Sustainable Supply Chain and its Risk Management: A Systematic Literature Review of Issues and Trends using a Bibliometric and Network Approach

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***Abstract*— The risks associated with sustainable supply chains (SSCs) have been receiving increasing attention. However, despite increasing research on SSCs, SSC-related risks have not been reviewed satisfactorily or comprehensively. Therefore, we conducted a systematic literature review incorporating bibliometric, citation network, and keyword network analysis. For this purpose, we selected the top journals in supply chain management and identified 823 related papers in the Scopus database. The analysis revealed the critical issues, topics, and changes over time in research regarding SSC-related risks. Furthermore, we identified specific issues and explored SSC risks via keyword network analysis.**

***Keywords*—** *Sustainable supply chain risks, Systematic literature review, Citation analysis, Keyword network analysis*

1. Introduction

In the last 20 years, supply chain management (SCM) has been gaining popularity as a source of competitive advantage in business [33], [36]. Existing supply chain literature attributes the increased attention toward sustainable supply chains (SSCs) to the rising awareness of environmental and social issues [36], [50], [54]. Traditional SCM focuses on financial business performance, whereas sustainable supply chain management (SSCM) primarily addresses the explicit integration of social and environmental objectives with economic growth [40], [41], [49], [52], [53], [60]. SSCM contributes to improved company performance due to its potential to reduce firms' exposure to certain types of risk.

SSC risks are relatively different from traditional supply chain risks since, for the former, firms focus on not only economic risks but also social and environmental issues [37]; [40], [53], [62]. In other words, SSC risks range from environmental issues such as the extinction of certain primates in the palm oil supply chain to unethical issues such as the unscrupulous treatment of workers in sweatshop manufacturing [18], which can damage a firm's reputation. External stakeholders, both within and outside the supply chain, can exert an impact on firms in terms of their social and environmental impact [55]. Negative impacts, such as severe pollution or unethical working practices, may damage companies' reputational, even if the SSC risks arise in the supply chain and not within the focal company itself [31]. Consequently, companies are exposed to an increased risk profile [28], [29]. In this context, it is critical to understand the sustainability-related risks that exist within supply chains.

However, despite increasing research on SSC, SSC-related risks have not been reviewed satisfactorily. Sustainability and SSC are broad topics that influence various business dimensions; therefore, a review of previous studies regarding SSC risks is necessary. In particular, we sought to identify the most influential studies as well as broad and specific issues related to SSC risks and explore the directions of this research area through a systematic literature review. We rigorously identified influential papers using not only citation frequency but also the degree of prestige assigned to these papers on PageRank. Additionally, the current study has a more advanced methodology

compared to previous studies, which only used citation frequency to assess the importance of papers.

2. Literature review

2.1 SSCs and associated risks

SSCs serve as critical managerial tools for firms' continuous growth and development to ensure their success in a volatile business environment [22], [31], [24], [56]. SSCs have three main sustainability dimensions: social, environmental, and economic dimensions. These dimensions also serve as criteria to evaluate SSC performance [37], [40], [53], [6]. SSCM is commonly defined as "the explicit integration of the environmental and social goals into economic development" [53]. These elements are closely related, and according to previous SSCM research, the terms "sustainability" and "environment" were used interchangeably in early conceptualizations of business sustainability [8]. Additionally, [1], defined SSCM as "The creation of well-coordinated supply chains by the active integration and equilibrium of economic, environmental, and social considerations with critical inter-organizational business process planned to conduct the material, information, and capital flows related to the procurement, production, and distribution of products or services to satisfy stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term."

Given the short- and long-term strategic and operational advantages of SSCM, understanding the risks associated with SSCM is essential. The more operations managers are aware of these risks, and the more secure a company's SSC will be. Compared with traditional supply chains, SSCs pose additional risks and tasks for organizations [5], including issues affecting the natural ecosystem, a company's reputation, financial statements, adherence to rules and regulations [24], and corporate social responsibility [45], [46]. These findings indicate that organizations may not have previously considered the risks to SSCs that mainly emanate from the social and environmental dimensions.

2.2 Systematic literature review of SSC-risk research

It is necessary to identify the themes in a given field to improve our understanding and stimulate further research. Scholars can identify potential research gaps by using literature reviews to map and evaluate the body of literature in a given field [57].

Researchers have adopted various perspectives when reviewing SSC-related literature. One particular view is a popularity-based approach known as the bibliometrics method. It analyzes the titles, authors, and keywords of studies from various research fields utilizing data mining tools. Specifically, a bibliometric analysis can give insights not obtained by other review studies regarding the primary authors, major journals, and reputation of reviewed papers based on the frequency of their occurrence in literature [44]. Therefore, we performed a bibliometric analysis to uncover hidden insights regarding supply chain risks [20] and SSCs [21]. However, although the frequency of occurrence of titles and keywords could measure their prestige and importance, it is difficult to account for redundancy [44]. Furthermore, previous studies that adopted a popular-based approach may not provide comprehensive insights from the perspective of SSC risks [44].

Another method is the network-based approach that is used to analyze network structures by mapping and visualizing citations and keywords. This approach includes citation [10] and co-citation analyses [35]. A co-citation network comprises a set of nodes that represent journal articles and links that indicate the co-occurrence of the nodes (articles) in other papers [35]. When two publications appear together in the references of other papers, the two publications are considered to be co-cited [20]. However, although network-based approaches determine the main issues and classify group topics in a field, it is difficult to identify both broad and specific content in a given area using these issues/topics. Therefore, we included relevant keywords not captured in the network to identify these issues comprehensively.

Given this gap in existing literature, we utilized a systematic literature review methodology [55] combined with bibliometric and network analysis

to evaluate SSC risks comprehensively. We aimed to identify the most influential studies and authors related to SSC risks and provide valuable insights for future research. More specifically, we utilized the keyword network approach to reveal both broad and specific published content related to SSC risks.

Table 1. The proposed three-level keywords assembly structure.

Level	Assembly structure	Search keywords
1	Context keyword	Supply Chain
2	Sustainable supply chain	Green AND Supply Chain
		Environmental AND Sustainable AND Supply Chain
		Environmental AND Sustainability AND Supply Chain
		Ecological AND Supply Chain
3	Risk/uncertainty keywords	Risk OR Uncertain OR Uncertainty OR Flexible OR Flexibility OR Robust OR Robustness OR Agile OR Agility OR Resilient OR Resiliency OR Resilience OR Vulnerable OR Vulnerability OR Disruption OR Interruption OR Variation OR Volatile OR Volatility OR Fluctuate OR Fluctuation

Source: [20], [21]

3. Data collection

Systematic literature reviews are typically structured and conducted through an iterative process of defining appropriate keywords, selecting related literature, and conducting appropriate analyses [51].

Previous studies suggest that SSC-related issues are strongly linked to supply risks [22]. Based on previous related research, SSC risks comprise two disciplinary areas: SSCs and SCM risks. Thus, this study utilized three search strings to ensure that both these research areas are fully captured by the keywords (Table 1). We designed a three-level assembly structure to accommodate a broad range of search keywords [20], [21]. Table 1 shows the assembly structure: Level one outlines the search context, levels two and three contain SSC-related keywords and SCM-risk-related keywords, respectively.

Using the "title, abstract, keywords" search in the Scopus database to identify the most reputable international journals, we collected papers using the above keywords (Table 1). We reduced the scope of the search only to include English-language journal papers. Moreover, "Conference papers, book series, commercial publications, and magazine articles were excluded" [44]. The initial search attempt generated 1,043 papers from 51 journals. To select the most influential articles, we further limited the raw data set to 823 papers using the recent five-year average impact factor of 3.0 from the Journal of Citation Reports (JCR)[1].

Fig. 1 shows the publishing trend in SSC-risk papers between 1974 and 2018. The number of articles published annually since 2000 demonstrates a rising trend. By 2003, the top 10 journals had published 515 articles, approximately 62.58%.

4. Network-based analysis

4.1 Network analysis

To identify the most influential papers and keywords to provide further insights into the current study, we adopted a bibliometric and network-based approach using NetMiner tools. This approach comprised two steps, as shown in Table 2.

4.1.1 Citation analysis

(a) PageRank analysis

[1] https://www.scimagojr.com/

We selected 823 papers to construct a network. Moreover, we examined the associations between the extracted keywords to obtain further valuable insights and to understand the academic structure and research trends regarding SSC risks.

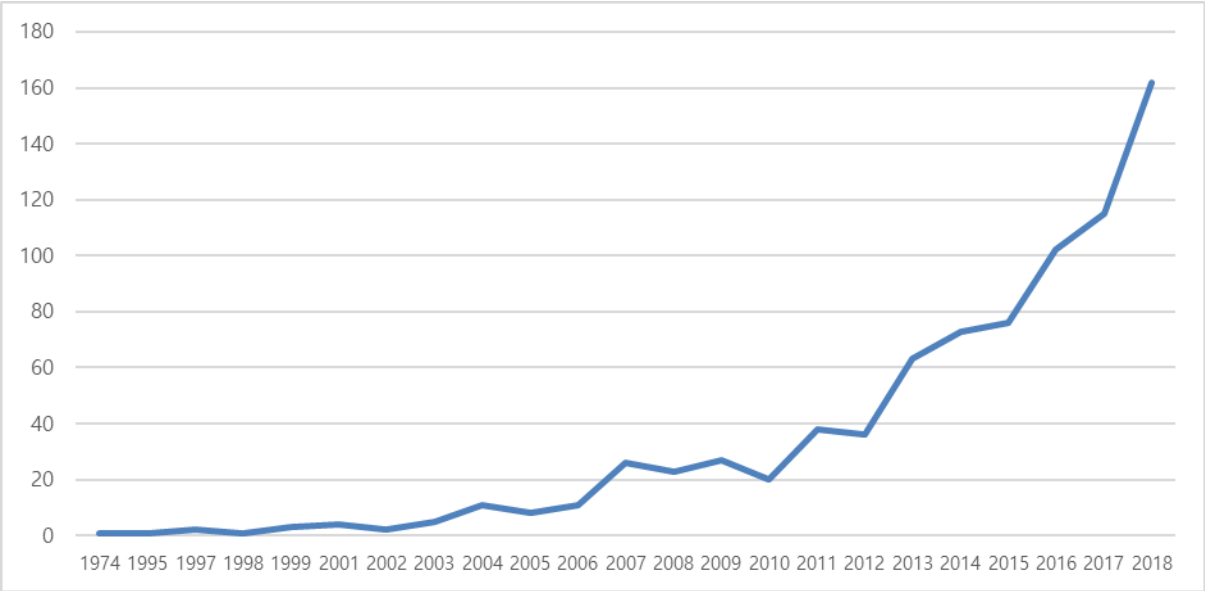

Figure 1. The publishing trend in SSC risk (n = 823)

Table 2. The overall process of the proposed network-based analysis

4.1. Network analysis	4.1.1. Citation analysis	(a) PageRank analysis
	4.1.2. Co-citation analysis	(a) Clustering analysis
		(b) Dynamic clustering analysis
4.2. Topical sub-network analysis	4.2.1. Keyword network analysis	(a) Keyword network structure analysis (density, average distance, clustering coefficient)
		(b) Keyword network centrality analysis (degree, betweenness, closeness)
		(c) Keyword network centrality analysis by year (1997–2016 vs. 2017–2018)

Source: [32]

Citation analysis has received increasing attention due to its usefulness in objectively identifying influential papers in a specific area [16], [26]. This methodology assesses the popularity of a publication by counting the number of times it is cited in other publications [15]. Citation frequency, therefore, indicates the significance of an article. Table 3 shows the top nine papers in terms of citation frequency. "Local citation" indicates how many other papers have cited an article within the 823-node network, meaning that 212 papers have cited others [20], [21].

[7] introduced PageRank, an algorithm-based application that prioritizes web pages when performing a keyword search on the Google Search engine. Since citations from other highly cited papers greatly influence PageRank, newer publications are typically at a disadvantage. It is because they have not had sufficient time to be cited by other highly cited articles. PageRank will likely provide better insights into the overall reputation of published papers if the research area matures and stabilizes [20], [21].

Table 3. Top 9 papers by citation frequency and PageRank position

Local citations			
No.	**Author (year)**	**Title of selected papers**	**PageRank**
1	Seuring and Müller (2008)	From a literature review to a conceptual framework for sustainable supply chain management	0.027120
2	Angell and Klassen (1999)	Integrating environmental issues into the mainstream: An agenda for research in operations management	0.017414
3	Matos and Hall (2007)	Integrating sustainable development in the supply chain: The case of life cycle assessment in oil and gas and agricultural biotechnology	0.016917
4	Vickery et al. (1999)	Supply Chain Flexibility: An Empirical Study	0.013089
5	Cousins et al. (2004)	The role of risk in environment-related supplier initiatives	0.012804
6	Vachon and Klassen (2006)	Green project partnership in the supply chain: The case of the package printing industry	0.008479
7	Ahi and Searcy (2013)	A comparative literature analysis of definitions for green and sustainable supply chain management	0.004953
8	Govindan et al. (2013)	A fuzzy multi-criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach	0.004586
9	Wu and Pagell (2011)	Balancing priorities: Decision-making in sustainable supply chain management	0.004543

(Note: Local citations were obtained from the 823 papers).

Furthermore, we created four main categories for local citations. The first category included studies that summarized the SSC concept. For example, [53] reviewed 191 papers published from 1994 to 2007 and offered a conceptual framework, summarizing studies regarding supplier relationship management regarding supply chain performance and associated risks. [2] focused on environmental operations management, aiming to provide a summary of operations management issues reflected in environmental management and to characterize the research as environmental operations management. [1] examined the published definitions of green SCM (GSCM) and SSCM. They identified 22 definitions for GSCM and 12 definitions for SSCM. After analyzing each definition using two sets of critical characteristics proposed for business sustainability and SCM, they suggested a new definition for SSCM because they could not find a complete definition.

The second category includes studies regarding the effects of SSC risks on firm performance. [42] discussed the risks and complexities of sustainable development innovation, particularly in the context of stakeholder management. They cautioned that the complexities, ambiguities, and idiosyncrasies of sustainable development render the use of deductive approaches in environmental management inadequate. [58] investigated the influence of environment-related interactions in supply chains on operational performance. Specifically, they evaluated the influence of green project partnerships in terms of their cost, quality, delivery, flexibility, and environmental performance.

The third category addresses the key capabilities and comprehensive approaches adopted in response to SSC risks. For example, [57] discussed the critical response of supply chain performance to risk. Specifically, they examined the dimensions of supply chain flexibility and its relationship to

environmental uncertainty. [14] identified the role of risk and motivation in different types of environment-related supply initiatives.

The fourth category included papers regarding effective SSC risk management strategies. [23] explored various SSC initiatives; they investigated the problem of identifying a useful model based on the "triple bottom line" (TBL) (i.e., the economic, environmental, and social perspectives) for the supplier selection process in supply chains by presenting a fuzzy multi-criteria decision-making approach. [61] examined how short-term profitability and long-term environmental sustainability could be balanced in organizations, given supply chain decisions undertaken in uncertain conditions. They presented five sets of propositions that describe how models in GSCM make decisions and balance short- and long-term objectives.

4.1.2 Co-citation analysis

(a) Co-citation analysis: clustering analysis

A co-citation network comprises a set of nodes that represent journal articles and several links that represent the co-occurrence of these nodes in other papers [35]. A co-citation refers to two published papers being cited together. The co-citation method assumes that the more often two papers are cited together, the closer their relationship. Hence, frequently cited papers are more likely to have similar subject areas [30] and are viewed as belonging to the same research field [16].

We used the selected papers as the basis of our co-citation analysis to map the academic structure of SSC risks. The first co-citation map we created using NetMiner revealed that 212 of the 823 selected papers had been co-cited by other papers within our sample. We utilized these 212 papers for further NetMiner data-clustering analysis.

The nodes of a network can be categorized into several clusters (modularity) in which the connection (density of links) between nodes of the same cluster is more significant than that in other clusters [13], [20], [21], [35], [47]. From a co-citation network perspective, a cluster is regarded as a group of well-connected publications in a research field with limited connections to publications in other clusters or research fields [20], [21]. Data clustering has been applied in the past as a classification approach for grouping a set of given publications [47]. The topological analysis of a co-citation network can help to identify topics, interrelations, and collaboration patterns in the network [20]. Data clustering has received considerable attention from scholars and research organizations, thus becoming a critical research point in the field of social network analysis [6].

To determine the research focus for each cluster, we identified the leading papers in each cluster based on PageRank. These leading papers provide a general description of each cluster.

We identified three clusters from the co-citation analysis. To determine the main research focus of each cluster, we examined and evaluated the contents of the top five leading papers in each cluster, as shown in Table 4. The three core topical issues are explained as follows.

Cluster 1 was mainly focused on "sustainability-related risks in the corporate context." The concept of sustainability is often closely associated with "corporate social responsibility." The characteristics of sustainability in a corporate context include economic, environmental, social, stakeholder, volunteer, resilience, and long-term foci [1]. In Cluster 1, [1] identified a set of critical characteristics for business sustainability in a corporate context. [23] explored various SSC initiatives and highlighted the problem of identifying a practical model based on the TBL model. [4] proposed the Ecosilient Index to evaluate the greenness and resilience of automotive firms and their supply chain. [19] developed an integrated optimization model for a closed-loop supply chain, wherein the dollar carbon costs represent carbon emissions.

Cluster 2 was mainly focused on "environmental sustainability risks in the supply chain." For example, [2] identified the work of a focus group of environmental and operations management researchers, which involved a broad framework useful for identifying abundant research opportunities. Furthermore, [2] suggested substantial opportunities for addressing environmental issues and developing practices that are relevant to the field of manufacturing strategy, quality, SCM, and technology management. [57] examined the dimensions of supply chain flexibility to respond to environmental uncertainty risks. The

Table 4. Leading papers per cluster according to PageRank

Cluster	Top 5 leading papers by PageRank measure	
1	Ahi and Searcy (2013)	A comparative literature analysis of definitions for green and sustainable supply chain management
	Govindan et al. (2013)	A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach
	Özkir and Basligil (2013)	Multi-objective optimization of closed-loop supply chains in uncertain environment
	Azevedo et al. (2013)	Ecosilient Index to assess the greenness and resilience of the upstream automotive supply chain
	Fahimnia et al. (2013)	The impact of carbon pricing on a closed-loop supply chain: An Australian case study
2	Seuring and Müller (2008)	From a literature review to a conceptual framework for sustainable supply chain management
	Angell and Klassen (1999)	Integrating environmental issues into the mainstream: An agenda for research in operations management
	Vickery et al. (1999)	Supply Chain Flexibility: An Empirical Study
	Wu and Pagell (2011)	Balancing priorities: Decision-making in sustainable supply chain management
	Moore and Manring (2009)	Strategy development in small and medium sized enterprises for sustainability and increased value creation
3	Matos and Hall (2007)	Integrating sustainable development in the supply chain: The case of life cycle assessment in oil and gas and agricultural biotechnology
	Cousins et al. (2004)	The role of risk in environment-related supplier initiatives
	Ragatz et al. (1997)	Success factors for integrating suppliers into new product development
	Christopher et al. (2011)	Approaches to managing global sourcing risk
	Chen et al. (2004)	Strategic purchasing, supply management, and firm performance

findings indicated that volume and launch flexibility were the essential pre-requisites for marketing practices uncertainty and product uncertainty, respectively, in the highly cyclical furniture industry. [61] discussed how to achieve a balance between short-term profitability and long-term environmental sustainability in supply chain decisions under uncertain conditions. These researchers addressed four environmental perspectives that explain the organizational decision-making process while aiming to identify strategic relations within the economic, social, and environmental dimensions of the TBL. Cluster 3 was mainly focused on "sustainable development concerns." For example, [42] discussed the applicability of life cycle assessments when combining sustainable development concerns into the supply chain. They argued that the pressures of sustainable development had caused complexities. Moreover, [42] highlighted the vague challenges that current environmental management practices could not adequately prepare for. [12] suggested various sustainable approaches for firms by understanding how managers assess global sourcing risks across the entire supply chain and the actions they may take to mitigate those risks.

Table 5. Number of papers published in each cluster (1997–2018)

Year	Number of published papers		
	Cluster 1	**Cluster 2**	**Cluster 3**
1997			1
1998			
1999		2	
2000			
2001			
2002			
2003			
2004		1	2
2005		1	
2006			
2007		1	1
2008		2	
2009		1	1
2010			1
2011		3	1
2012	1	2	2
2013	5	1	1
2014	3	1	1
2015	2		
2016	4		
2017	1		
2018			
Total	**16**	**15**	**11**

Table 6. Keyword network analysis process

Analysis process		
Data collection	Research& extract papers	Keywords and journal search (Scopus database)
		Journal and paper selection (impact factor 3.0)
Network construction	Keyword network construction	Refinement of search keywords
		Construction of keyword network based on the frequency of keyword co-occurrence
		Construction of commonly preferred keyword network based on component analysis
Network analysis	Keyword network analysis	Network structure analysis (density, average distance, clustering coefficient)
		Network centrality analysis (degree, betweenness, closeness)
		Network centrality analysis by year (1997–-2016 vs. 2017–2018)

Table 7. Statistics of the whole network and sub-networks by journal and periods

	Papers	**Keywords**	**Density**	**Clustering coefficient**	**Average distance**
ALL	287	882	0.008	0.883	3.178
JCP [1]	115	406	0.016	0.894	3.195
IJPE [2]	50	223	0.026	0.920	4.070
TRPE [3]	24	99	0.053	0.952	2.982
1997–2016	171	553	0.013	0.895	3.165
2017–2018	116	432	0.015	0.894	3.355

Sources: [1] Journal of Cleaner Production; [2] International Journal of Production Economics; [3] Transportation Research Part E: Logistics and Transportation Review

They asserted that a multidisciplinary approach is required when dealing with global sourcing risks. [9] addressed the links among strategic purchasing, supply management, and firm performance. They argued that strategic purchasing could lead to a sustainable competitive advantage by (1) encouraging adjacent working for associations with a limited number of suppliers, (2) promoting open communication among supply-chain partners, and (3) developing long-term strategic relationships to achieve mutual profits.

(b) Co-citation analysis: Dynamic clustering analysis

Additionally, we conducted a dynamic co-citation analysis of the selected papers to understand the evolution of supply risks in GSCM research over time, i.e., the evolution/development of clusters over time. Table 5 shows the number of articles published in each cluster since 1997. Clusters 2 and 3 appeared at nearly the same time in 2008, 2009, and 2010, respectively. The earliest publication, in 1997, belongs to Cluster 3. The papers under Clusters 2 and 3 began to increase in 1998 and declined from 2014 onwards. Clusters 2 and 3 stopped developing in recent years, while Cluster 1 continues to grow.

4.2 Topical sub-network analysis

4.2.1 Keyword network analysis

We identified both broad and specific issues and topics as well as the most important keywords for each issue/topic by examining the characteristics of keyword networks of SSC-risk-related papers. Based on the 882 keywords extracted from the 294 papers selected to construct a local citation network, we built a keyword network of SSC risks. However, seven articles, not including keywords, were excluded. Thus, we finally used 287 papers selected to analyze the keyword network of SSC risks.

To construct this keyword network, we followed the keyword network analysis process summarized in Table 6. In doing so, we aimed to (1) create keyword networks extracted from premier overseas business journals, (2) investigate issues and topics associated with SSC risks by conducting bibliometric and network analysis, and (3) examine the changes in critical issues and topics over time.

Before constructing a keyword network, we refined search keywords by changing all keywords with identical meanings to a standard form. Next, we performed the component analysis to construct networks comprising commonly preferred keywords using the NetMiner tool.

(a) Keyword network structure analysis

As shown in Table 7, we extracted 882 keywords from 287 papers published during the period 1997–2018. We applied several well-defined and widely used network-related measures to understand the structural characteristics of the keyword network. First, we utilized "density" to measure the degree of dense networks by dividing the number of links in the network by the total number of all possible links. The more extensive the network, the sparser it will be [11]. Second, we applied the "clustering coefficient," which indicates the degree of connectivity between neighboring nodes (keywords) in a network. A high clustering coefficient indicates the tendency of nodes (keywords) to cluster in densely interconnected nodules [11]. Third, we applied "average distance," which refers to the average number of steps along the shortest arcs for all pairs of nodes (keywords), indicating the degree of efficiency of information transmission on a network [11].

The analysis results imply that the entire SSC risk network could be represented as highly clustered local networks densely interconnected by hub nodes of the network (Table 7). Regarding the journal sub-networks, the results indicate that these sub-networks were relatively dense, as shown in Table 7. Furthermore, the *International Journal of Production Economics* (IJPE) had a longer average distance. In the period sub-networks, all networks were dense with relatively long average distances.

To further identify the structural characteristics of the entire network and sub-networks for various journals and periods, we constructed a cumulative degree distribution where the X-axis was the log scale of the degree, and the Y-axis was the proportion of the keywords. For instance, a value of approximately 0.1 on the X-axis corresponds to a value of 3 on the Y-axis, revealing that about 10% of the keywords analyzed include more than three links to other keywords (Fig 2).

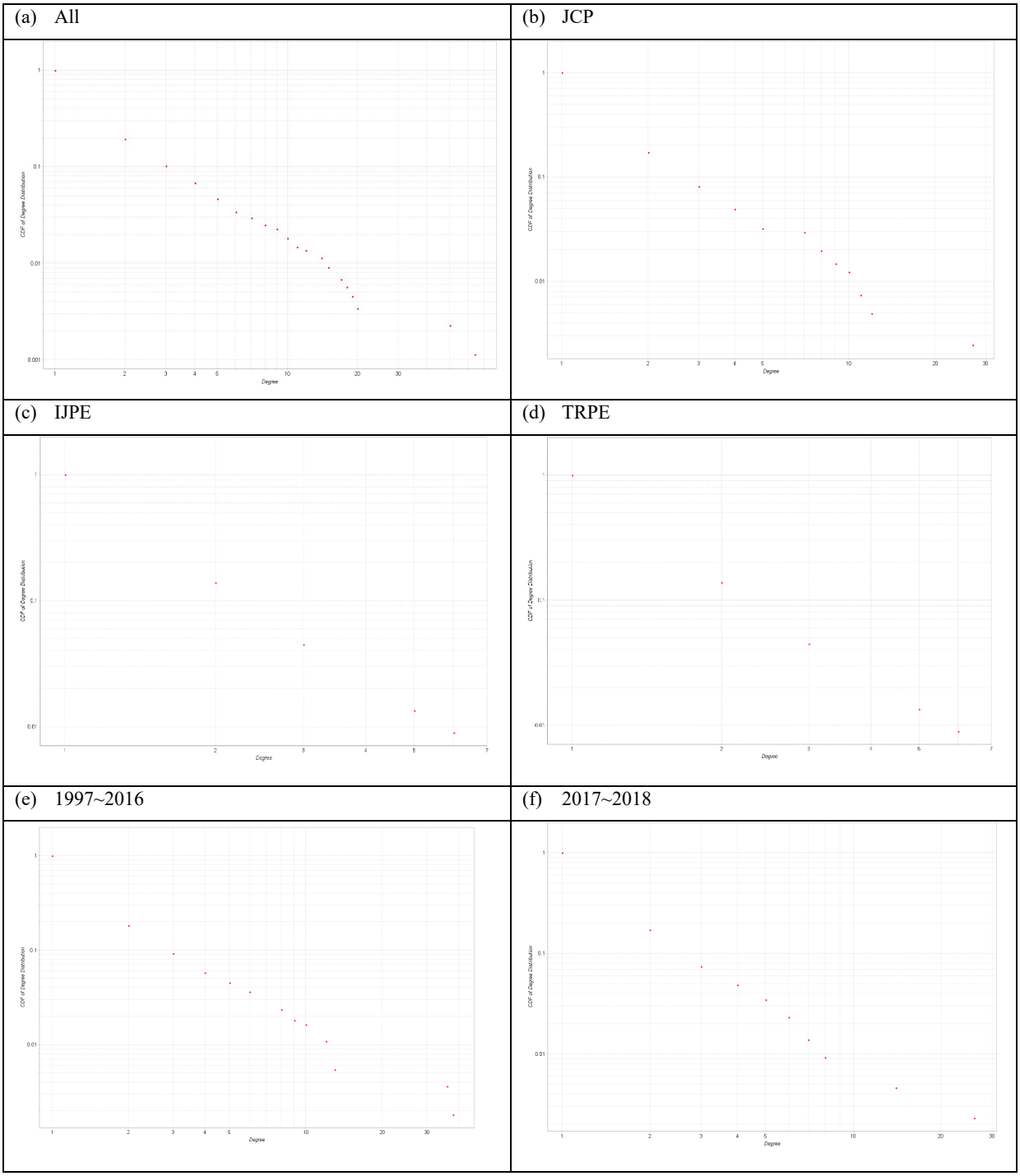

Figure 2. Cumulative degree distribution of the whole network and sub-keyword networks for journals

As shown in Fig 2, the cumulative degree of the whole network and sub-keyword networks for journals and periods followed a transparent power-law distribution. In other words, the entire network and sub-networks demonstrated preferential attachment, a well-known aspect of the power-law distribution, indicating that a node with more links to other nodes is likely to attain new links during the evolution of the network [11]. Accordingly, in these keyword networks related to SSC risks, the more popular a keyword became, the more often the keyword was selected by researchers, and consequently, the more it was associated with other keywords or concepts to establish and convey new ideas.

Table 8. Top 10 keywords by centrality analysis

Rank	Degree centrality	Betweenness centrality	Closeness centrality
1	Closed-loop supply chain	Environmental uncertainty	Supplier selection
2	Supplier selection	Supplier selection	Environmental uncertainty
3	Environmental uncertainty	Closed-loop supply chain	Closed-loop supply chain
4	Reverse logistics	Environmental management	Corporate social responsibility
5	Corporate social responsibility	Reverse logistics	Environmental management
6	Environmental management	Life cycle assessment	Reverse logistics
7	Carbon emission	Corporate social responsibility	Supply chain risk
8	Purchasing	Carbon emission	Carbon emission
9	Supply chain risk	Supply chain risk	Supplier development
10	Analytic hierarchy process	Sustainable development	Environmental sustainability

(b) Important keywords: Network centrality analysis

We observed differences in the classification of the top 10 keywords across measures. As shown in Table 8, the differences among the top-ranked keywords based on the three measures imply both the broad and specific issues and topics in a given research area.

The top 10 keywords, conforming to the degree of centrality, represent the relevant keywords in terms of their structural positions in a keyword network regarding carbon management in the supply chain. These keywords had numerous connections with other keywords, which indicates that they represent significant issues in the field of SSC risks. For example, a highly ranked keyword in the degree of centrality, "closed-loop supply chain," received considerable attention in previous research on SSC risks.

Similarly, in terms of betweenness centrality, the top 10 keywords represent relevant keywords in terms of their structural positions between keyword pairs. Betweenness centrality is a measure of the centrality of a keyword (node) in a network, calculated based on the shortest paths between keyword pairs. For example, the top-ranked keyword in terms of betweenness centrality, "environmental uncertainty," played a vital role in bridging separate groups with carbon management themes.

Furthermore, the top 10 keywords, in terms of closeness centrality, provided a higher level of access efficiency in the network (Freeman, 1978). For example, the highly ranked keyword "supplier selection" was located at the center of a keyword network, revealing that it was related to nearly all other keywords and themes within the network. The closeness centrality measures the average number of keywords that a focal keyword passes to connect with all the keywords in the network.

Table 9 indicates that the "closed-loop supply chain," "environmental uncertainty," and "supplier selection" were the most critical keywords related to SSC risks in all three aspects of the network.

The critical keywords across the three different measures (degree centrality, betweenness centrality, and closeness centrality), "closed-loop supply chain," "environmental uncertainty," "supplier selection," "reverse logistics," "corporate social responsibility," and "carbon emission," were almost continually recurring in the top 10 keywords.

Table 9. Top three keywords related to SSC risk by selected journals and three measures (1997–2018)

	Rank	Degree centrality	Betweenness centrality	Closeness centrality
Journal of Cleaner Production	1	Sustainability	Sustainability	Sustainability
	2	Green supply chain management	Green supply chain management	Green supply chain management
	3	Supply chain	Supply chain management	Supply chain management
	4	Supply chain management	Closed-loop supply chain	Carbon emission
	5	Closed-loop supply chain	Supply chain	Supply chain
	6	Supplier selection	Life cycle assessment	Closed-loop supply chain
	7	Green supply chain	Green supply chain	Multi-objective optimization
	8	Life cycle assessment	Carbon emission	Supplier selection
	9	Carbon emission	Sustainable supply chain	Sustainable supply chain management
	10	Sustainable supply chain	Supplier selection	Reverse logistics
International Journal of Production Economics	1	Sustainability	Sustainability	Sustainability
	2	Supply chain management	Sustainable supply chain	Supply chain management
	3	Environmental uncertainty	Supply chain management	Sustainable supply chain
	4	Carbon emission	Reverse logistics	Reverse logistics
	5	Sustainable supply chain	Environmental uncertainty	Carbon footprint
	6	Analytic hierarchy process	Carbon footprint	Environmental consideration
	7	Analytical network process	Analytical network process	Analytic hierarchy process
	8	Manufacturing	Carbon tax	Carbon emission
	9	Remanufacturing	Innovation	Carbon tax
	10	Closed-loop supply chain	Sustainability	Analytical network process
Transportation Research Part E: Logistics and Transportation Review	1	Sustainability	Sustainability	Sustainability
	2	Green supply chain	Multi-objective mathematical model	Multi-objective mathematical model
	3	Supply chain management	Green supply chain	Supply chain management
	4	Resilience	Supply chain management	Resilience
	5	Multi-objective mathematical model	Game theory	Dynamic sustainability tradeoff analysis
	6	Guanxi	Guanxi	Stochastic fuzzy goal programming
	7	Uncertainty	Resilience	Supply chain design
	8	Relational benefit	Uncertainty	Sustainability performance scoring
	9	Relational risk	-	Green supply chain
	10	Dynamic sustainability tradeoff analysis	-	Uncertainty

It is not surprising that "environmental uncertainty," "reverse logistics," "corporate social responsibility," and "carbon emission" were included in the list since environmental consciousness has been receiving considerable attention in supply chain research. However, in our results, "closed-loop supply chain" and "supplier selection" were identified as important keywords. We further searched for keywords directly linked to "closed-loop supply chain" and "supplier selection" to identify common issues in which these critical keywords were applied. The results imply that keywords related to recycled product issues, such as "reverse supply chain," "remanufacturing," and "product recovery," are directly linked to the "closed-loop supply chain." For example, [34] applied the closed-loop supply chain model to cope with the uncertainty associated with supplying recycled products, while [27] investigated manufacturers' selection of reverse channels in a closed-loop supply chain.

Moreover, "supplier selection" was directly linked to "supplier development" and "purchasing" keywords. This result mainly focuses on the importance of suppliers' response to SSC risks; for example, [17] proposed a method for the evaluation

and selection of green suppliers. [3] researched sustainable supplier selection considering quantity discounts and supplier risk.

Table 10. Top 10 keywords by centrality analysis (1997–2016 vs. 2017–2018)

Degree centrality		
Rank	**1997–2016**	**2017–2018**
1	Corporate social responsibility	Supplier selection
2	Environmental uncertainty	Carbon emission
3	Environmental management	Analytic hierarchy process
4	Closed-loop supply chain	Big data
5	Purchasing	Reverse logistics
6	Case study	Sustainable development
7	China	Supply chain risk
8	Supply chain integration	Life cycle assessment
9	Supplier selection	Analytical network process
10	Grounded theory	Multi-objective optimization
Betweenness centrality		
Rank	**1997–2016**	**2017–-2018**
1	Corporate social responsibility	Carbon emission
2	Environmental management	Supplier selection
3	Environmental uncertainty	Multi-objective optimization
4	Closed-loop supply chain	Analytic hierarchy process
5	Case study	Reverse logistics
6	Supplier selection	Life cycle assessment
7	Purchasing	Big data
8	Supply chain risk	Multi-criteria decision making
9	Environmental sustainability	Sustainable development
10	China	Supply chain risk
Closeness centrality		
Rank	**1997–2016**	**2017–2018**
1	Corporate social responsibility	Carbon emission
2	Environmental management	Supplier selection
3	Supplier selection	Analytic hierarchy process
4	Purchasing	Multi-objective optimization
5	Environmental uncertainty	Big data
6	Green	Supply chain risk
7	Case study	Fuzzy TOPSIS
8	Risk management	Fuzzy multi-objective programming
9	Stakeholder theory	Environmental performance
10	China	Sustainable development

Noticeably, we observed differences in the classification of the top 10 keywords across three prominent journals: "*Journal of Cleaner Production," "International Journal of Production Economics,"* and "*Transportation Research Part E: Logistics and Transportation Review."* As shown in Table 9, the differences among the top-ranked keywords demonstrate that SSC risk research focused on both broad and specific issues in the top journals. In other words, preliminary analyses focused on the overall importance of a keyword, while five journals presented the similarities and differences in keywords.

(c) Important keywords: Changes in important keywords over time

To address the ongoing changes in critical keywords over the years, we compared significant keywords in the 20 years between 1997 and 2016 with significant keywords during the period 2017–2018.

Due to the accumulation of connections between keywords over time, it was inherently difficult to identify the evolution of keyword networks. In other words, although a keyword network constructed for a certain period offers information about the associations among the keywords for articles published during that particular period, there is still the possibility that important information regarding keyword associations in other periods may be excluded. Therefore, associations among keywords across different periods affect one another since they are correlated. This problem is common when examining the evolution of citation, author, and keyword networks. Thus, comparing a keyword network of data obtained from earlier articles with that of data from more recent studies can alleviate the potential loss of information regarding recent changes in important keywords [44]. Therefore the comparison between significant keywords in the two periods provided some notable findings. According to the degree of centrality, "corporate social responsibility" was the most popular keyword until 2016, while "supplier selection" has been receiving increasing attention in the 2017-2018 period. Furthermore, "supplier selection" has become substantively more prevalent over both periods.

5. Discussions and Conclusions

We conducted a systematic literature review combining bibliometrics, citation and co-citation networks, and keyword network analysis to explore the topical trends of SSC risks. Additionally, we highlighted various significant theoretical and practical implications as follows.

First, we identified the critical issues most commonly discussed in influential papers based on the citation analysis. These include the definition of an SSC and how SSC-related risks affect firm performance. Current research on SSC risks remains focused on reviewing and understanding the threats that SSCs face. Other critical issues included effective approaches and responses to SSC risks.

Second, by identifying prevalent topics through co-occurrence, we classified research regarding SSC risks into three topic clusters: (1) sustainability-related risks in the corporate context, (2) environmental risks in the supply chain, and (3) sustainable development concerns.

Third, our results revealed that "closed-loop supply chains," "environmental uncertainty," and "supplier selection" were significant issues in SSC risk research. Similarly, "reverse logistics" and "corporate social responsibility" showed a high degree of centrality, along with high betweenness and closeness centrality. It indicates the significance of these sub-topics in SSC risk research. Thus, SSC risks related to "supply selection" and/or "environmental uncertainty" may be an appropriate beginning for researching the overall topic of SSC risks.

Fourth, in terms of structural characteristics, the keyword network of the *Journal of Cleaner Production* was extensive and sparse and characterized by high network density. In contrast, the network of the *Transportation Research Part E: Logistics* and *Transportation Review* was relatively small and dense due to high density and short distance. It means that, although new issues did not frequently emerge in the *Journal of Cleaner Production*, the journal remains the primary source of SSC-risk-related research. Furthermore, since the sub-networks of all three influential journals showed a precise power-law degree distribution, scholars are likely to focus on the few specific topics that are popular in these networks. Thus, literature reviews concerning carbon management must identify new issues and topics from relevant studies that exist in these journals.

Fifth, we observed differences in the top 10 keywords related to SSC risks across the three major journals. In the *Journal of Cleaner Production*, "closed-loop supply chain" was the most prevalent issue. At the same time, "environmental uncertainty" and "supplier selection" were significant issues in the *International Journal of Production Economics* and the *Transportation Research Part E: Logistics and Transportation Review*, respectively.

Sixth, identifying the changes in and the development of topics over time, our results showed that "risk of sustainability issues in the corporate context" had attracted researchers' attention in recent years. In contrast, the focus on topics like "environmental risk supply chain" and "sustainable development concerns" decreased. According to the keyword network analysis, "supplier selection" and "carbon emission" received increasing attention during the 12-year study

period. These results reveal that these keywords are the most frequently used terms in research titles and abstracts in the field of SSC risks, indicating that SSC risks are associated mainly with supplier and carbon emission issues.

Although this study offers interesting implications, it is not without limitations. Despite conducting network-based analyses to conduct a comprehensive review of the research area, other relevant papers may have been excluded since articles regarding SSC risks were only retrieved from the Scopus database. Similarly, although our selected keywords were related to SSC risks, they may not be exhaustive.

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