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Article

Blockchain Technologies in Logistics and Supply Chain Management: A Bibliometric Review

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Abstract: The emergence of blockchain technology has sparked significant attention from the supply chain management (SCM) and logistics communities. In this paper, we present the results from a thorough bibliometric review that analytically and objectively identifies the intellectual structure of this field, the seminal papers, and the most influential scholars. We employ a knowledge domain visualization technique to generate insights that go beyond other review studies on blockchain research within logistics and SCM. The analysis starts with selecting a total of 628 papers from Scopus and the Web of Science that were published during 2016–2020. The bibliometric analysis output demonstrates that the number of blockchain papers has rapidly increased since 2017. The most productive researchers are from the USA, China, and India. The top academic institutions contributing to the literature are also identified. Based on network analyses, we found that the literature concentrates mainly on the conceptualization of blockchain; its potentials for supply chain sustainability; its adoption triggers and barriers; and its role in supporting supply chain agility, trust, protection of intellectual property, and food/perishable supply chains. Besides systematically mapping the literature, we identify several research gaps and propose numerous actionable research directions for the future. This study enriches the extant blockchain literature, provides a timely snapshot of the current state of research, and examines the knowledge structure of blockchain research in logistics and SCM with the help of evidence-based scientometric methods.

Keywords: blockchain; supply chain management; logistics; bibliometrics; network analysis



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1. Introduction

Modern supply chains have recently witnessed tremendous changes, extending a formerly operational function to an independent supply chain management (SCM) function [1]. Supply chain processes contain numerous logistics operations, including planning, implementing, and controlling the effective flow and storage of goods, services, and related information from the source to the point of consumption to satisfy customer requirements [2]. Integrating and streamlining these activities bring a competitive advantage in visibility, revenue optimization, inventory turnover, supply chain speed, and efficient customer service delivery [3]. However, achieving these objectives is challenging since the complexities of supply chains have significantly increased due to the interplay of multiple geographically dispersed entities operating independently and frequently competing to serve their respective customers [4–7]. Besides complexities, supply chains also face numerous uncertainties and risks [8–10], such as the engagement of trading partners in opportunistic behavior (e.g., distorting information, cheating) [11,12], privacy leakage [13], fraud and cybercrime [14], and counterfeit product identification.

To overcome these issues, corporate managers across many industries attempt to improve SCM through digitalization [15]. The digitalization of supply chains refers to the process of organizations adopting inter-organizational systems to collaborate and transact with their trading partners (e.g., key suppliers and customers) along their respective chains. In total, the SCM market is anticipated to reach revenues of \$19 billion by 2021 through the digitalization of its operations [16–19]. The digitalization of supply chains offers increased business velocity and agility and contributes to the formation of supply chain networks that are highly interconnected, inclusive, trustworthy, and secure [20]. Digitalization has also played a key role in maximizing the speed of business transactions and supporting the development of traceability mechanisms that enable the identification and recording of products and processes [21]. Through digitalization, Kuhi et al. [15] argue that firms can obtain better visibility over key information, events, and collaborations across organizational boundaries, thereby maintaining competitiveness in the supply chain network. Firms can also rely on the digitalization of supply chain processes to better meet customer demands for a wide variety of individualized products through higher efficiency and lower costs.

Firms have recently begun deploying blockchain technology to sustain their activities and improve the management of their supply chains [22–24]. Blockchain can be defined as a “*digital, decentralized, and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamperproof records*” [25] (p. 547). The decentralized ledger contains a chain of time-stamped blocks that are linked by hashes using cryptography [26]. Each block comprises a set of entries (e.g., data, transactions, records) to be included in the network, and each new block is chained to the preceding block. Once blocks are added to blockchain, they are immutable and have been verified through sophisticated automation and governance protocols [27]. Blockchain is built using peer-to-peer (P2P) networks, and it necessitates agreement between all parties to validate transactions. This eliminates inaccurate or potentially fraudulent transactions from the database. Unlike conventional information technology (IT) platforms, blockchain alleviates the reliance on a single centralized authority and facilitates secure and pseudo-anonymous transactions and agreement among transacting partners [28]. A specific blockchain solution, according to Rejeb et al. [29], is seen as a combination of various methods, technologies, and tools that addresses a particular problem or business use case. This means that the technology is versatile and enables many solutions, while spanning multiple industries [30]. The concept of an online blockchain was introduced by the pseudonymous Satoshi Nakamoto [31] in 2008 with the cryptocurrency Bitcoin, representing a novel technological approach to develop trustless systems [32]. In the context of cryptocurrencies, the tamper-resistant nature of blockchain serves as an effective solution to prevent ‘double spending’ and assure that transactions are carried out properly without the risk of the same funds being allocated more than once [33]. Beyond flourishing in the finance industry, the spectrum of blockchain applications extends to other sectors, such as logistics and SCM [34–36], social media and marketing [37,38], e-commerce [39,40], tourism [41–43], and healthcare [12,44,45]. Likewise, research on blockchain technologies has gained global traction, particularly from the logistics and SCM community [46]. The reasons for this increasing interest in the technology are diverse. First, blockchain has emerged as a new boundary condition that gives rise to new frameworks and concepts for business models, organizational forms, and governance structures [47], while facilitating improvements in resource management, traceability, security, and data transparency [48]. Second, blockchain changes the relationship between parties in transactions [34] and allows the integration of participants within a supply chain network while reinforcing collaboration between them [49]. Third, blockchain technology offers the potential to radically transform current business operations in logistics and SCM by fostering sustainability and streamlining organizational operations, including distribution, order fulfillment, payment for intermediate goods, and information transmission [50].

Despite the fact the blockchain technology has been covered thoroughly in the logistics and SCM literature, there is a dearth of studies that focus exclusively on analyzing the

intellectual structure of blockchain research within this stream of literature. By closing this gap, the current study offers several contributions to the existing literature. Besides being the first attempt to use knowledge domain visualization, this study reviews the structure of blockchain knowledge through the analysis of information related to networks of co-citation and core content (i.e., keywords). This study is motivated by the study of Portugal Ferreira [51], who points out that, when fields of research become more complex and enter their maturity phase, scholars should periodically attempt to draw insights from the accumulated knowledge in order to identify new contributions, detect trends and research traditions, and reveal future research directions. By exploring the network structure and dynamics of blockchain knowledge and identifying prominent authors, we provide depth to the blockchain knowledge base from the perspective of logistics and SCM. In this respect, our research aligns with the view of Wang et al. [52], who argue that the rapid growth of emerging technologies (i.e., cloud computing in their study) requires periodic review to keep researchers updated on the latest progress. By conducting a thorough analysis of blockchain research in logistics and SCM, we seek to accelerate the conceptual development of this rapidly evolving research area. More precisely, our investigation answers the following research questions (RQ):

RQ1: How has blockchain research within logistics and SCM progressed since its emergence?

RQ2: Which countries/regions contribute most to the formation of a geographic atlas of blockchain research in logistics and SCM?

RQ3: Which scholars and studies are most impactful in the blockchain logistics and SCM field?

RQ4: What are the thematic trends of blockchain research in logistics and SCM?

RQ5: What are the key research discussions and hotspots in the literature?

RQ1 is relevant since blockchain is constantly expanding its scope; RQ2 considers how research could affect particular supply chains originating or terminating in specific locales; RQ3 identifies thought leaders that should be tracked to see where the field is heading; RQ4 detects key points of profitability and helps to anticipate important future developments; and RQ5 highlights the most likely adjacencies to current technologies.

This paper is structured as follows: Section 2 briefly summarizes existing literature reviews; in Section 3, we outline the methodology used in this study; Section 4 provides a detailed summary of the descriptive quantitative analysis; Section 5 discusses the study findings and presents key research implications; in Sections 6 and 7, we present several theoretical and managerial implications and conclude the paper.

2. Literature Reviews on Blockchain in Logistics and SCM

Numerous research studies have recently discussed the applications of blockchain in logistics and SCM. Several dimensions of deploying blockchain in logistics and SCM have been examined, varying from conceptualizing the promises of the technology [53] and exploring successful use cases for companies [54–56] to examining the impact of blockchain's connectivity inhibitors on supply chain interaction and resilience [57]. For example, Cole et al. [58] investigate the implications of blockchain for the field of operations SCM (OSCM) and find that the technology could reshape several practices, including product safety and security, quality management, inventory management and replenishment, disintermediation, new product development, and supply chain cost transactions.

The studies listed in Table 1 predominantly employed a systematic literature review (SLR) or bibliometrics to summarize the literature and derive new insights. For example, Queiroz et al. [53] study existing applications, the main challenges, and future research directions of the literature at the intersection of blockchain and supply chain integration. The authors find that the electric power industry tends to have a relatively mature understanding of blockchain and its ability to increase supply chain integration through smart contracts. Chang et al. [59] analyze 106 articles to explore the use of blockchain and smart contracts in SCM. Their findings reveal several areas that can benefit from blockchain adoption, namely: traceability and transparency, stakeholder involvement and collaboration, supply chain integration and digitalization, trust and performance, process automation,

and distributed governance. Similarly, Wang et al. [54] investigate how blockchain could impact supply chain practices and argue that the technology brings extended visibility and traceability, supply chain digitalization and disintermediation, improved data security, and smart contracts. Vivaldini and de Sousa [57] review the inhibitors of connectivity during blockchain implementation in supply chain interaction and resilience. The study details the technical and organizational influences that determine the adoption of blockchain in the supply chain as well as identifying barriers to interaction between the involved agents and supply chain resilience.

Since its inception, companies in the food industry have been scrutinizing blockchain as a game-changing logistics and SCM technology. Recognizing its strengths in meeting several food supply chain requirements, several SLRs have been conducted to better understand the development of blockchain and its value-creation potential. For example, Nurgazina et al. [56] summarize the insights from 69 articles to identify existing applications of blockchain and IoT in food supply chains and the challenges of their implementation. Challenges related to scalability, security, privacy, cost, standardization, regulation, interoperability, and energy consumption, for instance, are highlighted as highly relevant barriers to integrating these technologies in food supply chains.

When it comes to bibliometrics, a few review studies have sought to examine the application of blockchain in logistics and SCM. For example, Pournader et al. [60] conduct a co-citation analysis of blockchain applications in supply chain, logistics, and transport management, and identify four main clusters which center on technology, trust, trade, and traceability/transparency. In the same vein, Muessigmann et al. [55] provide a bibliometric analysis of blockchain technology using 613 selected articles collected from several academic databases. Based on co-citation analysis, the authors classify the literature into five distinct research clusters, including theoretical sensemaking, conceptualizing blockchain and experimenting with applications, framing the technology within supply chains, the technical design of blockchain applications for logistics and SCM applications, and the possibilities of blockchain in digital supply chains. Lastly, Tandon et al. [61] conduct a bibliometric analysis of 586 articles identified on Scopus to study the use of blockchain in management.

Although several reviews have been carried out to systematize the literature about the use of blockchain in logistics and SCM, the use of SLRs is not always the best strategy since they are somewhat subjective, labor-intensive, and impractical for analyzing larger bodies of literature [62]. The current array of research streams employing bibliometric techniques to investigate blockchain is still very limited. Additionally, existing bibliometric studies either draw on a relatively small sample of articles [60] or a single academic database [61], and use different bibliometric tools that lead to different clustering outcomes and insights [55]. In order to address these shortcomings, in this study, we carry out a comprehensive bibliometric analysis of the blockchain literature in the logistics and SCM field. We aim to guide researchers, practitioners, and decision makers from the emergence of blockchain towards its future potentials. The study's findings will enrich the current literature and contribute to an increased understanding of the interplay between blockchain and SCM.

Table 1. Review studies on blockchain in the logistics and SCM field.

Article	Review Method	Database(s) Used	Sample	Time Span	Type of Reviewed Publications
[53]	SLR	Multiple (except WoS)	27	2008–2018	Journal articles
[54]	SLR	Multiple	29	2016–2018	Journal articles Conference papers
[55]	Bibliometric	Multiple	613	2016–2020	Journal articles Conference papers Book chapters

Table 1. Cont.

Article	Review Method	Database(s) Used	Sample	Time Span	Type of Reviewed Publications
[56]	SLR	Multiple (except Scopus and WoS)	69	2016–2020	Journal articles Conference papers Book chapters
[57]	SLR	Scopus WoS	89	2015–2020	Journal articles
[58]	Narrative review	-	-	-	-
[59]	SLR	Multiple	106	2016–2019	Journal articles Conference papers
[60]	Bibliometric	Scopus WoS	48	2016–2018	Journal articles
[61]	Bibliometric + content analysis	Scopus	586	2015–2019	Journal articles
[63]	SLR	Multiple (except Scopus and WoS)	187	2017–2020	Journal articles
[64]	SLR	Multiple (except Scopus)	22	2010–2020	Journal articles
Our study	Bibliometric	Scopus WoS	628	2016–2020	Journal articles Conference papers

3. Methodology

3.1. Data Collection

An initial search in the Scopus database was carried out using the following search string: blockchain* AND ("supply chain*" OR logistic*). Scopus was chosen because of its extensive coverage in comparison to other academic databases (e.g., the Web of Science) [65] and its specific functionalities that allow researchers to efficiently pull and aggregate references from a sample of articles [66]. Similarly, Scopus is recognized for its reliability and the large amount of scholarly publications that it indexes, including academic journals published by leading publishers such as Elsevier, Emerald Insight, Taylor and Francis, Springer, IEEE, and the ACM [67]. Besides Scopus, Web of Science (WoS) was used to complement the searches and capture all potentially relevant publications that are not indexed in Scopus. Initially, the search keywords were sought in the abstract, title, or keywords fields. This resulted in a total number of 2583 publications. The subject areas were then limited to Management and Accounting, Business, Decision Sciences, Social Sciences, and Economics, Econometrics and Finance. To ensure the academic nature of the retrieved literature [68], only peer-reviewed articles and conference papers in English language were considered. The selection procedures finally resulted in 628 publications being retrieved for further analysis. The references and citations of these articles were saved in CSV format. The search and selection procedure is outlined in Figure 1.

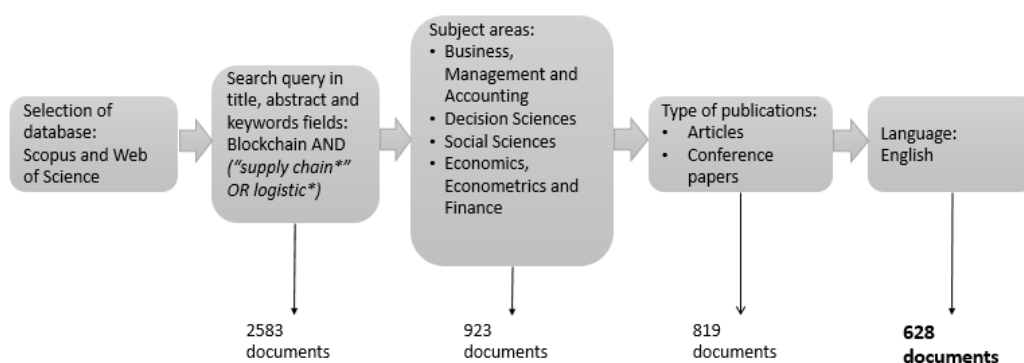


Figure 1. Search and selection process.

3.2. Research Method

According to Tranfield et al. [69], the main goal of a literature review is the identification, specification, mapping, and assessment of the existing body of pertinent literature in a systematic, objective, and easily reproducible manner. A structured literature review covers a wide range of publications and methodologies, resulting in a thorough and detailed analysis that considers clear and contextual relationships [70]. The use of bibliometrics in our study has three main justifications. First, as opposed to other methods for text analysis such as content analysis, a bibliometric analysis is more reliable and scalable. Second, bibliometric techniques help to deeply and thoroughly analyze relations among selected publications, citations, keywords, and co-citations, and can therefore provide valuable and comprehensive information. The last reason is that bibliometric techniques enable researchers to visualize important clusters of research topics in an intuitive and interpretable way.

3.2.1. Quantitative Analysis

We first analyzed the evolution of blockchain research in the field of logistics and SCM by plotting the selected publications according to their annual distribution. Next, following the process of Fahimnia et al. [71], we investigated several quantitative measures such as publications per author, citations per publication, as well as the location of publications to evaluate the impact and quality of the research. To facilitate data input and manipulation, we used the software package BibExcel to analyze the bibliometric data. The main benefit of BibExcel lies in its extensive compatibility with numerous academic databases (e.g., Scopus) and visualization tools (e.g., Gephi, VOSviewer).

Scholars attracting many citations are considered to be influential in their respective fields. We also ordered the authors of all selected papers according to their frequency of appearance. The authors' affiliation information was retrieved from the papers and imported into BibExcel to identify the leading academic institutions and the countries in which these institutions are situated. To gain a better understanding of the foci of blockchain research in the field of logistics and SCM, we carried out a keyword analysis to identify the most commonly used keywords in the selected publications. Tracking citations and understanding their trends are crucial for evaluating the impact and influence of research. The number of times a single paper is cited reflects its degree of importance within the academic community and provides an indication of its impact and influence [72]. We measured the frequency of local citations by considering the number of citations each publication received from other articles in our sample. The number of global citations per publication drew on the citation counts in the Google Scholar database. Given that Google Scholar covers major academic databases like Scopus, Web of Science, and EBSCOHost, the difference between local citations and global citations for a given paper indicates the amount of interest attracted within its own versus other research domains.

3.2.2. Network Analysis

After the descriptive analysis of the selected publications, we conducted a thorough analysis of the inner patterns and trends among these studies. We employed network analysis using bibliometric data and the visual software Gephi to depict the network structure of blockchain research in the field of logistics and SCM. The strength of network relations between two papers can be detected by keyword co-occurrences or co-citations [73].

Co-citation analysis was originally introduced by Henry Small in 1973 [74] to evaluate the semantic similarity of papers that share the same references. This is referred to as bibliographic coupling, wherein two papers share at least one common reference, and thus exhibit one co-citation. The co-citation frequency quantifies how many co-citations exist between two papers, whereby a higher frequency indicates that the two papers are closely related to each other. In order to identify the topic clusters, we rely on the references of each paper for the co-citation analysis.

The input data from BibExcel were imported into the visualization software Gephi to generate a co-citation network. We followed several steps to produce a map of co-citation clusters. Before using Gephi, we pre-processed the bibliometric data and fixed the co-citation frequency at an appropriate threshold. Too high a threshold value may lead to only a few articles being clustered, whereas too low a threshold value may result in too many clusters being generated. Therefore, to generate a meaningful visualization in the Gephi layout, the circle pack layout recommended by prior studies [75,76] was applied in our research to create a simple and readable graph. Each node represents a paper, and each edge linking two nodes reflects a co-citation relation. To generate the network, we manually adjusted the hierarchies, node size, and other parameters (e.g., color). This can be considered a form of manual regularization of the clustering.

To obtain an in-depth understanding of blockchain research within the logistics and SCM field, we created a keyword co-occurrence network. Akin to a co-citation network, a keyword co-occurrence network indicates that author-supplied keywords co-occur and shows the respective relationships [77]. According to Lee and Su [78], keyword co-occurrence analysis allows researchers to detect research topics and monitor the transitions of research frontiers in a particular knowledge domain. In a keyword co-occurrence network, two keywords have a closer relationship if they appear in the same papers more frequently. By generating the keyword co-occurrence network, we analyzed the core content from the used keywords and described the current structure of the blockchain research. The software selected for generating this network was VOSviewer because it is highly compatible with the BibExcel tool. The radius of the node reflects the frequency of each keyword, while the width of the edges indicates how often each pair of keywords were used together. By visualizing the mutual relationships between keywords, it is possible to reveal the topics addressed in blockchain research within the field of logistics and SCM. Figure 2 summarizes the research approach applied in this study.

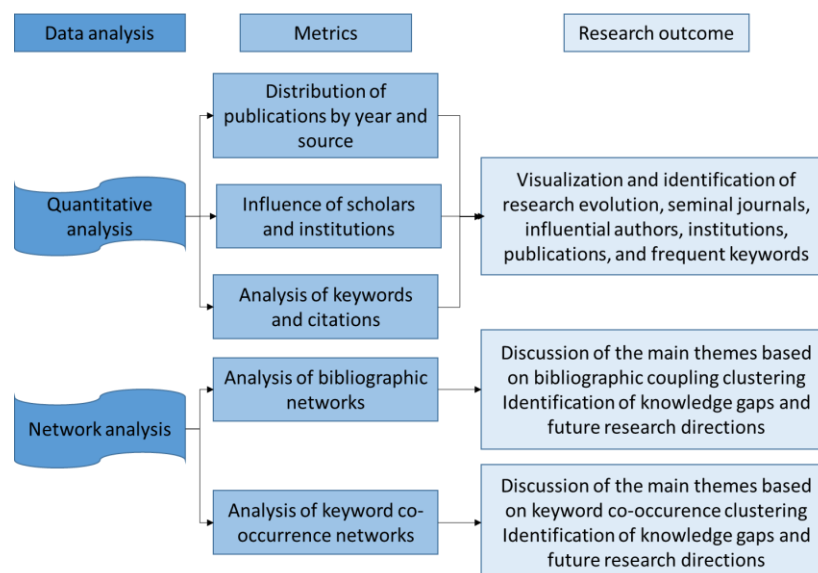


Figure 2. Research approach.

4. Results of Quantitative Analysis

4.1. Distribution of Publications by Year and Source

The final sample contained 628 papers. To answer the first research question, we traced the evolution of blockchain research in the field of logistics and SCM. Figure 3 shows a trend of consistent growth since 2016. A substantial increase in publications occurred during 2018–2020, when the number of papers on blockchain technology mushroomed. The earliest paper was published in 2016 and focused on the design of traceability in agricultural supply chains using Radio Frequency Identification (RFID) as well as blockchain technology [79].

This research is seminal because it inspired researchers and paved the way for them to investigate the potentials of blockchain for logistics and SCM. Overall, the results show that blockchain has garnered a lot of attention from scholars, especially from 2019 onwards. This finding also reflects the increasing popularity of blockchain within the logistics and SCM academic community.

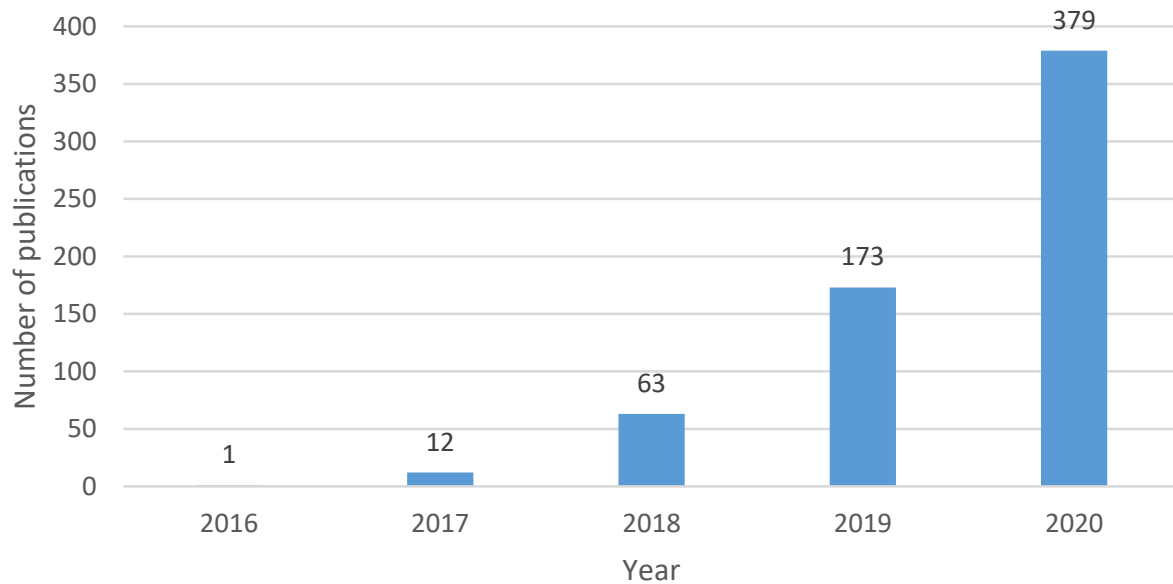


Figure 3. Blockchain research in the field of logistics and SCM.

Table 2 shows the top ten journals publishing articles relating blockchain technology to logistics and SCM. Overall, these journals published 156 articles, representing 24.8% of the 628 identified papers. As can be seen from Table 2, Sustainability tops the list by publishing a total of 25 articles on the topic. Next in the list, the International Journal of Production Research published 24 articles, Lecture Notes in Business Information Processing published 18 articles, and Transportation Research Part E Logistics and Transportation Review published 15 articles. The journal-wise distribution of articles indicates that blockchain research was published in a wide variety of top-tier journals that focus on the implications of the technology for business, management, production operations, sustainability, and logistics. That papers appear in such a diversity of journals reflects the interdisciplinary nature of blockchain and the versatility of its applications throughout logistics and across other fields.

Table 2. Top ten journals in terms of number of publications.

Journal Title	Count	%
Sustainability	25	16%
International Journal of Production Research	24	15%
Lecture Notes in Business Information Processing	18	12%
Transportation Research Part E Logistics and Transportation Review	15	10%
IFIP Advances in Information and Communication Technology	14	9%
International Journal of Information Management	13	8%
Supply Chain Management	9	6%
IEEE Transactions on Engineering Management	8	5%
International Journal of Production Economics	8	5%
International Journal of Supply Chain Management	8	5%
International Journal of Recent Technology and Engineering	7	4%
Frontiers of Engineering Management	7	4%
	156	100%

4.2. Scholars' Influence and Institution Statistics

Table 3 depicts the ten most productive scholars in the field. T.M. Choi published 13 papers to rank as the leading author with the highest number of publications in blockchain research within the field of logistics and SCM. J. Sarkis published seven papers, while A. Gunasekaran and M.M. Queiroz contributed equally to the literature with six papers each. The majority of the scholars listed in Table 3 have a background in SCM, operations management, and sustainability. Their studies employed theoretical and empirical methods such as literature reviews, surveys, and case studies.

Table 3. Top ten most productive authors according to number of published papers.

Author	Author's Institution	Count	%
Choi T. M.	Hong Kong Polytechnic University, Kowloon, Hong Kong	13	24%
Sarkis J.	Worcester Polytechnic Institute, Worcester, MA, USA	7	13%
Gunasekaran A.	California State University, Bakersfield, Bakersfield, USA	6	11%
Queiroz M. M.	Universidade Paulista, Sao Paulo, Brazil	6	11%
Fosso Wamba S.	TBS Business School, Toulouse, France	5	9%
Kouhizadeh M.	Foisie Business School, Worcester, MA, USA	5	9%
Casino F.	University of Piraeus, Piraeus, Greece	4	7%
Ravishankar B.	B.M.S. College of Engineering, Bengaluru, India	4	7%
Van Hoek R.	Sam M. Walton College of Business, Fayetteville, NC, USA	4	7%
		54	100%

Table 4 shows the top academic institutions according to the number of papers published, along with their locations. Scholars affiliated with Hong Kong Polytechnic University top the list with 16 published papers, followed by Worcester Polytechnic Institute, National Institute of Industrial Engineering, and Universidade Paulista. Table 5 lists the ten countries whose academic institutions have contributed most prolifically to blockchain research in the field of logistics and SCM. Overall, the top ten countries are responsible for the publication of 545 out of the 628 papers in our sample (87%). Researchers from the USA and China published the most papers, 113 and 100, respectively, while India ranks third with 88 publications. The number of publications from these countries has grown rapidly over recent years, reflecting the increasing popularity of blockchain and its relevance to both developed and developing countries. For example, the Government of the Indian state of Kerala has considered the implementation of blockchain technology in the food supply chain to reduce food wastage and increase overall transparency [80]. Similarly, Walmart has piloted the use of blockchain to track the exact origin of pork originating from China and its processing in the USA [12]. The remainder of the papers were primarily contributed by researchers from European countries such as the UK, Germany, France, and Italy, as well as from Australia, Russia, Canada, and Hong Kong. This illustrates that research relating blockchain to logistics and SCM has gained interest worldwide. When it comes to geographical distribution, North America and Europe contributed more than Asia.

Table 4. Academic institutions with over five publications.

Institutions	Count	Location
Hong Kong Polytechnic University	16	Hong Kong
Worcester Polytechnic Institute	8	United States
National Institute of Industrial Engineering	8	India
Universidade Paulista	8	Brazil
University of Derby	7	United Kingdom
California State University, Bakersfield	7	United States
Foisie Business School	7	United States
B.M.S. College of Engineering	6	India
TBS Business School	6	France

Table 5. Top ten countries according to the number of publications.

Country	Count	%
USA	113	21%
China	100	18%
India	88	16%
UK	61	11%
Germany	43	8%
Australia	31	6%
Russia	23	4%
Canada	22	4%
France	22	4%
Italy	22	4%
Hong Kong	20	4%
	545	100%

4.3. Analysis of Keywords and Citations

Table 6 lists the top 20 keywords by frequency. In addition to the search terms used to identify papers for analysis, smart contracts, IoT, and DLT are the most popular keywords, which underlines the potential of blockchain-based smart contracts in reforming supply chain operations [81]. Unsurprisingly, the term IoT is also often used in the blockchain research, indicating that these two technologies are often applied together. This technological interplay, according to several studies, is supposed to have a significant impact on SCM and logistics [82], since it enables resilient and truly peer-to-peer distributed systems [83] by offering supply chain partners increased openness, transparency, neutrality, reliability, and security [84]. In addition, “traceability”, “transparency”, and “trust” appear in the list, which suggests that these supply chains’ characteristics are among the goals of blockchain technology. These elements are essential to create a healthy and sustainable business ecosystem. Similarly, trust and transparency are necessary in supply chain networks to ensure compliance with legal regulations, reduction of risks, and mitigation of fraud [54]. The high frequency of keywords such as “food supply chains” and “additive manufacturing” indicates that the current industrial focus of blockchain technology lies in the food and additive manufacturing sectors. The food industry has been under increasing pressure to meet traceability requirements, overcome issues of product perishability, and enhance productivity [85–87]. “Additive manufacturing” is applied in SCM to leverage three-dimensional (3D) printers throughout the different stages of the SC with the goal to boost manufacturing flexibility, shorten lead times, support product individualization, and reduce inventory [88]. Additionally, it is typically more distributed than traditional manufacturing, which may require greater collaboration and trust assurance.

Table 7 shows the top ten publications according to the total number of global citations. Local citation counts are also presented. A closer look at the citation analysis reveals that F. Tian and N. Kshetri are the most influential scholars, both in terms of the number of articles and total citations received. Tian has the highest number of global citations among all publications. Kshetri received the second-highest number of global citations and was ranked second on local citations. These findings indicate that these two scholars have made seminal contributions and laid the foundations for later research. Several other studies revolved around the technical aspects of blockchains necessary for different application scenarios and the critical role of the technology for provenance tracking. A closer look at the ten most productive authors in Table 3 reveals that M. Kouhizadeh, J. Sarkis, and S. Saberi were members of the same author team, whose background was blockchain and sustainable SCM.

Table 6. Top 20 most frequently occurring keywords.

Keyword	Frequency
Blockchain	520
Supply chain	145
Smart contracts	94
SCM	89
IoT	66
DLT	50
Traceability	39
Logistics	30
Ethereum	29
Sustainability	27
Industry 4.0	21
RFID	20
Transparency	19
Bitcoin	18
Technology	14
Trust	14
Digitalization	14
Food supply chains	13
Security	13
Additive manufacturing	13

Table 7. Top ten papers according to global citations.

Publications	Global Citations	Local Citations
Tian [79]	416	81
Kshetri [12]	354	105
Saberi et al. [6]	326	94
Ivanov et al. [88]	233	35
Tian [84]	215	49
Wüst and Gervais [89]	182	25
Kim and Laskowski [90]	182	43
Kshetri [91]	172	19
Queiroz et al. [92]	146	50
Wang et al. [54]	130	54

5. Findings from Network Analysis and Discussion

5.1. Bibliographic Coupling Network

Following the example of previous studies [71,73], we chose a threshold of 2 for co-citation frequency. The generated bibliographic coupling network contains 296 papers. The nodes of a network can be grouped into different clusters or partitions in which the density of links is greater among nodes of a similar cluster versus those of different clusters [93]. Each cluster in the network constitutes a group of well-connected papers on blockchain in SCM and logistics, with these papers having only a limited association with papers grouped in the other clusters (see Figure 4). The clustering of papers enables analysis of the topology of the network and reveals topics, connections, and collaboration patterns.

To generate the co-citation network, we used Gephi's default modularity tool, which uses the Louvain algorithm. This is an iterative optimization model, whose algorithm can identify the optimal number of clusters to maximize the so-called modularity index [94]. The modularity index of a specific partition adopts a value between -1 and 1 that measures the density of edges inside of communities as compared to links between distinct communities [95]. The application of this algorithm led to the generation of six main clusters. The quantity of papers in each cluster ranges from 2 in cluster 6 to 101 in cluster 1, the latter representing the largest community. The modularity index in Figure 4 equals 0.151 , revealing the important interrelationships between the six clusters. This result can be seen by comparing the left (Figure 4A) and the right side of the figure (Figure 4B),

with and without the links/edges depicted. Since closely connected papers share similar characteristics, a cluster with strong co-citation relations indicates similar subject areas [96]. A careful examination of each paper within a certain cluster helps to identify the main research focus of that specific cluster. Because of the high volume of papers in each cluster, we decided to consider only the top ten articles of each cluster for further content analysis. The lead papers were determined according to their co-citation PageRank. Based on these papers, we identified the research focus of each cluster and labeled them accordingly. The lead papers from each cluster are shown in Table 8.

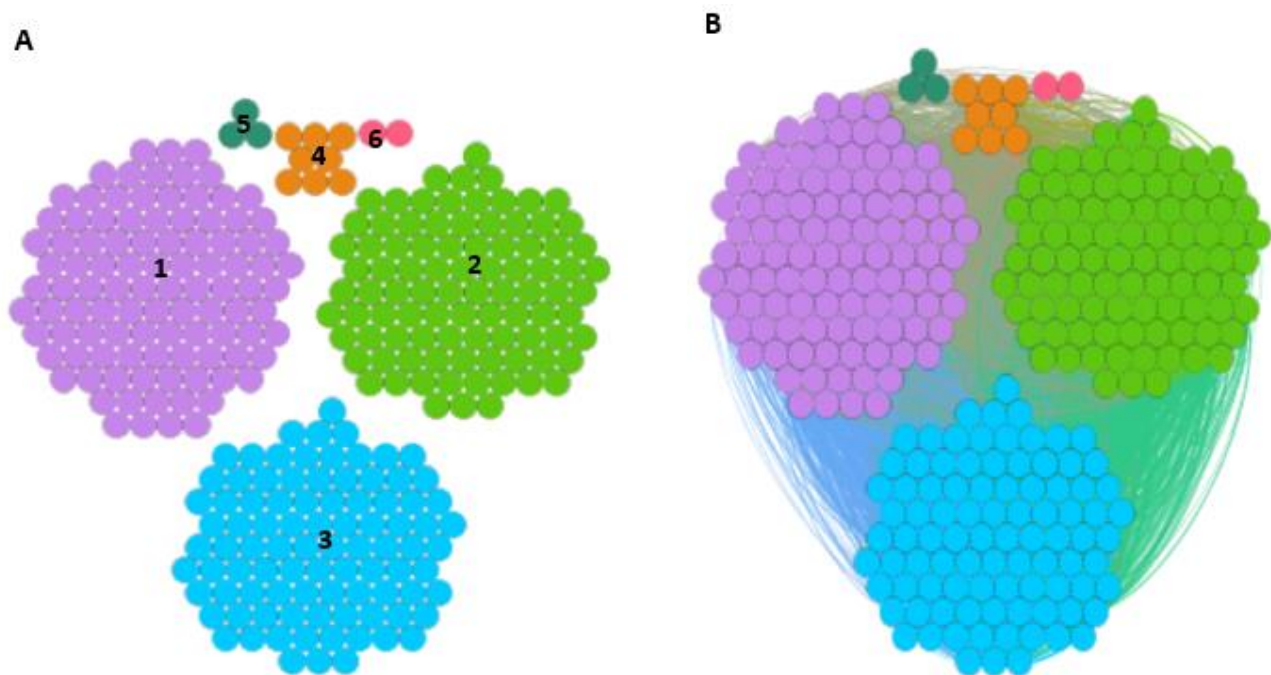


Figure 4. Clustering network for the co-citation analysis (A: without edges; B: with edges).

5.1.1. Blockchain for Supply Chain Sustainability

The classification of research foci summarized in Table 8 reveals that blockchain research in the logistics and SCM field frequently focuses on sustainability aspects of supply chain ecosystems. In this regard, Bai and Sarkis [50] argue that the technology can coordinate order fulfillment, payment of goods, information flows, and distribution. By adopting blockchain, firms can achieve real-time transparency, reduce networking costs, and realize substantial cost savings in their manufacturing activities [117]. The need for cost efficiencies arises from a variety of pressures faced by companies, including competition. In response to these pressures, firms can gain economic benefits from the use of blockchain. For example, Hastig and Sodhi [111] point out that blockchain can be an effective option for companies trading in commodities (e.g., cobalt, timber) as the origins of products can be easily verified, resulting in higher operational efficiencies, elimination of illegal practices, and increased sustainability. Allen et al. [130] note that blockchain can result in substantial reductions in the cost of trading food products in global supply chains. Similarly, Yadav and Singh [107] argue that blockchain can increase customer and end-user awareness of supply chain activities, thereby increasing customer trust and satisfaction.

Table 8. Lead papers from each cluster according to their PageRank.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Blockchain for supply chain sustainability	Conceptual development of blockchain research in the field of logistics and SCM	Adoption triggers and barriers of blockchain technology in supply chains	Blockchain as an enabler for supply chain agility and adaptability	Blockchain for the protection of intellectual property	Blockchain for the management of food/perishable supply chains
Bai and Sarkis [50]	Wang et al. [54]	Kouhizadeh et al. [97]	Kamble et al. [98]	Holland et al. [99]	Mondragon et al. [100]
Yadav and Singh [101]	Behnke and Janssen [102]	Di Vaio and Varriale [103]	Sheel and Nath [104]	Holland et al. [105]	Mondragon et al. [106]
Yadav and Singh [107]	Saberi et al. [6]	Kamble et al. [108]	Sheel and Nath [109]	Engelmann et al. [110]	
Hastig and Sodhi [111]	Kim and Shin [83]	Fosso Wamba et al. [112]	Miraz et al. [113]		
Muller et al. [114]	Schmidt and Wagner [47]	Wong et al. [115]	Gunasekaran et al. [116]		
Ko et al. [117]	Divey et al. [118]	Karamchandani et al. [119]	Delafenestre [120]		
dos Santos et al. [121]	Cole et al. [58]	Batwa and Norrman [122]	Srivastava et al. [123]		
Lustenberger et al. [124]	Wang et al. [125]	Ghode et al. [126]	Denis et al. [127]		
Lu et al. [128]	Palas and Bunduchi [129]	Wong et al. [46]			
Allen et al. [130]	Caldarelli et al. [131]	Pournader et al. [60]			

Blockchain can be used to ensure that products are certified by authorities throughout various supply chain stages without compromising the privacy of the company [121]. Therefore, the main insight from cluster 1 is the opportunity for additional research on the role of blockchain in improving the environmental performance of supply chains by, for example, increasing green supply chain transparency, supporting green sourcing strategies, and facilitating the development of eco-design practices in logistics and SCM. The extant literature is remarkably silent on how the increased process integration due to blockchain transparency and information availability can improve the speed of green product development, the sales of environmentally friendly products, and the responsiveness of firms to stakeholders' environmental concerns. Although the economic implications of blockchain have been repeatedly reported in prior studies, the importance of the technology to promote socially responsible operational practices in logistics and SCM is still missing. Increasing customer awareness of social conduct through blockchain transparency may impose additional pressure on firms to fulfill their corporate social responsibilities and improve their corporate citizenship [132]. The social performance of supply chains can benefit from the ability of blockchain to enhance the alignment of exchange partners' business strategies with social/ethical standards [133]. Thus, the investigation of cooperative mechanisms by means of which firms can acquire knowledge, augment alignment, and establish higher levels of mutuality and trust in the supply chain presents a promising avenue for future research. Researchers may also empirically investigate the impact of blockchain on the social performance of supply chains, thus extending previously suggested performance models [134].

5.1.2. Conceptual Development of Blockchain Research in the Field of Logistics and SCM

Although clusters 2 and 3 overlap when it comes to theory development, the leading papers in cluster 2 focus on advancing the conceptual underpinnings of blockchain technology. The existing studies are exploratory in nature, laying the theoretical foundation of blockchain and structuring the field [125]. The set of review and conceptual papers [6,47,54] is indicative of the need for researchers to define and explain the possibilities of blockchain for logistics and SCM.

5.1.3. Adoption Triggers and Barriers of Blockchain Technology in Supply Chains

Cluster 3 revolves around applications of well-established theories such as the force field theory, the technology, organization, and environment (TOE) theory [97,115,135], technology acceptance model (TAM), technology readiness index, theory of planned behavior [108], and the unified theory of acceptance and use of technology (UTAUT) [46,112]. These theories were challenged and advanced through empirically oriented testing methods, including surveys. According to the previous studies, the adoption triggers of blockchain technology in logistics and SCM consist of facilitating conditions (e.g., regulatory support), technology readiness, and technology affinity [46].

In a recent study, Wong et al. [115] found that cost was not statistically supported as an inhibitor, but rather a driver for blockchain adoption. In general, the barriers to blockchain adoption have received more attention from scholars than the motivators. For a novel technology, the expectations are high, but the challenges are also enormous. In this context, Ghode et al. [126] reported that organizational challenges (i.e., inter-organizational trust, relational governance), technological challenges (i.e., data transparency, data immutability), operational challenges (i.e., interoperability, product type), and social challenges (i.e., social influence, behavioral intention) all hamper willingness to adopt blockchain into supply chains.

While the technology has been hyped for years [136], many constraints stand in the way of mainstream adoption of blockchain. These include data immutability, security risks, implementation costs, privacy concerns, and lack of governance [60]. Although empirical studies have investigated the drivers and barriers of blockchain adoption in both developed and developing countries (e.g., India and the USA [112], Malaysia [47,116], and

India [108]), there is scope for confirming and extending the results of these investigations in other geographical contexts such as Africa, Europe, and Latin America.

To date, there are no observational studies applying a longitudinal approach to examine the responses to blockchain adoption in various industries across the technology adoption life cycle. Moreover, additional empirical research using more comprehensive models for the inter-organizational drivers of blockchain adoption and other theories (e.g., institutional theory, contingent resource-based theory) are required to help firms use blockchain technology more efficiently and effectively. The results of such research may provide clearer guidelines for practitioners who are eager to make informed and evidence-based decisions regarding the key characteristics of the blockchain into which they will commit their efforts and limited resources.

A key question for scholars to examine is the role of culture in blockchain adoption and use. Supply chain scholars should consider the cross-cultural testing of technology adoption models or theories, recognizing the likelihood of cultural differences. Although TAM has been previously tested as a tool for predicting technology use [108], so far there are scant attempts by scholars to look into the antecedents of perceived usefulness and ease of use in the case of blockchain. A better understanding of these antecedents will help firms to devise appropriate strategies that will accelerate the uptake of blockchain in logistics and SCM.

5.1.4. Blockchain as an Enabler for Supply Chain Agility and Adaptability

We labeled cluster 4 as “blockchain as an enabler for supply chain agility and adaptability”. Agility commonly refers to the ability of firms to sense and respond to environmental changes in a timely manner [137–139]. In the context of logistics and SCM, agility represents a key competitive advantage that allows firms to quickly adapt to continuously changing demand patterns, short product lifecycles, dynamic markets, competition, and demand for customized products [140]. Supply chain partners can increase agility by using blockchain to further automation and facilitate data integration across their business processes [116].

A key feature of an agile firm is flexibility, and blockchain can improve supply chain alignment, adaptability, and agility, which, taken together, sustain competitive advantage and firm performance [113]. Blockchain can also boost capabilities to respond effectively to the changing and dynamic nature of the business environment because the technology facilitates supply chain efficiency and responsiveness [98]. Using the technology, firms can better respond to the dynamics of customer demand fluctuations and abrupt changes within the supply chain.

Even though the extant literature has highlighted an enabling role for blockchain in shaping future agile manufacturing practices [116], a specific focus on the implications of the technology for supply chain agility is, so far, missing. Therefore, further research is required to truly understand the impact of blockchain on supply chain agility and the influence of this agility on firm performance. It is vital that supply chains are continually assessed with respect to competitiveness; blockchain-enabled agility is a paradigm that may allow managers to redesign their competitive strategies.

Blockchain’s ability to improve supply chain agility depends on the integration of firms and suppliers into the blockchain ecosystem. Thus, examination of inter-organizational processes, trust, and other determinants of blockchain’s ability to improve supply chain agility generates valuable insights when it comes to devising strategies and effective investments that optimize blockchain’s impact on agility and, eventually, on business performance.

5.1.5. Blockchain for the Protection of Intellectual Property

Cluster 5 contains articles that discuss the enablers of blockchain for the protection of intellectual property. For instance, scholars contend that blockchain can protect 3D print supply chains and prevent intellectual property (IP) theft [99,105]. The encryption and licensing of data can be significantly facilitated by blockchain and the technology can also address the need for traceable, digital administrative data relevant for 3D printing [105].

One compelling avenue for future research involves investigating the role of blockchain-enabled IP protection as a mediator in the collaborative relationships between supply chain partners and their efforts to launch new products and create new markets. The enforcement of IP rights with blockchain can constitute a strategic and competitive asset, and thus researchers should examine how blockchain can support IP rights policies, particularly for industries with high-value-added products and creative content. The use of blockchain to protect IP rights illustrates its potential for knowledge generation and innovation among supply chain partners. The evaluation of this impact may help to open new doors for innovation research in logistics and SCM.

5.1.6. Blockchain for the Management of Food/Perishable Supply Chains

Cluster 6 focuses on the application of blockchain in food/perishable supply chains. Mondragon et al. [100] argue that blockchain enables better responses to the increasing requirements for compliance in the food chain through tamper-proof records and provenance tracking. The combination of blockchain with specialized IoT devices (e.g., intelligent sensors/containers) can provide the necessary synopsis to control the status of perishable foods throughout transportation, handling and storage, and delivery to final consumers [106].

Among the numerous opportunities for future research in food logistics and SCM, scholars could analyze how blockchain-enabled traceability can enhance food safety through the reduction of information asymmetries and the allocation of incentives encouraging upstream suppliers to ensure they provide quality and safe food raw materials. Empirical investigations are needed to evaluate the impact of blockchain-based systems in the food industry in terms of costs, benefits, barriers, and changes to consumer purchasing decisions and habits.

5.2. Keyword Co-Occurrence Network Analysis

Before generating the keyword co-occurrence network, we set a frequency threshold of 3 to obtain a better visualization. As a result, the number of keywords considered for the keyword co-occurrence network analysis was 71. The algorithm used by the VOSviewer software generated five significant clusters. Each node in Figure 5 represents a keyword, and the radius of a node relates to the occurrence frequency of the keyword in each paper. According to the number of nodes, the red cluster, which constitutes the center, comprises the most frequently used concepts that attracted greater attention from researchers. We listed the ten most common keywords in each cluster as shown in Table 9 (except for the purple cluster on the bottom, which only contains five keywords, as shown in the visualization map). Each cluster in the network was labeled according to the main theme emerging from the keywords.

5.2.1. Blockchain Fundamentals and Technical Aspects

The red cluster revolves around the early implementation of blockchain in the finance sector through cryptocurrencies such as Bitcoin and Ethereum, and their potential to disrupt other industries and all sorts of business operations, including logistics and SCM [33,141]. Therefore, we labeled this cluster as *“blockchain fundamentals and technical aspects”*. The most relevant keywords in this cluster are *“blockchain”*, *“supply chain”*, *“smart contracts”*, and *“IoT”*.

Researchers have further argued that smart contracts and IoT can support continuous improvements in supply chain processes [6] and augment sustainability through improved coordination, cooperation, and communication between supply chain actors [142]. Moreover, the role of blockchain to strengthen the security and privacy of supply chain data has been emphasized in the literature, implying that the technology can improve the function of smart contracts by implementing real-time quality monitoring and control of processes [143] and guarantee data security without compromising the privacy of participants [144,145].

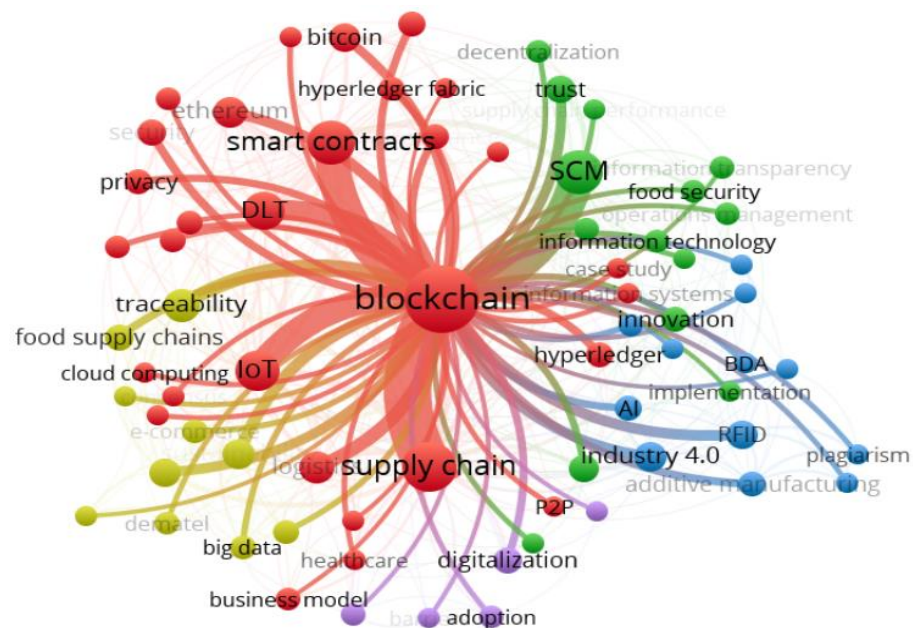


Figure 5. Keyword co-occurrence network.

Table 9. Top ten ranked keywords based on frequency in the cluster.

Red Cluster	Green Cluster	Blue Cluster	Yellow Cluster	Purple Cluster
Blockchain Fundamentals and Technical Aspects	Blockchain for Digitally-Enabled Supply Chains and Trust Mechanisms	the Combination of Blockchain with Industry 4.0 Technologies	Blockchain for Traceable and Sustainable Supply Chains	Barriers to Blockchain Adoption
blockchain supply chain smart contracts IoT DLT logistics Ethereum Bitcoin security cryptocurrencies	SCM technology trust innovation decentralization food security information technology information transparency operations management systematic literature review	industry 4.0 RFID additive manufacturing AI food safety BDA food traceability intellectual property license management plagiarism	traceability sustainability transparency food supply chains big data e-commerce supply chain finance DEMATEL agriculture supply chain visibility	digitalization adoption survey barriers literature review

5.2.2. Blockchain for Digitally-Enabled Supply Chains and Trust Mechanisms

The green cluster in the upper right corner discusses and reviews the importance of blockchains for increasing supply chain trust, stimulating innovation, and promoting information transparency. Therefore, we labeled this cluster as “*blockchain for digitally-enabled supply chains and trust mechanisms*”. In the supply chain context, trust is a necessary yet insufficient condition for repeated business transactions [146]. The architecture of blockchain and its tamper-proof nature helps to overcome trust issues in the supply chain [12] because it eliminates the need to evaluate the trustworthiness of intermediaries or other network participants [147].

Keywords such as “*innovation*”, “*decentralization*”, “*food security*”, and “*information transparency*” appear in the cluster. The high frequency of “*innovation*” in this cluster indicates that blockchain serves as an impetus to unlock the potential for innovation across the supply chain. For instance, Liao and Wang [148] note that blockchain is one of the key innovation drivers in logistics that can revamp logistics operations and magnify the impact of ICT on supply chain integration. Due to the growing importance of innovation in logistics and SCM, future research is needed to understand the dynamics and processes

of blockchain-induced innovations and their impact on firm performance. Research in this direction can provide managers with guidelines on the innovation paths that firms should follow to sustain and accelerate their supply chain digitalization efforts and initiatives.

5.2.3. The Combination of Blockchain with Industry 4.0 Technologies

Another research focus of the reviewed literature regards the integration of blockchain with other technologies. Accordingly, we labeled the blue cluster on the right as *“the combination of blockchain with industry 4.0 technologies”*. Industry 4.0 is an evolutionary concept that originated in Germany and aimed to bring to firms novel perspectives on enhancing services and production methods [149], largely through computerized manufacturing [150,151]. The industry 4.0 initiative has sparked several discussions concerning the digitalization of organizational processes through the use of advanced technologies like cyber-physical systems, wireless sensor networks, the IoT, big data, cloud computing, and blockchain technology [15]. The shift toward smart, data-driven, and highly integrated supply chains and logistics can be significantly facilitated by the blockchain. For example, blockchain can be incorporated with RFID tracking to verify transfers of ownership [34], improve food safety and traceability [58,84,152], and increase the automation of supply chain processes.

Interestingly, additive manufacturing is a commonly used term in this cluster, gaining increasing attention from both academics and practitioners [153]. As opposed to subtractive manufacturing methods, additive manufacturing (AM) is conceptualized as the formation of complex components by continuously adding layers of material [154]. AM involves a complex network of automated and manual workflows that depend on a secure cyber-physical-system (CPS) to ensure reliable physical (e.g., material) and informational hand-offs between multiple partners in the manufacturing process to ultimately produce a high-quality component. The implementation of this technique could benefit from blockchain as it would make AM documentable from a design perspective [105], resulting in increased efficiencies, lower risks, and higher manufacturing flexibility [88].

Blockchain use cases are often associated with other forthcoming technologies such as artificial intelligence (AI) to optimize the collection and parsing of data [155], develop fast learning expert systems [156], and help firms develop sophisticated strategies for the real-time monitoring of changes in their supply chains and the swift formulation of effective responses. In addition, firms that recognize the potential benefits of big data analytics (BDA) for logistics and SCM can expand the value of this technology by the use of blockchain to streamline flows of supply chain data, derive actionable insights, and enhance decision-making [98].

Notwithstanding the benefits promised by the implementation of blockchain, more in-depth studies on its interplay with industry 4.0 technologies are needed. For example, future studies should investigate how firms can use blockchain to positively influence changes and improvements in the workflows of their supply chains. It is of interest whether blockchain can enable artificial neural network models to help managers identify and improve targeted aspects of supply chain activities to bring higher returns to the firm and improve customer satisfaction. Effective quality improvement strategies and policies are becoming ever more important in the context of increasingly dynamic market conditions. Another interesting avenue for research is to examine the contribution of blockchain in establishing reliable analytical infrastructure for logistics and SCM.

5.2.4. Blockchain for Traceable and Sustainable Supply Chains

The lower left cluster in yellow contains articles with a focus on the effectiveness of blockchain in enhancing supply chain traceability, transparency, and visibility for sustainability. Mounting consumer concerns over food safety and quality are pushing for increased transparency regarding the origin of products. As a result, we labeled this cluster as *“blockchain for traceable and sustainable supply chains”*. Traceability is a key requirement

that enables consumers, regulators, producers, and marketers in food supply chains to mitigate potential risks and deliver high-quality and safe products [121].

Thanks to the tracking capabilities of blockchain and its ability to provide a complete audit of transactions, firms can develop more traceable supply chains, quickly identify the provenance and authenticity of products, and demonstrate environmental and social sustainability credentials to their trading partners. As shown in Table 9, articles in this cluster mainly conducted survey-based studies using the DEMATEL methodology to visualize the complex causal relations between various blockchain enablers. For example, Kamble et al. [108] identify the major drivers for sustainable supply chains following the integration of blockchain [107], and explore significant barriers that hinder blockchain adoption in the agri-food supply chain [157]. Another notable result from this cluster is that keywords pertaining to practical blockchain applications for services such as “e-commerce” and “supply chain finance” are included. There are several challenges facing e-commerce, such as lack of security and trust in online transactions [158]. These concerns could be alleviated by the use of blockchain since enhanced trust between trading partners would enable transactions to be conducted directly and without involving third parties [159,160]. The integration of blockchain in e-commerce could also enable the secure storage of documents and the transfer of data during transactions [161].

Furthermore, blockchain can be used in supply chains to integrate financial and logistic services more efficiently. Previous studies have established that blockchain coupled with smart contracts can support the development of highly secure and convenient supply chain financial systems [162], coordinate collaboration data sharing between parties [163], and improve capital availability for businesses [164].

Empirical research into the behavior of customers engaging in blockchain-based e-commerce is necessary to understand their value concepts and how to design and deliver better customer experiences with matching value propositions. There is a need for blockchain solutions addressing the pressures caused by surges in e-commerce activities and just-in-time deliveries. The benefits of blockchain for e-commerce have been examined, yet the impact of blockchain-based platforms on supply chain performance is still neglected in the literature. For supply chain finance, researchers may be interested in empirically investigating how blockchain can contribute to the reduction of upstream and downstream supply chain costs. The potential of blockchain to improve cash management and identify the risk preferences of supply chain partners is also an intriguing research direction.

5.2.5. Barriers to Blockchain Adoption

The last cluster examines the challenges that limit the widespread implementation of blockchain in logistics and SCM. We labeled this cluster “*barriers to blockchain adoption*”. For example, despite many promising use cases, the adoption of blockchain has not seen rapid acceptance [97] because of regulatory uncertainty, lack of stakeholder awareness and ease of use, and the high complexity of blockchain-based systems [157]. In the AM sector, Kurpjuweit et al. [153] posit that the shortage of blockchain-skilled specialists, governance mechanisms, and firm-internal technical expertise represent key barriers to blockchain adoption.

Due to scalability and speed issues, technological access limitations [6], and security and privacy concerns [157], the mainstream adoption of blockchain in the logistics and SCM field is not imminent. The exploration of these barriers has been conducted from both theoretical and empirical perspectives using literature reviews and surveys. However, there is a lack of studies looking into technical solutions that could overcome scalability issues in logistics and SCM. The causal relationships among the technical, organizational, and regulatory barriers are often blurred and therefore further empirical research is needed. Similarly, there are additional research opportunities in determining the organizational mechanisms that can facilitate and accelerate the uptake of blockchain in supply chains.

6. Discussion

6.1. Theoretical Contributions

Scholars have recently begun to apply bibliometric analyses to investigate the applications of blockchain in the logistics and SCM field. However, most of the bibliometric studies on the technology have relied on datasets with a relatively small number of articles. A more holistic approach was needed to expand understanding of the topic and inform gaps in the literature. Our study accomplished this by examining blockchain in a broader context. Specifically, we focus on the works published in the last five years (2016 to 2020) to enlighten bibliometric indicators such as the influential authors, journals, and academic institutions that have contributed to the evolution of blockchain research and advanced its applications in logistics and SCM. Moreover, the network analysis of selected publications provides insights that serve to inform an agenda for future research.

Our study offers several contributions to the logistics and SCM literature. First, we unearthed the core research foci of related blockchain research, which span three major themes: (1) blockchain for supply chain sustainability, (2) conceptual development of blockchain research in logistics and SCM, and (3) triggers and barriers of blockchain adoption in supply chains. The findings from the co-citation analysis indicate that most of the influential papers focus on the conceptualization and review of blockchain possibilities and challenges for supply chains. Empirical works mainly employ surveys to identify the drivers and barriers of blockchain adoption. The early works on blockchain tended to define the technology, present its technical features, and suggest opportunities and challenges. More recently, scholars have become more focused on specific research topics such as the application of blockchain for digitally enabled supply chains and trust, its combination with industry 4.0 technologies, traceability, and barriers in the transition toward blockchain-based supply chains. Unlike previous reviews on blockchain, this study employed an objective method to structure the related research themes and reveal avenues for future research. Our findings provide logistics and SCM scholars with a thorough understanding of the current status of blockchain research in the field, and our suggestions for future research will direct them towards noteworthy topics when they dig deeper into this auspicious but still uncharted research area.

6.2. Managerial Contributions

Leveraging digitally-enabled supply chains presents several opportunities in the context of fierce competition, market instability [116,165], demands for reduced time-to-market, and challenges associated with access to critical technologies. The main challenges in today's supply chains include a lack of data visibility and transparency, extended supply chain traceability, and the validation of claims regarding sustainability. The ability to identify and verify critical information related to products transitioning along the supply chain can be facilitated by the deployment of blockchain. The technology provides a unified way to monitor the entire supply chain and streamline information processes among the parties involved. Data discrepancies and inconsistencies [108] arising from the lack of IT platform integration along the supply chain may lead to inefficient management and poor performance [15]. As a result, this study recommends that managers consider blockchain to improve transparency, achieve fair pricing, enhance product qualities, and reduce business costs.

Organizations can use blockchain to enhance traceability and make information about products' origins or content more accessible, thereby meeting the growing expectations of consumers, associations, and regulators [166]. With the support of blockchain, complete supply chain traceability is possible as managers can maintain the required amount of detailed information and degree of precisions [167]. Other supply chain stakeholders can similarly capitalize on blockchain to develop unified approaches addressing concerns over product quality traceability. Defective products are hard to trace back in supply chains featuring numerous stages and production lines [160], yet blockchain's traceability enables

transparency and empowers trust even along geographically dispersed and disconnected supply chains [108].

Organizations and regulatory bodies can obtain additional insights from this review. First, managers can grasp the development of blockchain research in logistics and SCM, the potentials of the technology for supply chain sustainability, and the challenges hampering the transition toward blockchain-enabled business models. The findings of the study clarify expectations about blockchain deployment and highlight trends and opportunities on the path towards a comprehensive blockchain ecosystem. Decision makers and regulatory bodies must also understand blockchain as they tackle regulatory barriers such as the lack of legal frameworks related to smart contracts, which would enable managers to improve compliance and adherence to regulations such as food traceability and safety standards.

6.3. Study Limitations

This study provides meaningful support for understanding the present state of blockchain technology and potential directions for future research. However, several limitations should be addressed in further investigations. This study only considered journal articles and conference papers for the bibliometric analysis. Hence, other documents such as books and chapters could potentially be included in future work. Another limitation is that bibliographic coupling provides a static and retrospective view that requires periodic renewal to keep track of recent advances in blockchain deployments in logistics and SCM. Therefore, researchers may address this shortcoming by replicating the co-citation network analysis presented in this paper. Finally, the exact keywords used for the retrieval of studies can influence the sample and subsequent analysis. Accordingly, the use of different keywords in the search query may result in novel insights.

7. Conclusions

The goal of this paper is to present a structured review of blockchain research in the field of logistics and SCM. The number of papers published in this area is rapidly increasing as blockchain applications begin to revolutionize aspects of supply chains and reshape their structures. Even though several literature reviews on the potentials of blockchain for logistics and SCM have previously been published, this bibliometric review provides a timely snapshot of the current state of research and objectively identifies the intellectual structure of the field as well as the influential publications and scholars.

Overall, 628 papers published between 2016 and 2020 were selected from the Scopus and Web of Science databases for our analysis. Blockchain attracted little attention in the years prior to 2017, but since then the technology has become increasingly popular in the scholarly press. The academic outlets publishing the most blockchain studies in logistics and SCM are Sustainability, International Journal of Production Research, Lecture Notes in Business Information Processing, and Transportation Research Part E: Logistics and Transportation Review. Meanwhile, several articles were published in other top-tier journals, such as Supply Chain Management, the International Journal of Production Economics, and the International Journal of Supply Chain Management. This indicates that leading journals have significantly contributed to the advancement of research into the business implications of blockchain.

In terms of national contributions, both developed countries including the USA and UK along with emerging economies such as China and India have devoted significant attention to the investigation of blockchain applications. The geographic distribution of papers revealed that authors affiliated with European and North American academic institutions dominated early contributions, yet a noticeable diffusion of research efforts into Asia is underway.

For those seeking a better understanding of blockchain research in logistics and SCM, the identified influential papers in this study may prove a good starting point to grasp the conceptual foundations of the field. In addition, the co-citation analysis helps to capture the more recent publications that have the potential to make enduring contributions and trigger

further research. Being aware of the prominent scholars within the academic community may inspire future developments, motivate collaboration, and stimulate further research. Recent studies from influential scholars have focused on the nexus of blockchain, supply chain management, and sustainability, and the adoption drivers and barriers to blockchain implementation in logistics and SCM.

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