for each country. Most of the countries with a high intensity of papers were the countries that also faced more serious situations in regard to COVID-19.

Table 3. Top five countries contributing to research publications on supply chains and COVID-19.

| Rank	Country	Documents	Percentage *
1	United States	65	25.3
2	India	43	16.7
3	United Kingdom	38	14.8
4	China	35	13.6
5	France	18	7
6	Germany	18	7

* Percentage of the total documents in the sample ($N = 257$).
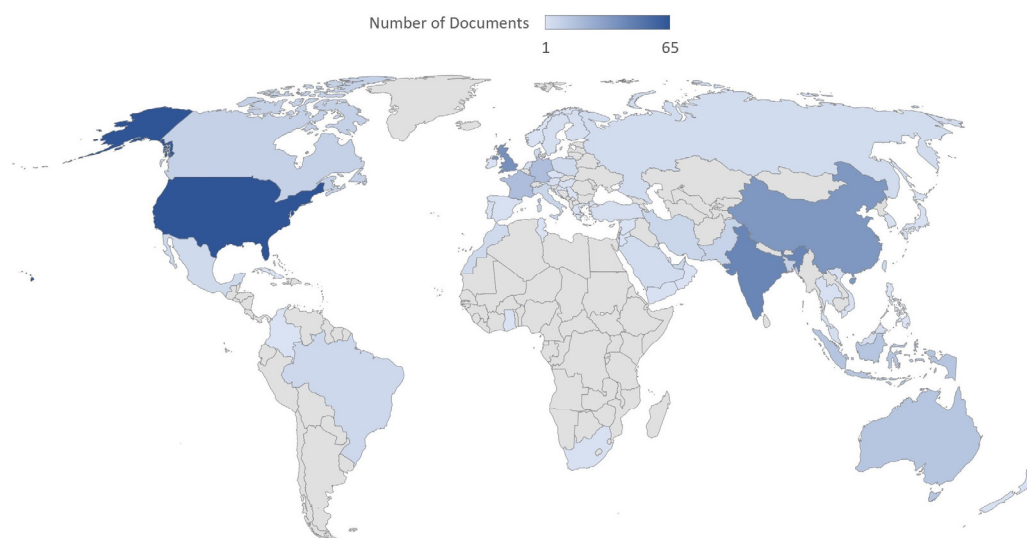
Figure 2. Geographical distributions around the globe.

3.4. Co-Authorship Network

Figure 3 illustrates the whole network of author cooperation with clusters in different colors, although some authors are isolated. Among the various authorship clusters, we examined the four most dominant clusters to determine the common interests and areas of expertise of the contributors within each cluster.
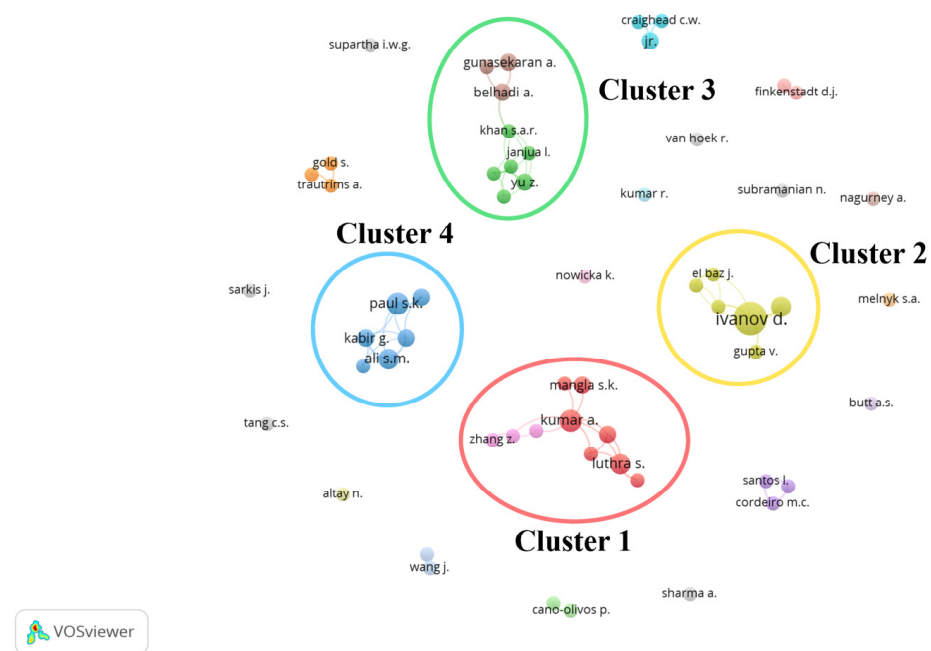
Figure 3. Author cooperation network and the four dominant clusters.

3.4.1. Cluster 1

As shown in Figure 3, the authorship was centered around Kumar, A. and extends into two subclusters. The first subcluster included Kumar, A., Kumar, P., Mangla, S.K., Sharma, M., Joshi, S., Luthra, S., and Haleem, A. Their main areas of research relate to supply chain vulnerability, resilience in agri-food supply chains, healthcare supply chains during the COVID-19 pandemic, survivability of sustainable supply chains, retail supply chain performance, the internet of things (IoT), and medical supply chains. The second subcluster included Zhang, Z., Srivastava, P.R., and Gupta, S. Papers in this cluster were focused on supply chain resilience, a time delay COVID-19 propagation model, and artificial intelligence (AI) technologies. In conclusion, most of the authors in this cluster have publications in the area of supply chain resilience and vulnerability in agricultural, food, and healthcare supply chains related to implementing AI technologies and IoT during the COVID-19 pandemic. Kumar, A. played the most important role in this area. This cluster showed the extensive amount of work produced by the various authors to improve supply chain resilience during COVID-19 which could be supported by technology, such as AI or IoT. The contexts highlighted within this group were the agriculture industry, which was more vulnerable, and the healthcare industry, which was highly focused on during the pandemic.

3.4.2. Cluster 2

The authorship in Cluster 2 is strongly connected with Ivanov, D. as a central node. Other authors in this cluster included Das, A., Ruel, S., El Baz, J., Gupta, V., and Dolgui, A. The area of study in this cooperative group was related to the resilience and viability of supply chains, and Ivanov, D. was the main author in this field. This group of authors initiated the concept of improving supply chain resilience and, at some point, they shifted the concept towards supply viability, which is more focused on adaptability rather than recovery. They conceptualized supply chain resilience in a new normal approach, which they called 'supply chain viability', which focused on adaptability to survive and thrive. Some tools to help supply chain decision-making during the difficult times in the COVID-19 pandemic were also introduced, e.g., a digital supply chain twin [8] and a nonlinear programming model [6].

3.4.3. Cluster 3

The authorship in Cluster 3 has Khan, S.A.R. as a bridge between two small subclusters, with one group consisting of Belhadi, A., Kamble, S., and Gunasekaran, A., and the other group consisting of Khan, S.A.R., Janjua, L., Shah, A., Razzaq, A., Yu, Z., and Mor, R.S. The first group studied manufacturing and service supply chain resilience, agriculture supply chain risk, and supply chain risk mitigation. The latter group's studies concerned disruption in the agriculture and food supply chains and further examined AI-driven innovation. In conclusion, the papers within this cluster were mostly about the lessons learned from COVID-19 related to the disruptions in agricultural and food supply chains, supply chain risk, and the effects of COVID-19. Common interests related to these areas were mitigating supply chain risk and improving supply chain resilience by using technology such as AI. The two concepts of risk and resilience studied within this cluster represent two sides of the same coin.

3.4.4. Cluster 4

In Figure 3, Cluster 4, the author relationships are somewhat scattered. There is no specific main contributor in this section of the network. The six co-writing authors in this cluster include Paul, S.K., Moktadir, M.A., Chowdhury, P., Kabir, G., Ali, S.M., and Ahmed, S. Most of their publications were related to the systematic review of the impacts of the COVID-19 pandemic in relation to supply chains, supply chain sustainability, supply chain disruption, and recovery plans. The areas of study in this cluster ranged from systematic reviews of supply chains during the COVID-19 pandemic, to proposing strategies to deal with the disruptions COVID-19 has caused.
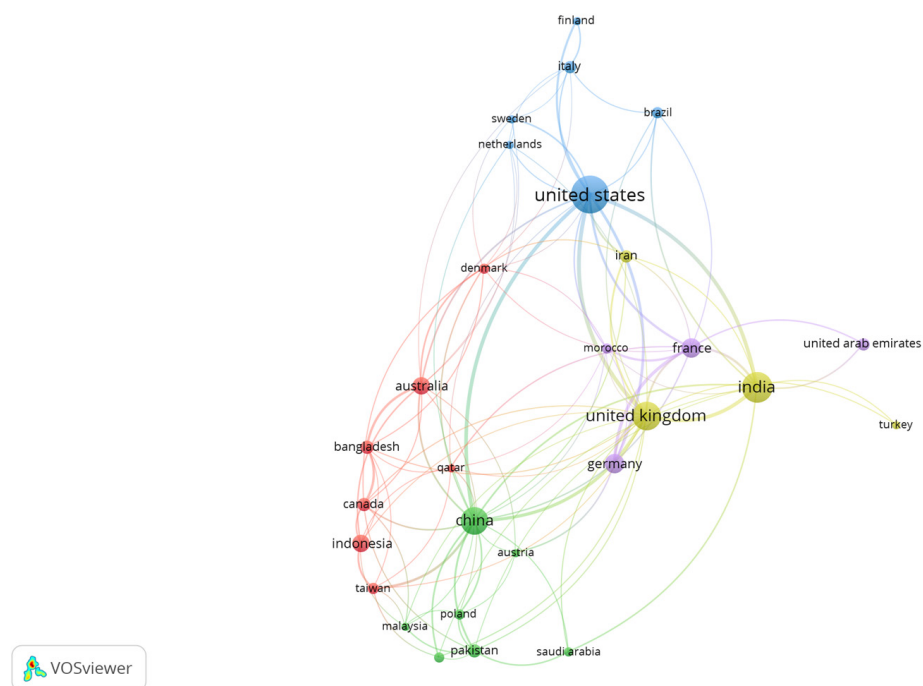
3.5. Country Collaboration Network

In considering the level of academic contributions by each country, this analysis will provide more insightful implications regarding how documents from each country are connected to one another, regardless of their authorship cooperation. The results of evaluating the cooperation network between countries and territories are presented in Figure 4. Based on the numbers of documents, the top four contributors were the US, the UK, and two countries from Asia, India, and China. The first, or largest, cluster, was centered around the US and mostly consisted of European countries such as Sweden, the Netherlands, Finland, and Italy. There were also two smaller clusters. The second cluster was formed around three countries, namely Germany, France, and Morocco, while the third cluster mostly comprised Asian countries, like Indonesia, Bangladesh, Taiwan, but also included Australia, Denmark, and Canada. The fourth cluster, which formed around the UK, consisted of India, Turkey, and Iran. The fifth cluster was centered around China and included countries such as Pakistan, Poland, Malaysia, Austria, and Saudi Arabia.

As a result, these main clusters depict a geographical culture of authorship cooperation where scholars from the US and European countries are inclined to work together, as are groups of Asian countries. However, there are also some cross-continental collaborations, such as those seen in the relationships between the UK and India, China and the US, France and the United Arab Emirates, and Bangladesh and Australia.

3.6. Co-Citation Analysis

Figure 5 represents the connections of each author in relation to the citations they have among the others. The bigger the circle, the greater the number of times an author has been cited. It is noticeable that Ivanov, D. is oriented as both the main contributor and the most cited author in this study. This result could affirm the previous analysis where Ivanov, D. was the most productive author and authored the most cited articles. The cluster surrounding Ivanov, D. includes Sokolov, B., Paul, S.K., Pavlov, A., Essam, D., Hishamuddin, H., Ivanova, M., Sarket, R., and Dolgui, A. This largest co-citation cluster is focused on the study of supply chain resilience and supply chain viability. By considering the distance separating authors, several scholars from the other main clusters were found to

be prevalent, even though they were not usually directly cited by those in the central cluster, e.g., Goel, R.K., Lee, H.L., Tang, C.S., Sarstedt, M., Venkatesh, V., Grewal, D., and Singh, S. The cluster that was the furthest separated from the other clusters belonged to a group related to an outstanding author named Nagurney, A. Such a distance of separation means that they had the least frequent instance of co-citations with the others in the network. The overall results imply that the list of authors share a common interest in supply chain resilience and supply chain viability, in which Ivanov, D. is the most influential author. It also implies that the listed studies by these authors could, or do, complement one another.


Figure 4. Country collaboration network for research on supply chains and COVID-19.
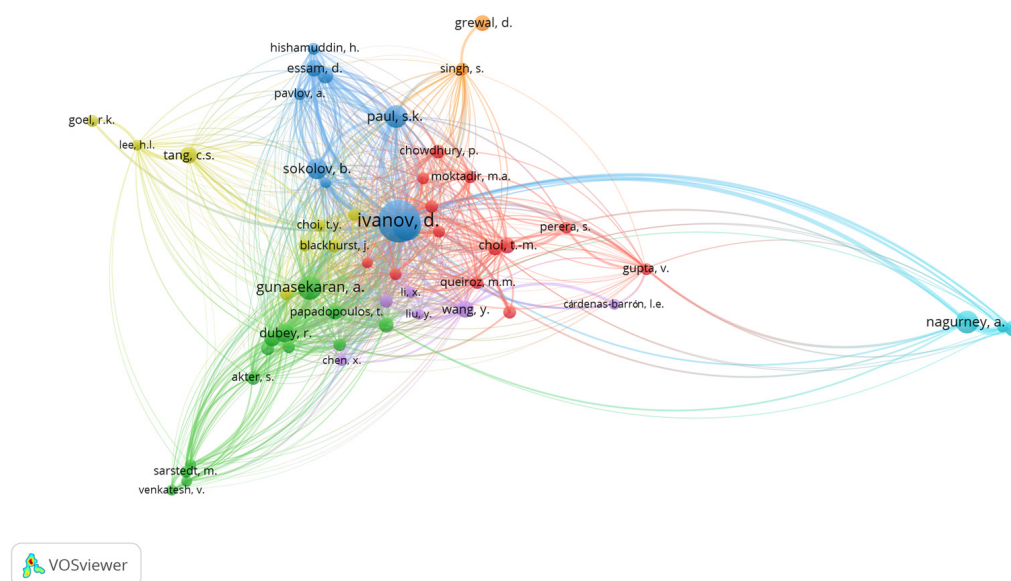
Figure 5. Co-citation network for research on supply chains and COVID-19.

3.7. Co-Word Network

The co-word network helped us to understand the research interests and the relationships among keywords which allowed the prominent research themes to emerge from the analysis. Based on our analysis, four different themes (different colors from Figure 6) emerged from the words most frequently used in each cluster. Thematizing the words that appear can help scholars capture the trends of research during the time period being investigated (Figure 6 and Table 4).
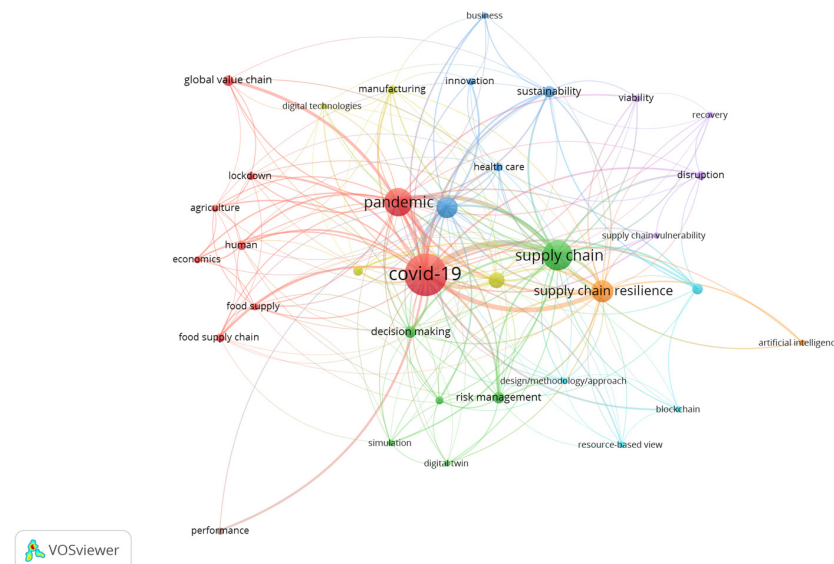
Figure 6. Co-word network for COVID-19 and supply chain literature in business and management.

Table 4. Themes, sub-themes, and keywords related to COVID-19 and supply chain research.

Themes	Sub-Themes	Keywords
Cluster 1 (Red color) Impact of the COVID-19 pandemic upon supply chains	The impact of the COVID-19 pandemic on supply chains	Pandemic Lockdown Food supply chain Food supply Agriculture Economics Human
	Food and agricultural supply chains during the COVID-19 pandemic	
Cluster 2 (Purple color, Orange color) Improve supply chain resilience for viability	Reducing supply chain vulnerability	Artificial intelligence Supply chain vulnerability Disruption Supply chain resilience Viability Recovery
	Supply chain responses	
	Improving supply chain resilience	
	Shifting to supply chain viability	
Cluster 3 (Blue color) Technology and innovation for supply chain sustainability	Emphasis on digital technology and innovation in supply chain management	Digital technologies Supply chain management Sustainability Manufacturing Healthcare Innovation Business
	Moving towards sustainable supply chains	
	Achieving supply chain sustainability	
Cluster 4 (Green color) Supply chain risk management in COVID-19	Understanding and assessing supply chain risks	Risk management Decision-making Risk assessment Digital twin Simulation
	Decision-making challenges	
	Mitigating supply chain risks	

3.7.1. Cluster 1: Impact of the COVID-19 Pandemic on Supply Chains

Unlike the other clusters, there were no sub-themes in Cluster 1. This is due to the fact that the main concepts of the studies were all in the same vein, which was about the impact of COVID-19, but with a particular focus on the food and agriculture sectors. Furthermore, we can see from Figure 6 that the distance between the keywords in Cluster 1 of the co-word network appears to be small, which means they are strongly related.

Although both supply and demand shocks have negatively affected supply chains due to the pandemic, firms, on average, have largely viewed this crisis as a demand shock and have responded to it as a demand shock rather than as a supply shock [33]. This, once again, highlights that supply chain disruptions are not highly visible, since the issues are not clearly detected or defined. In terms of context, the agriculture and food industries were the most highlighted, as they were affected more severely by the disruptions [15,34,35]. The disruptions also affected the manufacturing industry, which is the main pillar of the global supply chain [36]. During the COVID-19 outbreak, manufacturing industry operations were restricted, and the supply chain faced severe challenges. The poor health of employees, and their life expectancy rates, can have a negative effect on economic growth [37]. Finally, the aspect of waste cannot be ignored. Although plastic packaging may provide convenience during the COVID-19 situation, the plastic waste it has created has produced a negative effect on the environment [36].

3.7.2. Cluster 2: Improving Supply Chain Resilience for Viability

As COVID-19 challenges the entire supply chain, there is a growing body of research regarding how to create a more resilient supply chain. Although supply chain resilience is crucial for firms, supply chain viability represents a novel and impactful research perspective [38]. The co-existence of resilience and viability are concepts that have been advanced because of the adversity that firms have to face these days. Recovery from a shock by merely being resilient does not seem to be sufficient since the world may no longer allow us to remain the same. The COVID-19 pandemic made apparent that supply chain resistance to disruption needs to be considered at the scale of survivability or viability to avoid supply chain and market collapses and to secure the provision of goods and services [29]. Viability is the highest analysis level for supply chain reactions to disturbances and is based upon stability, robustness, and resilience [29]. It is an extended concept arising from resilience that requires not only adaptability, but transformation to survive and thrive in the face of change.

a.   Reducing Supply Chain Vulnerability

Vulnerability is the tendency to be damaged, and firms try to reduce it as much as possible. Vulnerability can be controlled by reducing supply chain complexity. This can be done by enhancing the transparency of information sharing with critical part suppliers and fixing process owners in supply chains [39]. Four drivers of supply chain vulnerabilities come from the supply chain's structure, organizational complexity, relationship complexity, and information management [39].

b.   Supply Chain Responses

Supply chain response is considered one of the three reactive resilience capabilities, namely supply chain response, agility, and recovery [40]. Procurement and supply management contribute significantly to responding and recovering from the pandemic's effects on supply chains. In the short term, it could involve things like inventory buffering in response to demand risks. In the medium term, it is related to the acceleration of key projects and focusing on collaboration [41]. A mathematical model was constructed to handle both supply and demand disruptions [42]. Operational research (OR) methods that can help to cope with the ripple effect in the five stages of a pandemic were also proposed (Anticipation; Early Detection; Containment; Control and Mitigation, and Elimination) [8].

c.   Improving Supply Chain Resilience

The primary objective of supply chain resilience is to be able to quickly recover from unexpected supply chain disruptions and to improve a supply chain's original performance. Supply chain resilience is built on a multi-faceted, hierarchical concept, which includes three primary dimensions: proactive capability, reactive capability, and network design quality [43]. Because many strategies from traditional supply chain disruption preparedness, mitigation, and recovery strategies cannot be used for recovery in regard to COVID-19 disruptions, an adaptive strategy, which includes restructuring the supply chain and facing the supply chain disruption and its impacts is required [44]. Emerging technologies such as AI, industry 4.0, additive manufacturing, and advanced product tracking applications hold significant potential for improving supply chain resilience [45].

d.   Shifting to Supply Chain Viability

Adaptation capabilities are essential in managing supply chains during pandemic disruptions. Adaptability has become a significant challenge for firms accustomed to long-term planning and lean structures and processes. Firms encountering this challenge generally have confidence in the future, if things seem to be controllable [8]. The challenge from COVID-19 is different; it is unpredictable, so it requires a proper passive reaction in the beginning to mitigate the impact. However, recovery to the original state might not always be possible. Instead, adaptation from this point is needed to survive and thrive. This concept is called "viability", and it can also be depicted by the term "antifragility" used by Taleb [46]. The antifragile "loves" disorder and thrives in a world of randomness [46]. Viability is considered as an underlying supply chain property spanning three perspectives: agility, resilience, and sustainability [29]. Sustainability is a key step beyond the prior resilience concept that scholars can further investigate. To achieve supply chain viability under the conditions of the COVID-19 pandemic, four major adaptation strategies were proposed: intertwining, scalability, substitution, and repurposing [8]. This theme of research is becoming more impactful and is attracting a great deal of interest among scholars.

3.7.3. Cluster 3: Technology and Innovation for Supply Chain Sustainability

Although the three key pillars, social, environmental, and economic, are equally important in a sustainable supply chain, economic sustainability might be more strongly emphasized during the COVID-19 pandemic as firms struggle to survive. How to keep the three pillars balanced during such a difficult time is a significant challenge in supply chain management that scholars must resolve. Technology could become a main driver to allow supply chains to adapt in time to avoid severe disruption. The greatest benefit of technology will be realized when it leads to long-term solutions, or to supply chain sustainability. Collaboration with core supply chain members to reach an agreement on how to solve the environmental and social challenges is one of the key drivers of sustainability.

a.   Emphasis of Digital Technology and Innovation in Supply Chain Management

The COVID-19 crisis has particularly highlighted the importance of digitization for companies. The only certain aspect born out of all the uncertainty that COVID-19 has brought to the world is the requirement for digital adaptations in the future [47]. Technology will be the main player in building future supply chain strategies. The studies have revealed the advantages of using digital technologies for supply chain management over traditional business management technologies and logistics systems, especially in light of the conditions created by COVID-19 [48,49]. Blockchain technology is likely to affect key supply chain management objectives, such as cost, quality, speed, dependability, risk reduction, sustainability, and flexibility [50]. For long-term performance, it is recommended for firms to exploit their information processing capabilities to build supply chain resilience [51]. Big data analytics is particularly suitable for improving supply chain resilience [20] and has a significant impact on supply chain integration [52]. Drones could also be a viable option to improve the efficiency and effectiveness of supply chains to combat the effects of the pandemic [53].

b.   Moving towards a Sustainable Supply Chain

Sustainability can be viewed through various lenses. The first and most popular view is the triple-bottom-line—profits, people, planet—coined by John Elkington [54]. Another popular one is the multi-generational philosophy under the Brundtland Report— meeting the needs of the present without compromising the ability of future generations to meet their own needs [55]. While there is more attention being paid to improving supply chains and building supply chain resilience, there is also emerging attention toward the need for more sustainable supply chains. Sustainable supply chains are the intersection of supply chain management and sustainable development. They include addressing economic, social, and environmental issues to manage the relationships with suppliers [7]. Although it has been known for quite some time that sustainable supply chain practices consist of economic, environmental, and social aspects, firms have only recently begun to emphasize the social and environmental aspects [56]. COVID-19 has opened avenues for developing sustainable supply chain practices [55]. This crisis has highlighted the problems related to sustainable supply chain management and sustainable economics when they are confronted with disruptive shocks that threaten firm survival [57]. More precisely, an interesting avenue for future research will be whether the pandemic and the economic crisis will lead to a focus on financial survival and thereby neglect social and environmental concerns [57].

c.   Achieving Supply Chain Sustainability

In order to achieve worldwide supply chain sustainability, firms need extra cooperation with governments and companies, whether their rivals or partners, while they also have to concentrate on integration and collaboration with their core supply chain members and central governments. Sustainability is more feasible to achieve with a differentiation strategy than a cost leadership strategy [58]. To succeed in a dynamic and uncertain world, a firm should consider leveraging industry 4.0 associated technologies to build three capabilities—namely, connectivity, clarity, and continuity—in order to achieve efficiency, resilience, and sustainability [59].

3.7.4. Cluster 4: Supply Chain Risk Management in COVID-19

Supply chain risk management has never appeared more important than today when global supply chains have been disrupted so heavily by the COVID-19 pandemic. The COVID-19 crisis has shown the risks to global supply chains that are focused solely on efficiency while revealing how localization and redundancy in sourcing can reduce risk [55]. Collaboration with key supply chain members in sharing information, ideas, and response strategies is immensely helpful in supply chain risk management [41,60–62]. Interorganizational collaboration is always required in order to handle diverse risks, regardless of the type of organization [63]. Supply chain risk management practices have been found to mediate the relationships between the disruptions' impacts and supply chain resilience and robustness [9]. Risk mitigation is one of the common strategies used to address resilience [64]. The resilience of a supply chain's networks to an epidemic outbreak's risks is a significant predictor of corporate sales growth [65] and the fit between information processing capacities and requirements enhances supply chain risk management capabilities, which, in turn, results in enhanced supply chain resilience [66].

a.   Understanding and Assessing Supply Chain Risks

Firms that analyze their networks to identify sources of risks can better withstand disruptive effects and recover more quickly. When knowledge about risks is shared early, risk management can be more effective [39]. However, many executives avoid sharing bad news related to those risks with their teams. Risk analysis should be used where possible to help prepare for, and prevent, the consequences of foreseeable events. Categorizing and analyzing risks, in addition to understanding the effects of information sharing on visibility throughout the supply chain, can help firms to reduce supply chain vulnerability and improve supply chain resilience. During the COVID-19 pandemic, it was found that the

magnitude of the impact of disruption risks on supply chain performance was greater on the upstream side of the supply chain than on the downstream side of the supply chain [67].

b.   Decision-Making Challenges

During the COVID-19 pandemic, sudden fluctuations in demand have created ambiguity and uncertainty for supply chains, affecting both forecasting and decision-making. Visibility and velocity are the two key elements for critical decision-making accuracy, since both increase the ability of the decision-makers [68]. Visibility might be open-source COVID-19 data, real-time supply chain data, or demand change per region or country, required for considering the opportunities and drawbacks of each decision. In addition, information technology and operations research models play a critical role in supporting the decision-making process [69]. There are numerous decision support tools, such as simulation models to examine the implications of various pandemic supply, risk mitigation measures and potential recovery paths [11], nonlinear programming models to guide manufacturers in developing an optimal recovery plan [6], or a digital supply chain twin—a computerized digital supply chain model that represents the network's state at any given moment in real-time [8].

c.   Mitigating Supply Chain Risks

Traditional risk management focuses on planning and reducing vulnerabilities. For a sustainable future, the focus should be on understanding risks and preparing for them through adaptation and mitigation measures. When firms achieve high risk management capabilities, they can effectively minimize their supply chain risks and ensure continuity during severe disruptions, such as the COVID-19 pandemic. Collaborative management, proactive business continuity planning, and financial sustainability are the three most effective strategies to mitigate risks [61]. The rest include digital and technological transformation, central response teams, enhanced transparency, information management, flexible business models, and training and communication [61]. Reshoring is one supply chain risk management technique that has been suggested in the literature [41], but it can be relatively complex and requires long-term decision-making and implementation. Alternative risk management techniques could include supplier collaboration in the short-to-medium term [41]. Establishing supply chain risk management is necessary because it helps firms to orient their investments to allow their supply chain to be more responsive to disruptions.

4. Discussion

The COVID-19 pandemic is an extreme example of force majeure, creating supply chain disruptions that push firms to develop resilient capabilities to reduce their impact. Firms' survival and growth in turbulent periods have become more important. Disruptions are the manifestations of supply chain risks that first force companies to react to the disruption and then require firms to develop new resources, solutions, and capabilities to survive. Risk management could be a prerequisite to ensure supply chain robustness, but it has proved not to be sufficient when facing unforeseen crises such as COVID-19. Reducing supply chain vulnerability could be one way to enhance resilience. In a proactive approach, firms can have well-established supply chain risk management to reduce vulnerability. However, in enhancing supply chain resilience or initiating supply chain viability, the focus is upon a more reactive approach. Building relevant capabilities is more coherent than reducing vulnerabilities when supply chain resilience is addressed but the two still have to go hand in hand. While most essential elements for supply chain resilience such as flexibility, agility, visibility, or risk management culture have been thoroughly studied in past research, the connections to reach those capabilities are still fragmented. There are numerous enablers, approaches, practices, or strategies introduced to improve supply chain resilience, especially during the COVID-19 pandemic. They include, for example, using technology to enhance visibility, flexibility, or decision-making. Nevertheless, the lack of clarity refers to the common layer of those initiatives as they could be the macro layer from the planning level, the meso layer from the architectural level, or the micro layer from the

implementation level. Considering initiatives from all layers without expressing them with the connection in between layers, the concept of resilience will not be unified and will be difficult to adopt. Starting the exploration with the level clearly in mind, the consolidation of the supply resilience concept will be within reach for both scholars and practitioners.

The analysis of the four clusters identified a number of opportunities for future studies. These opportunities are intended not to just address the immediate impacts of COVID-19, but the underlying weaknesses that the COVID-19 pandemic has exposed in supply chain management.

4.1. Impact of the COVID-19 Pandemic on Supply Chains

The most prominent issue for future research in Cluster 1 is the long-term effect of COVID-19 on sustainability and what the pandemic implies for supply chain sustainability. Several of the studies reviewed have addressed the most immediately obvious impacts of the pandemic in terms of supply chain sustainability, including social, environmental, and economic sustainability impacts. Overall, these studies have shown a negative impact on sustainability and raised the possibility of losing progress on long-term sustainability initiatives and movements. Furthermore, the studies have revealed that there could also be negative effects on economic performance that persist across entire supply chains, not just in individual firms. Thus, firms require a monitoring system for following the long-term impacts of systemic shocks to supply chain environmental and social sustainability, along with financial performance.

4.2. Improving Supply Chain Resilience for Viability

Research into resilience to the shocks and disruptions caused by the COVID-19 pandemic has determined that the supply chain management literature was significantly underdeveloped, only considering the effects of pandemics in very limited situations. The research into supply chain resilience during COVID-19 has shown that this limited perspective was entirely inadequate to deal with the scale and scope of the challenges that a pandemic poses for supply chains, especially globalized supply chains, perishable supply chains, and those that are still developing. This calls for much more robust research into supply chain resilience from a broader and more global perspective, to understand both supply chain needs and how to navigate the problems that have become apparent. Thus, the integration of supply chain resilience with systemic risk is a central concern for supply chain management moving forward. Furthermore, the interrelated and similar concepts of supply chain resilience and supply chain viability require differentiation. Recovery to an original state is highly connected with resilience, but not with viability. With viability, adaptation to the new situation is the greater concern. In a world of more frequent disruptions, recovery might not always be the best option.

Based on the rich and impactful research into this area found in this review, viable supply chains could be a better option and might be the only option to survive. Mainstream research has therefore now shifted from supply chain resilience to the more adaptable concept of supply chain viability. Bridging the gap between supply chain resilience and supply chain viability is still an evolving process. The underlying capabilities of supply chain viability and the strategies underlying this concept that are used to deal with disruptions are still in the realm of the unknown and waiting for scholars to explore them.

4.3. Technology and Innovation for Supply Chain Sustainability

Much of the research on digital technology had been focused on technologies like additive manufacturing, AI, 3D printing, and big data analytics, all of which have possible applicability to enhancing supply chain management practices. However, what is far less clear is the extent to which firms are actually ready to implement these technologies for supply chain management practices. This raises questions such as: How expensive is it to implement these technologies? What resources and capabilities are required to implement them? To what extent do they actually improve the performance of a supply chain, both

under and outside normal operations? Thus, technologies and innovations should be assessed to determine their capacity for implementation over both the short term and long term and to evaluate whether they can be considered a feasible solution to systemic threats to supply chain resilience and stability.

4.4. Supply Chain Risk Management in COVID-19

In the final cluster, it was revealed that there are likely to be some long-term implications of the COVID-19 pandemic for supply chain resilience and risk management, which could have significant impacts on how firms manage risk. However, suggestions for improving risk management, such as reshoring and supplier collaboration, are very limited. Thus, an opportunity exists for further research into the development of better strategies for supply chain risk management to deal with pandemic risks or other systemic risks that have not yet been anticipated. Risk management is central to the study and practice of supply chain management and sustainable, resilient supply chains. It should therefore be explored both in the short term and in the long term to develop new tools, strategies, and approaches to promote its active and effective use.

5. Conclusions and Recommendations

This research set out to conduct a bibliometric review of the supply chain management literature related to the global COVID-19 pandemic. We investigated the current state of supply chain research during COVID-19 related to performance and network analysis. This study also offered research questions and directions for further investigation based on a co-word network analysis. Speaking of the supply chain literature and COVID-19, the statistical results provided a deeper understanding of the contributions of the most prolific scholars in the field and will assist other researchers seeking to build on their work by helping them to choose and follow a line of inquiry. Ivanov is the most prolific and cited researcher in this genre, and has primarily focused on the short- and long-term impacts of epidemic outbreaks on global supply chains and the resilience of interconnected supply networks. One of the key benefits of Ivanov's work has been identifying the various elements related to risk preparedness, mitigation, and recovery policies. The US has accounted for about a quarter of all documents in the sample and there are a pronounced number of cross-continental collaborations among authors from the US, Europe, Asia, Africa, and Australia.

More importantly, the results of the co-word network revealed the evolution of the keywords associated with articles over time. The analysis revealed four related clusters of studies addressing topics such as the impacts of COVID-19 on firms and supply chains, supply chain resilience and possibilities for recovery, the use of digital technology to mitigate the impacts of the pandemic, and the role of supply chain risk management in dealing with the COVID-19 pandemic. What this analysis exposed, above all else, is that neither supply chain management as a discipline nor supply chains in practice were ready for a global pandemic. In fact, it is unclear whether the risk of a pandemic was ever taken seriously either in theory or practice, and the COVID-19 pandemic has highlighted the weaknesses of the approaches that were used. This lack of preparedness has had significant effects on supply chains in high-income industrial economies around the world, and to an even greater extent in developing economies. The COVID-19 pandemic may have enduring effects on supply chain sustainability and resilience, which should be monitored following the research strategies outlined in Section 4. This also has implications for the academic discipline of supply chain management, which, like professional practice, has not taken sufficient notice of the risks of pandemics as a serious challenge to supply chain sustainability and resilience. Such weaknesses need to be addressed at multiple levels in order to improve global supply chain performance, especially under conditions of systemic stress.

The review suggests that global supply chains—even the supply chains of large companies—are far more fragile than anticipated in the face of a global pandemic. This

suggests that although supply chains may have been designed to mitigate specific risks, they were not actually designed to address systemic risks in a meaningful way. The result of this is that global supply chains have proved to be highly vulnerable to conditions such as lockdowns, labor shortages, and disruptions in the activities of, and relationships with, suppliers and logistics firms. Overall, there could be significant impacts on sustainability goals, particularly environmental and social sustainability goals. Consequently, this literature review strongly suggests that there is a need for firms to invest in developing more resilient supply chains that can address pandemic risks, rather than either ignoring pandemic risks or assuming that a pandemic would have a geographically limited impact. Firms need to take the risk of any potential future pandemics seriously in their supply chain planning, which is probably an obvious insight by this point in the COVID-19 pandemic. Perhaps, more importantly, it is critical that firms put more effort into building resilience and risk management into their supply chain planning to address long-term risks. In conclusion, the bibliometric analysis of academic writing on supply chain management in the COVID-19 pandemic has ascertained that pandemic risk is not just an isolated problem, as it has been treated in the past. Instead, pandemic risk, and all it entails, is a systemic weakness that needs to be addressed at the level of the supply chain management field.

Some limitations to this study exist. First, the review process used only articles and review papers, whereas future studies could also focus on related books and book chapters to extend the range of the data. Second, this study captured the evolution of research in the early stages of the pandemic. Future studies are suggested to cover longer periods of time as the COVID-19 pandemic is ongoing and firms have become more adaptable to the crisis.

Author Contributions: Conceptualization, K.S., P.L., N.A., S.B.-i.; methodology, K.S., P.L. and N.A.; writing—original draft preparation, K.S., P.L. and N.A.; writing—review and editing, K.S., P.L., N.A., S.B.-i.; project administration, K.S. and N.A. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hosseini, S.; Ivanov, D. A multi-layer Bayesian network method for supply chain disruption modelling in the wake of the COVID-19 pandemic. *Int. J. Prod. Econ.* **2021**, 1–19. [CrossRef]
2. Kim, K.; Kim, S.; Park, C.-Y. Food Security in Asia and the Pacific amid the COVID-19 Pandemic. *ADB Briefs* **2020**. [CrossRef]
3. Lin, B.-X.; Zhang, Y.Y. Impact of the COVID-19 pandemic on agricultural exports. *J. Integr. Agric.* **2020**, *19*, 2937–2945. [CrossRef]
4. Ho, W.; Zheng, T.; Yildiz, H.; Talluri, S. Supply chain risk management: A literature review. *Int. J. Prod. Econ.* **2015**, *53*, 5031–5069. [CrossRef]
5. Singh, S.; Kumar, R.; Panchal, R.; Tiwari, M.K. Impact of COVID-19 on logistics systems and disruptions in food supply chain. *Int. J. Prod. Econ.* **2021**, *59*, 1993–2008. [CrossRef]
6. Chowdhury, M.; Sarkar, A.; Paul, S.K.; Moktadir, M. A case study on strategies to deal with the impacts of COVID-19 pandemic in the food and beverage industry. *Oper. Manag. Res.* **2020**, 1–13. [CrossRef]
7. Sharma, A.; Adhikary, A.; Borah, S.B. COVID-19's impact on supply chain decisions: Strategic insights from NASDAQ 100 firms using Twitter data. *J. Bus. Res.* **2020**, *117*, 443–449. [CrossRef]
8. Ivanov, D.; Dolgui, A. OR-methods for coping with the ripple effect in supply chains during COVID-19 pandemic: Managerial insights and research implications. *Int. J. Prod. Econ.* **2021**, *232*, 107921. [CrossRef]
9. El Baz, J.; Ruel, S. Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *Int. J. Prod. Econ.* **2021**, *233*, 107972. [CrossRef]

10. Gupta, V.; Ivanov, D.; Choi, T.-M. Competitive pricing of substitute products under supply disruption. *Omega* **2021**, *101*, 102279. [CrossRef]

11. Ivanov, D.; Das, A. Coronavirus (COVID-19/SARS-CoV-2) and supply chain resilience: A research note. *Int. J. Integr. Supply Manag.* **2020**, *13*, 90–102. [CrossRef]

12. Ruel, S.; El Baz, J.; Ivanov, D.; Das, A. Supply chain viability: Conceptualization, measurement, and nomological validation. *Ann. Oper. Res.* **2021**, 1–30. [CrossRef]

13. Zhang, Z.J.; Srivastava, P.R.; Eachempati, P.; Yu, Y. An intelligent framework for analyzing supply chain resilience of firms in China: A hybrid multicriteria approach. *Int. J. Logist. Manag.* **2021**. [CrossRef]

14. Khan, S.A.R.; Razzaq, A.; Yu, Z.; Shah, A.; Sharif, A.; Janjua, L. Disruption in food supply chain and undernourishment challenges: An empirical study in the context of Asian countries. *Socio-Econ. Plan. Sci.* **2021**, 101033. [CrossRef]

15. Mor, R.S.; Srivastava, P.P.; Jain, R.; Varshney, S.; Goyal, V. Managing Food Supply Chains Post COVID-19: A Perspective. *Int. J. Supply Oper. Manag.* **2020**, *7*, 295–298.

16. Yu, Z.; Razzaq, A.; Rehman, A.; Shah, A.; Jameel, K.; Mor, R.S. Disruption in global supply chain and socio-economic shocks: A lesson from COVID-19 for sustainable production and consumption. *Oper. Manag. Res.* **2021**, 1–16. [CrossRef]

17. Alam, S.T.; Ahmed, S.; Ali, S.M.; Sarker, S.; Kabir, G. Challenges to COVID-19 vaccine supply chain: Implications for sustainable development goals. *Int. J. Prod. Econ.* **2021**, *239*, 108193. [CrossRef]

18. Chowdhury, P.; Paul, S.K.; Kaisar, S.; Moktadir, M.A. COVID-19 pandemic related supply chain studies: A systematic review. *Transp. Res. Part E Logist. Transp. Rev.* **2021**, *148*, 102271. [CrossRef]

19. Pujawan, I.N.; Bah, A.U. Supply chains under COVID-19 disruptions: Literature review and research agenda. *Supply Chain. Forum: Int. J.* **2022**, *23*, 81–95. [CrossRef]

20. Spieske, A.; Birkel, H. Improving supply chain resilience through industry 4.0: A systematic literature review under the impressions of the COVID-19 pandemic. *Comput. Ind. Eng.* **2021**, *158*, 107452. [CrossRef]

21. Govindan, K.; Mina, H.; Alavi, B. A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19). *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *138*, 101967. [CrossRef] [PubMed]

22. Cordeiro, M.C.; Santos, L.; Angelo, A.C.M.; Marujo, L.G. Research directions for supply chain management in facing pandemics: An assessment based on bibliometric analysis and systematic literature review. *Int. J. Logist. Res. Appl.* **2021**, 1–21. [CrossRef]

23. Swanson, D.; Santamaria, L. Pandemic supply chain research: A structured literature review and bibliometric network analysis. *Logistics* **2021**, *5*, 7. [CrossRef]

24. Xu, S.; Zhang, X.; Feng, L.; Yang, W. Disruption risks in supply chain management: A literature review based on bibliometric analysis. *Int. J. Prod. Res.* **2020**, *58*, 3508–3526. [CrossRef]

25. Ferreira, J.J.M.; Fernandes, C.I.; Ratten, V. A co-citation bibliometric analysis of strategic management research. *Scientometrics* **2016**, *109*, 1–32. [CrossRef]

26. Van Eck, N.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef]

27. Ivanov, D. Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *136*, 101922. [CrossRef]

28. Ivanov, D.; Dolgui, A. Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *Int. J. Prod. Res.* **2020**, *58*, 2904–2915. [CrossRef]

29. Ivanov, D. Viable supply chain model: Integrating agility, resilience and sustainability perspectives—Lessons from and thinking beyond the COVID-19 pandemic. *Ann. Oper. Res.* **2020**, 1–21. [CrossRef]

30. Guan, D.; Wang, D.; Hallegatte, S.; Davis, S.J.; Huo, J.; Li, S.; Bai, Y.; Lei, T.; Xue, Q.; Coffman, D.; et al. Global supply-chain effects of COVID-19 control measures. *Nat. Hum. Behav.* **2020**, *4*, 577–587. [CrossRef]

31. Ivanov, D.; Dolgui, A. A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Prod. Plan. Control* **2021**, *32*, 775–788. [CrossRef]

32. Remko, V.H. Research opportunities for a more resilient post-COVID-19 supply chain closing the gap between research findings and industry practice. *Int. J. Oper. Prod. Manag.* **2020**, *40*, 341–355. [CrossRef]

33. Meyer, B.H.; Prescott, B.; Sheng, X.S. The impact of the COVID-19 pandemic on business expectations. *Int. J. Forecast.* **2022**, *38*, 529–544. [CrossRef] [PubMed]

34. Dorcheh, F.R.; Hajiagha, S.H.R.; Rahbari, M.; Jafari-Sadeghi, V.; Mahdiraji, H.A. Identification, analysis and improvement of red meat supply chain strategies considering the impact of COVID-19 pandemic: A hybrid SWOT-QSPM approach in an emerging economy. *Br. Food J.* **2021**, *123*, 4194–4223. [CrossRef]

35. Trivedi, S.; Negi, S.; Anand, N. Impact of COVID-19 on agriculture supply chain in India and the proposed solutions. *Int. J. Sustain. Agric. Manag. Inform.* **2020**, *6*, 359–380. [CrossRef]

36. Chen, Z.; Tan, A. Exploring the circular supply chain to reduce plastic waste in Singapore. *LogForum* **2021**, *17*, 271–286.

37. Qin, X.; Godil, D.I.; Khan, M.K.; Sarwat, S.; Alam, S.; Janjua, L. Investigating the effects of COVID-19 and public health expenditure on global supply chain operations: An empirical study. *Oper. Manag. Res.* **2021**, 1–13. [CrossRef]

38. Ivanov, D.; Dolgui, A. Stress testing supply chains and creating viable ecosystems. *Oper. Manag. Res.* **2021**, 1–12. [CrossRef]

39. Sharma, S.K.; Srivastava, P.R.; Kumar, A.; Jindal, A.; Gupta, S. Supply chain vulnerability assessment for manufacturing industry. *Ann. Oper. Res.* **2021**, 1–31. [CrossRef]

40. Wieland, A.; Wallenburg, C.M. The influence of relational competencies on supply chain resilience: A relational view. *Int. J. Phys. Distrib. Logist.* **2013**, *43*, 300–320. [CrossRef]

41. Van Hoek, R.; Dobrzykowski, D. Towards more balanced sourcing strategies—Are supply chain risks caused by the COVID-19 pandemic driving reshoring considerations? *Supply Chain Manag.* **2021**, *26*, 689–701. [CrossRef]

42. Paul, S.K.; Chowdhury, P. Strategies for managing the impacts of disruptions during COVID-19: An example of toilet paper. *Glob. J. Flex. Syst. Manag.* **2020**, *21*, 283–293. [CrossRef]

43. Chowdhury, M.M.H.; Quaddus, M. Supply chain resilience: Conceptualization and scale development using dynamic capability theory. *Int. J. Prod. Econ.* **2017**, *188*, 185–204. [CrossRef]

44. Paul, S.K.; Chowdhury, P. A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *Int. J. Phys. Distrib. Logist. Manag.* **2020**, *51*, 104–125. [CrossRef]

45. Ivanov, D.; Dolgui, A.; Sokolov, B. The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. *Int. J. Prod. Res.* **2019**, *57*, 829–846. [CrossRef]

46. Taleb, N. *Things that Gain from Disorder*; Random House & Penguin: New York City, NY, USA, 2012.

47. Gurbuz, I.B.; Ozkan, G. Transform or perish: Preparing the business for a postpandemic future. *IEEE Eng. Manag. Rev.* **2020**, *48*, 139–145. [CrossRef]

48. Alikhani, R.; Torabi, S.A.; Altay, N. Retail supply chain network design with concurrent resilience capabilities. *Int. J. Prod. Econ.* **2021**, *234*, 108042. [CrossRef]

49. Nandi, S.; Sarkis, J.; Hervani, A.; Helms, M. Do blockchain and circular economy practices improve post COVID-19 supply chains? A resource-based and resource dependence perspective. *Ind. Manag. Data Syst.* **2020**, *121*, 333–363. [CrossRef]

50. Doan, K.; Carrino, S.; Ivanova, N.; Evtodieva, T. Digital economy and intelligent supply chain management: International experience. In *Current Achievements, Challenges and Digital Chances of Knowledge Based Economy*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 743–751.

51. Belhadi, A.; Mani, V.; Kamble, S.S.; Khan, S.A.R.; Verma, S. Artificial intelligence-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism: An empirical investigation. *Ann. Oper. Res.* **2021**, 1–26. [CrossRef]

52. Yu, W.; Zhao, G.; Liu, Q.; Song, Y. Role of big data analytics capability in developing integrated hospital supply chains and operational flexibility: An organizational information processing theory perspective. *Technol. Forecast. Soc. Chang.* **2021**, *163*, 120417. [CrossRef]

53. Koshta, N.; Devi, Y.; Patra, S. Aerial bots in the supply chain: A new ally to combat COVID-19. *Technol. Soc.* **2021**, *66*, 101646. [CrossRef] [PubMed]

54. Elkington, J. Enter the Triple Bottom Line. In *The Triple Bottom Line*; Routledge: London, UK, 2013.

55. Sarkis, J. Supply chain sustainability: Learning from the COVID-19 pandemic. *Int. J. Oper. Prod. Manag.* **2020**, *41*, 63–73. [CrossRef]

56. Villena, V.H.; Gioia, D.A. A more sustainable supply chain. *Harv. Bus. Rev.* **2020**, *98*, 84–93.

57. Trautrims, A.; Schleper, M.C.; Cakir, M.S.; Gold, S. Survival at the expense of the weakest? Managing modern slavery risks in supply chains during COVID-19. *J. Risk Res.* **2020**, *23*, 1067–1072. [CrossRef]

58. López-Santos, Y.; Sánchez-Partida, D.; Cano-Olivos, P. Strategic model to assess the sustainability and competitiveness of focal agri-food smes and their supply chains: A vision beyond COVID 19. *Adv. Sci. Technol. Eng. Syst.* **2020**, *5*, 1214–1224. [CrossRef]

59. Zhang, F.; Wu, X.; Tang, C.S.; Feng, T.; Dai, Y. Evolution of operations management research: From managing flows to building capabilities. *Prod. Oper. Manag.* **2020**, *29*, 2219–2229. [CrossRef]

60. Friday, D.; Savage, D.A.; Melnyk, S.A.; Harrison, N.; Ryan, S.; Wechtler, H. A collaborative approach to maintaining optimal inventory and mitigating stockout risks during a pandemic: Capabilities for enabling health-care supply chain resilience. *J. Humanit. Logist. Supply Chain Manag.* **2021**, *11*, 248–271. [CrossRef]

61. Kumar, A.; Mangla, S.K.; Kumar, P.; Song, M. Mitigate risks in perishable food supply chains: Learning from COVID-19. *Technol. Forecast. Soc. Chang.* **2021**, *166*, 120643. [CrossRef]

62. Sharma, R.; Shishodia, A.; Kamble, S.; Gunasekaran, A.; Belhadi, A. Agriculture supply chain risks and COVID-19: Mitigation strategies and implications for the practitioners. *Int. J. Logist. Res. Appl.* **2020**, 1–27. [CrossRef]

63. Ahlqvist, V.; Norrman, A.; Jahre, M. Supply chain risk governance: Towards a conceptual multi-level framework. *Oper. Supply Chain Manag.* **2020**, *13*, 382–395. [CrossRef]

64. Dohale, V.; Ambilkar, P.; Gunasekaran, A.; Verma, P. Supply chain risk mitigation strategies during COVID-19: Exploratory cases of "make-to-order" handloom saree apparel industries. *Int. J. Phys. Distrib. Logist. Manag.* **2021**, *52*, 109–129. [CrossRef]

65. Mertzanis, C. Epidemiological Susceptibility Risk, Adaptive Management and Firm Performance. *Br. J. Manag.* **2021**, *32*, 1242–1264. [CrossRef]

66. Yang, J.; Xie, H.; Yu, G.; Liu, M. Antecedents and consequences of supply chain risk management capabilities: An investigation in the post-coronavirus crisis. *Int. J. Prod. Res.* **2021**, *59*, 1573–1585. [CrossRef]

67. Parast, M.M.; Subramanian, N. An examination of the effect of supply chain disruption risk drivers on organizational performance: Evidence from Chinese supply chains. *Supply Chain Manag.* **2021**, *26*, 548–562. [CrossRef]

68. Finkenstadt, D.J.; Handfield, R. Blurry vision: Supply chain visibility for personal protective equipment during COVID-19. *J. Purch. Supply Manag.* **2021**, *27*, 100689. [CrossRef]
69. Nikolopoulos, K.; Punia, S.; Schäfers, A.; Tsinopoulos, C.; Vasilakis, C. Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions. *Eur. J. Oper. Res.* **2021**, *290*, 99–115. [CrossRef]