Hindawi
Mobile Information Systems
Volume 2023, Article ID 6046503, 23 pages
https://doi.org/10.1155/2023/6046503

Research Article

Blockchain Technology Applied to Supply Chain Management: A Systems' Analysis

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Received 8 May 2022; Revised 26 July 2022; Accepted 6 August 2022; Published 22 August 2023

Academic Editor: Mohammed Shuaib

Blockchain technology can be used to record real data at various nodes in the entire supply chain and can achieve timely data sharing and full traceability of the whole lifecycle of products in the supply chain. This study conducts a systematic literature review based on the WOS database, focusing on the research topic of the application of blockchain technology in supply chain management. We propose clear search and screening criteria based on 4 research questions and finally obtain 591 target studies. We conduct a detailed study on the distribution of the target literature in this research area, country/region, institution, and journal. Different countries/regions cooperate with each other and, thus, are clustered into five significant countries regions' cooperation networks. There is a strong coupling relationship between research institutions, forming four major institutional cooperation networks. According to the analysis of those papers with a high number of citations, most of such papers were published in 2019, while the cross-citation phenomenon between papers occurred more frequently in 2021 and 2022. We use VOSviewer for visual coupling analysis of all keywords, which are automatically clustered into three research hotspots. Using CiteSpace to perform timeline-based keyword cooccurrence analysis, we find that scholars have gone through a "discovery-acceptance-question-improvement" process for the application of blockchain technology in supply chain management. According to the intensity and duration of burst detection words in different years, we draw three key points for future research. (i) Blockchain technology should be used to restructure and optimize the high-end food and medical cold chain supply chains. (ii) Blockchain technology should be used to enhance the cooperative relationship between supply chain members and the overall competitiveness of the supply chain. (iii) Innovate blockchain encryption technology that should be used to reduce the risk of information and privacy leakage in the supply chain.

1. Introduction

The supply chain plays an important role in production and people's lives, as people depend on it for daily necessities. A supply chain is like a bridge, providing a link for the exchange of materials between nature and human beings. Real product information can be shared and traced throughout the supply chain in a timely manner to avoid overproduction. Moreover, blockchain technology can be used to record real data at each node in the entire supply chain to achieve timely data sharing and full traceability throughout the product lifecycle of the supply chain, which not only greatly improves the efficiency of supply chain management but also helps solve the problem of product traceability and accountability in the supply chain. Of course, the timely sharing of product circulation data based on blockchain technology increases the service satisfaction of consumers, which effectively improves overall supply chain competitiveness. Blockchain technology can be widely applied in various supply chain management scenarios (Alam et al. [1]).

For supply chain management, blockchain technology was first applied in the financial field. As early as 2016, Nguyen et al. [2], Huckle et al. [3], Tsai et al. [4], and Singh et al. [5] studied how blockchain technology could contribute to changes and developments in the financial

industry. In 2017, blockchain technology rapidly penetrated the healthcare sector (Kuo et al. [6] and Benchoufi et al. [7]), automotive sector (Drubin [8] and Kennedy et al. [9]), and field of e-commerce (Lee et al. [10] and Zhang and Wen [11]). In the past three years, blockchain technology has been further integrated with the Internet of Things (IoT), artificial intelligence, big data, and 5G technology and not only is used in the medical (Rahmani et al. [12]), food (Ehsan et al. [13]), energy, flower, timber, and automobile supply chains but also plays an important role in land registry management (Shuaib et al. [14–16] and Khalid et al. [17]) and enterprise resource planning (ERP) (Aslam et al. [18]).

With the increasingly extensive application of blockchain technology in supply chain management, faced with numerous previous studies, researchers urgently need to clarify the research context, hotspots, and bottlenecks in the literature to identify a new breakthrough. Literature review papers play an important role in the development and progress of this research field. Many scholars, such as Niknejad et al. [19], have conducted meaningful bibliometric studies including those on blockchain technology in food supply chains (Pandey et al. [20]) and blockchain technology in healthcare (Saeed et al. [21]). The majority of the large number of literature review papers in this area focus on the application of blockchain technology to a specific supply chain. Thus, it is necessary to discuss the application of blockchain technology by including the whole supply chain (Britta et al. [22] and Musigmann et al. [23]). Literature review papers must be timely and novel and present a detailed analysis. Only in this way can such works provide fresh research ideas to later researchers and a basis for the government to formulate relevant policies.

In this study, 591 studies in Web of Science (WOS) from 2017 to 01-01 to 2022-03-15 are selected for systematic analysis, aiming at accomplishing the following objectives. (i) We conduct the most detailed analysis of the targeted literature on the application of blockchain technology to supply chain management, including the number of annual studies, subject areas, funding institutions, and research journals. (ii) Is there collaborative research or independent research among the target literature? We make a judgment by analyzing whether there is a high degree of clustering in different countries/regions or different research institutions. Furthermore, cross-citations between papers and authors can also reflect the degree of cooperation between the target literature. (iii) Use VOSviewer for the cooccurrence network analysis of the keywords, which are automatically clustered into different clusters according to the frequency of occurrence, intimate relationships, and affiliation relationships, and according to these different keyword clusters, we explore the hot spots and difficulties in the application of blockchain technology in supply chain management research from a macroperspective. (iv) Use CiteSpace to conduct timeline-based keywords and burst detection words cooccurrence analysis. We try to explore the innovation and breakthrough points of applying blockchain technology to supply chain management research. The above aims provide some clear ideas for future research direction.

This study is divided into six sections. Section 2 introduces the research background and related concepts in detail. Section 3 describes the specific steps of the research method, including the research question, database selection, retrieval conditions, retrieval process, data screening criteria, and finally 591 target studies. Section 4 makes a systematic bibliometric analysis of the target literature based on four research questions. Section 5 is the discussion. Section 6 presents the summary and prospects.

2. Research Background and Concept Definition

If blockchain technology can prevent information tampering and forgery, then this feature provides a starting point for its application in supply chain management.

Furthermore, the global outbreak of COVID-19 in recent years has provided a new opportunity for the application of blockchain technology in supply chain management. COVID-19 led to the rupture of the global supply chain and large-scale regional blockades (Free et al. [24]), which made the circulation of products in the supply chain difficult. The efficient operation of the food and drug supply chains is directly related to people's lives and health. Blockchain technology escorts the circulation of products in the supply chain, ensuring that they can be delivered to the place of need for the first time and of the appropriate quality and quantity. In view of this, the relevant literature on the application of blockchain technology in supply chain management has mushroomed in recent years.

2.1. Supply Chain. The supply chain first originated from the economic chain proposed by Peter Drucker and then developed into a value chain according to Michael Porter [25], before eventually evolving into its current form. The supply chain has always been a hot spot in management research, and its concept and connotation have been constantly enriched over time. A definition of a supply chain has been widely accepted by scholars. That is, the supply chain involves the following: the core enterprise, through the control of information flow, logistics, and cash flow, from raw materials procurement, made into intermediate and final products, which are finally sent to the hands of consumers through the sales network. The supply chain links suppliers, manufacturers, distributors, and retailers to end users as a whole function net chain structure. The supply chain is the link between nature and human beings and provides a variety of clothing, food, housing, and transportation products and services.

2.2. Supply Chain Management. Supply chain management refers to the planning, coordination, operation, control, and optimization of the entire supply chain system through close cooperation between trading partners to provide the best service at the lowest cost. Effective supply chain management must ensure "5 rights": the right time, right place, right quantity, right quality, and right people. The goal of supply chain management is to establish an efficient supply chain

and create higher value for end users. The implementation of supply chain management means not only that enterprises strive to build strategic alliances but also that they strive to integrate themselves from a management perspective. The bullwhip effect refers to a phenomenon of demand variation amplification in the supply chain. When the information flow is transmitted from the final client to the original supplier, the real information cannot be shared effectively and, thus, becomes distorted and amplified step by step, leading to the increasing fluctuation in demand information in the supply chain, which is the largest obstacle to improving its operational efficiency. The supply chain must introduce new technologies to achieve timely and highly shared real information.

2.3. Blockchain Technology. Blockchain technology is an emerging technology with the features of being distributed, tamper evident, and traceable, it can compensate for the shortcomings of traditional credit systems, prevent information tampering and forgery, and reduce credit costs across society [26]. The concept of blockchain was first proposed by Satoshi Nakamoto in the article "Bitcoin: a Peer-to-Peer Electronic Cash System" [27] and has gradually attracted the attention of scholars in countries worldwide. Blockchain technology is a technical solution that stores, verifies, transfers, and communicates network data by its own distributed nodes without relying on a third party. Moreover, blockchain provides instant, shared, and completely transparent information stored on an immutable ledger that can be accessed only by licensed network members. Furthermore, the advent of a search encryption scheme based on blockchain technology (Xu et al. [28]) has made the circulation of data transmitted through blockchain technology maintain strong commodity demand information.

2.4. Blockchain Technology and Supply Chain Management. The application of blockchain technology has greatly improved the efficiency of supply chain management. Through blockchain technology, all information on the whole lifecycle of products in the supply chain can be recorded, and the obtained information can be shared among the members of the entire supply chain in a timely manner. This immutable information flow effectively alleviates the "bullwhip effect" in the supply chain and ensures that real product demand information is transmitted from consumption to production ends. Blockchain technology not only solves the problem of information distortion in the supply chain but also plays an important role in tracing the source of problematic products in the supply chain. Once the end consumer receives a defective product, the relevant enterprise in the supply chain must be held accountable. Supply chain data that can be falsified lack the necessary information for accountability. Blockchain technology acts as a public ledger that records detailed information about products as they move along the supply chain, providing data support and even a legal basis for the traceability and accountability of problematic products in the supply chain. Information sharing in the supply chain improves consumers' shopping experience, and product traceability enables consumers to buy greener and safer products. Blockchain technology effectively improves supply chain competitiveness, providing a broad prospect for the application of blockchain technology in supply chain management. The action mechanism diagram of blockchain technology applied to supply chain management is shown in Figure 1.

3. Research Methods and Data Selection

Following the practice of Shuaib et al. [29], we obtain the data required in this paper by selecting research methods, putting forward research questions, selecting research databases, setting retrieval conditions, and carrying out data deduplication and purification. Finally, 591 references are obtained. The specific steps are shown in Figure 2.

3.1. Research Methods. We adopt the bibliometrics research method and choose visualization software as a research tool. The visualization software VOSviewer can classify a large number of samples for research. Let us take the example of a keyword cooccurrence analysis for the blockchain technology literature as it applies to supply chain management. VOSviewer can visualize (i) keyword frequency, which is shown by the keyword size in the graph, (ii) keyword affinity, which is shown by the distance among the keywords in the graph, and (iii) whether the keywords belong to the same cluster, which is shown by the keyword colour in the graph. Compared to VOSviewer, CiteSpace has the advantages of performing a keyword cooccurrence analysis based on timelines and determining the burst detection words in each period, which allows us to visualize the hotspots and difficulties of the research in each period. Therefore, VOSviewer and CiteSpace are selected as the research tools in this study to capitalize on the advantages of both.

3.2. Research Problems. Aiming at the research objectives of this study, we propose four research questions accordingly. In the following, the bibliometric study on the target literature will focus on how to solve these four problems.

> Question 1: what are the distribution characteristics of the target literature in the research years, subject areas, and research journals?
>
> Question 2: is there collaborative research or independent research among the target literature? Specifically, it includes the following. (i) Is there any cooperative research among different countries/regions? (ii) Is there collaborative research between different institutions? (iii) Is there cross-citations among study authors? (iv) Is there cross-citations among highly cited papers?
>
> Question 3: what are the research hotspots of blockchain technology applied to supply chain management (based on keyword clustering analysis)?

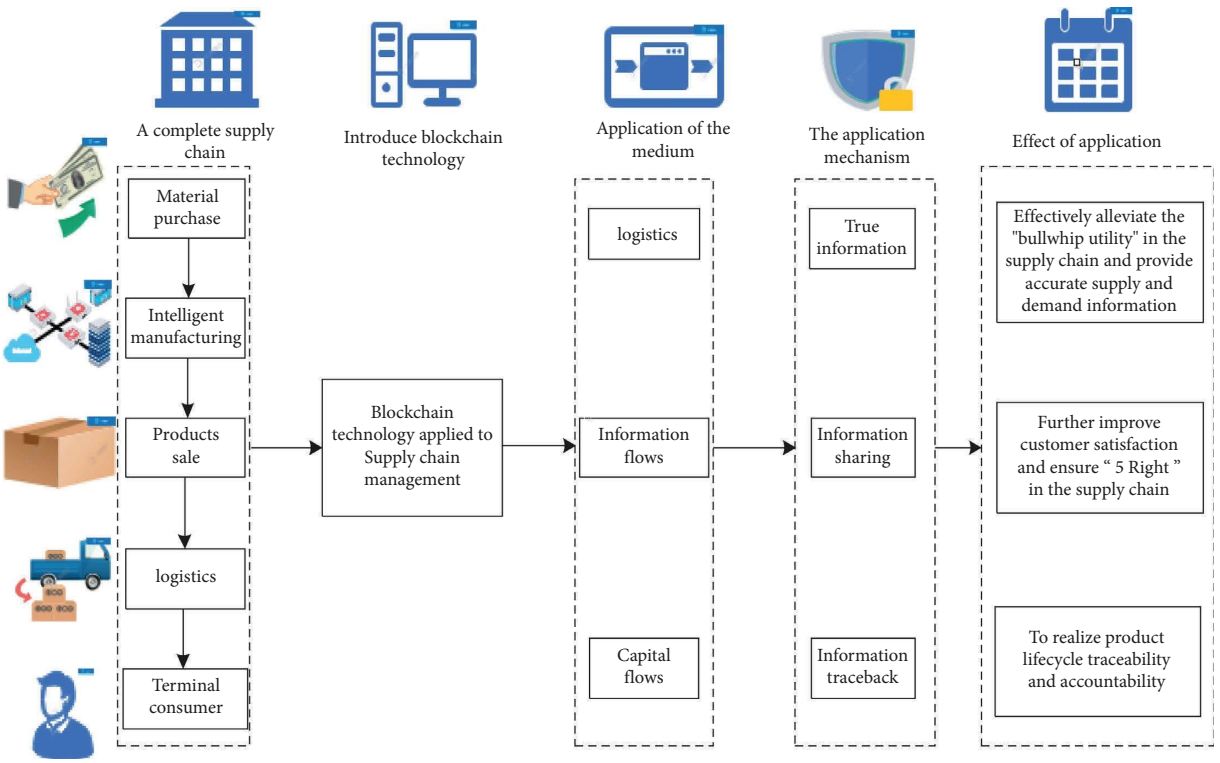

Figure 1: Action mechanism diagram of blockchain technology applied in the supply chain management.

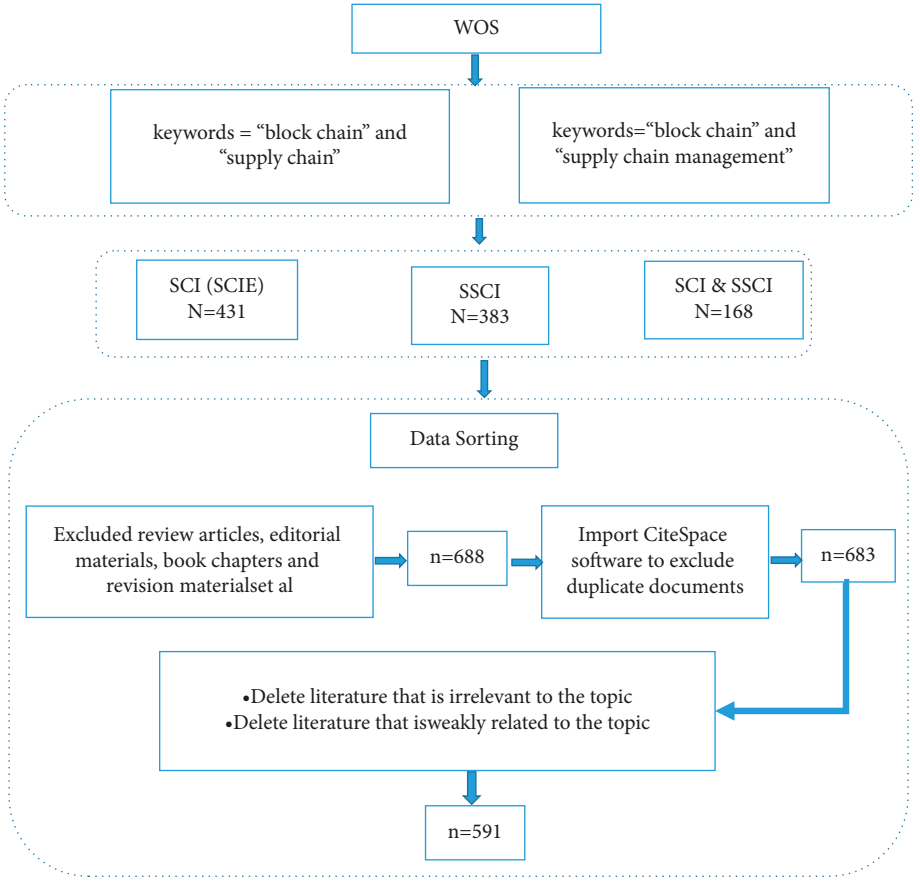

Figure 2: Flowchart of target document acquisition.

Question 4: what are the innovations and breakthroughs in different years (based on keywords and burst detection words analysis)?

3.3. Data Acquisition. On March 15, 2022, we selected the WOS core collection database as the literature source. The selection criteria are (keywords = "blockchain" and "supply chain") or (keywords = "blockchain" and "supply chain management"). The search time span was 6 years, from 2017 01-01 to 2022-03-15 (note: the studies in Science Citation Index (SCI), Science Citation Index Expanded (SCIE), and Social Sciences Citation Index (SSCI) in the WOS for this topic are available from 2017 and on). A literature search yielded 814 initial documents meeting the above requirements.

3.4. Data Selection. This study conducts data selection in three steps. Step 1: the search results were sorted according to the subject correlation, and we excluded review articles, editorial materials, book chapters, and revision materials, for a total of 688 articles. Step 2: to eliminate the interference of duplicate works in this study, we imported the 688 studies into CiteSpace to purify them, eliminated the duplicate studies, and finally obtained 683 required studies. Step 3: following the practice of Chakraborty et al. [30], we further screened 683 studies individually by year and carefully read the title, abstract, keywords, research direction, and text. We removed (i) papers irrelevant to the topic and (ii) papers only weakly related to the topic. The judgment criteria for weak correlations were as follows: LR1: "blockchain" and "supply chain" were found only in cited expressions, LR2: "blockchain" and "supply chain" were seen only in keywords or references, LR3: "blockchain" or "supply chain" was seen only in problem definitions, and LR4: any of the above in combination. After selection, 591 articles were obtained. Each selected study contained information such as paper title, author, author unit, publication, country/region, keywords, abstract, publication date, and references. Journal articles were the main literature types. These studies were imported into CiteSpace and VOSviewer in plain text file format for processing. All of the following analyses are based on these 591 articles. The inclusion and exclusion criteria for material selection are shown in Table 1.

Table 1: Inclusion and exclusion criteria for material selection.

Year	2017	2018	2019	2020	2021	2022	Total
Inclusion	4	20	80	198	331	50	683
Exclusion	1	2	10	34	39	6	92
Actual	3	18	70	164	292	44	591

4. Bibliometric Analysis of Blockchain Technology Applied in Supply Chain Management

Question 1: what are the distribution characteristics of the target literature in the research years, subject areas, and research journals?

4.1. Distribution Characteristics in the Research Years. Because the SCI (SCIE) and SSCI works on blockchain technology as it applies to supply chain management were included in WOS starting in 2017, the research period was relatively short: from 2017 01-01 to 2022-03-15. To better show the research trend on blockchain technology as it applies to supply chain management, we used the trend function to forecast the quantity of studies in 2022. The predicted value was 376 before excluding the interfering literature, and the actual value was 312 after excluding this literature. This result is shown in Figure 3. As a whole, in 2017 and 2018, the number of studies on blockchain technology as it applies to supply chain management did not increase significantly. Starting in 2019, the number of such studies started to grow significantly. In 2021, approximately 300 studies were published. Blockchain technology solves the challenge of full traceability in the supply chain, based on which it establishes a trust mechanism. Especially at the present time, when the world is facing COVID-19, new technology such as blockchain can be widely applied to medical and food supply chains to safeguard people's lives. In view of this special situation, more scholars are likely to devote themselves to researching blockchain technology as it applies to supply chain management in the coming years.

4.2. Distribution Characteristics in the Subject Areas. The 591 papers in this work on blockchain technology as it applies to supply chain management cover 68 subject areas, the top 10 of which are shown in Figure 4. Among them, 158 papers (17%) belong to computer science information systems, followed by operations research management science (12%), electrical and electronic engineering (12%), telecommunications (11%), and industrial engineering (11%). These four fields of study accounted for 46% of the articles published, had approximately the same number of articles, and had a weight of more than 10%. As the international situation has changed, the price of oil in some countries/regions has soared, and the green low-carbon supply chain has become more popular. Thus, more scholars are expected to conduct research on the application of blockchain technology in supply chain management in environmental sciences, environmental studies, green sustainable science technology, and other disciplines in the future.

4.3. Distribution Characteristics in the Research Journals. We performed a bibliometric analysis of blockchain technology as it applies to supply chain management, one particularly important task of which was to perform a descriptive statistical analysis of the publishing journals. Table 2 shows the top ten journals in terms of the contribution rate. These journals had a cumulative volume of 255 articles, accounting for 43% of the 591 articles. This result demonstrates that these top ten journals were the major publishing journals for blockchain technology as it applies to supply chain management and that they made significant contributions to article published in this field. The journal with the

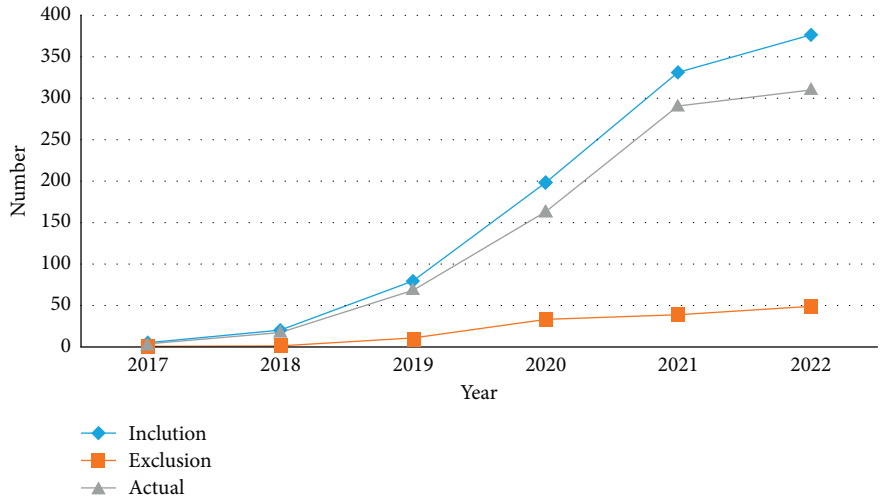

Figure 3: Publication volume of the target studies from 2017 to 2022.

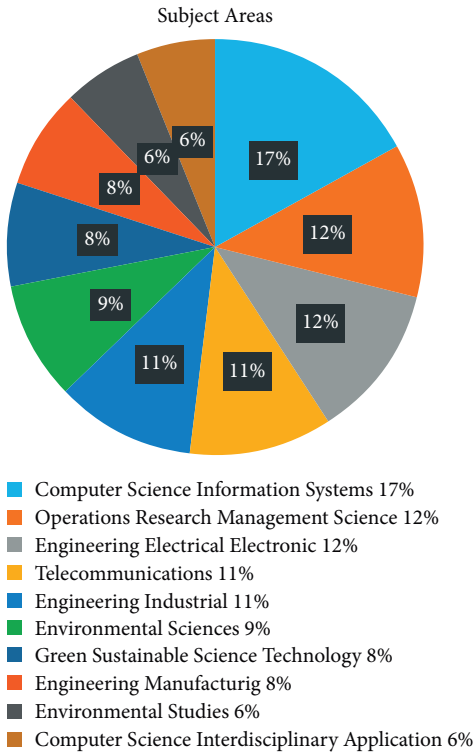

Figure 4: Contributions and proportions of the top 10 subject areas.

highest number of publications was IEEE Access, with a cumulative total of 57 articles. The second largest contributor was sustainability, with 55 articles. Overall, the annual publication volume of major journals in 2021 increased significantly compared to that in the previous year. The application and research of blockchain technology continue to emerge, and we expect the number of publications in 2022 to increase compared to that in 2021.

Question 2: is there collaborative research or independent research among the target literature? Specifically, it includes the following. (i) Is there any cooperative research among different countries/regions? (ii) Is there collaborative research between different institutions? (iii) Are there cross-citations among study authors? (iv) Are there cross-citations among highly cited papers?

4.4. Research Countries/Regions. From a worldwide perspective, the number of studies on the topic of blockchain technology as it applies to supply chain management differed significantly across different countries/regions. Table 3 shows that China published a total of 210 such studies, which makes it the country with the largest contribution to blockchain technology as it applies to supply chain management. Moreover, the 210 Chinese studies received 406 grants from 246 funding agencies; as the average number of grants received per study was 1.93, it can be seen that China had a higher number of studies than other countries/regions. The US, which ranks second in terms of the contribution rate, published 118 papers related to the research topic, with an average of 1.2 grants per article. At the same time, we found that the funding for the target literature was mainly from the official government funding institutions and supplemented by private funding institutions. From this finding, we speculate that the application of blockchain, a new technology, has a certain national orientation. When one country/region provides more financial support for the application of blockchain technology in supply chain management compared to other countries/regions, it produces more papers on the topic.

Scholars from different countries/regions are increasingly jointly publishing certain works. Figure 5 shows the coupling between different countries/regions, which is based on three points: (i) the number of collaborations between countries/regions, (ii) the affinity between different countries/regions, and (iii) whether different countries/regions belong to the same cluster category. We obtained five major countries/regions' cooperative networks of blockchain technology as it applies to supply chain management. (i) The red cluster class has China as its core, and the country is

Table 2: Top 10 most productive journals.

Journal (year)	IEEE	SUS	IJPR	SEN	AOR	TRPELTR	CIE	JCP	IJPE	ASB
2017	1									
2018	2	4		1						
2019	14	2	7	1		4	5	1	2	1
2020	18	12	12	4	3	6	3	3	4	
2021	21	31	14	9	10	7	7	11	7	8
2022	1	6	3	3	4					3
Total	57	55	36	18	17	17	15	15	13	12

IEEE, IEEE Access; SUS, sustainability; IJPR, International Journal of Production Research; SEN, sensors; AOR, Annals of Operations Research; TRPELTR, Transportation Research Part-e Logistics and Transportation Review; CIE, Computers Industrial Engineering; JCP, Journal of Cleaner Production; IJPE, International Journal of Production Economics; ASB, Applied Sciences Basel.

Table 3: Top 10 most productive countries/regions (based on any author of an article).

Country/region	NA	Proportion	NOFI	TFI	TNF	TNF/NA
PEOPLE'S *R* CHINA	210	0.327	National natural science foundation of China (NSFC)	246	406	1.93
US	118	0.184	National science foundation (NSF)	108	142	1.20
INDIA	76	0.118	Department of science & technology (India)	34	36	0.47
ENGLAND	62	0.096	UK research & innovation (UKRI)	35	53	0.85
AUSTRALIA	40	0.062	Australian government	26	32	0.80
ITALY	32	0.050	Italian ministry of agriculture (MiPAAF)	17	18	0.56
SOUTH KOREA	32	0.050	National research foundation of korea	36	46	1.44
CANADA	29	0.045	Natural sciences and engineering research council of Canada (NSERC)	28	33	1.14
FRANCE	23	0.035	European commission	15	15	0.65
GERMANY	21	0.032	German research foundation (DFG)	11	11	0.52

NA : number of articles; NOFI : number-one funding institution; TFI : total number of funding institutions; TNF : total number of funding sources; PEOPLE'S R CHINA : The People's Republic of China.

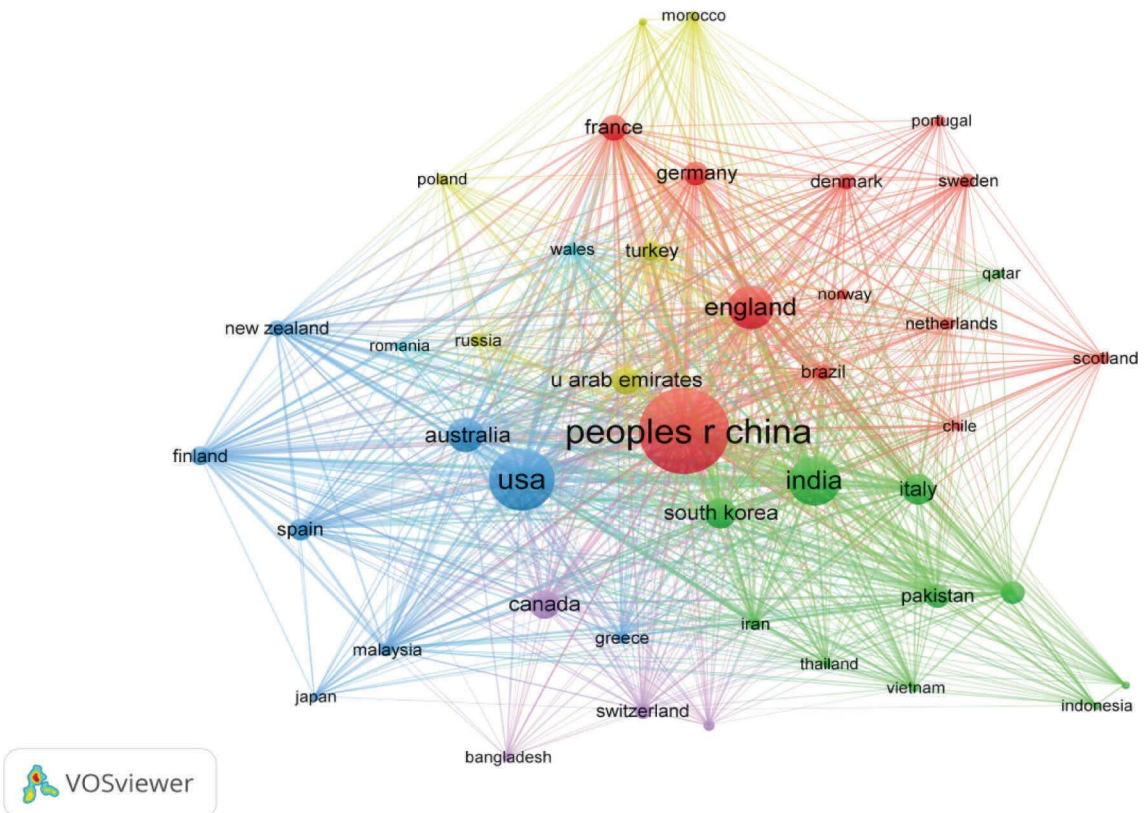

Figure 5: Cooccurrence maps of those countries/regions with a threshold of 2 articles (peoples *r* China: The People's Republic of China).

Table 4: Top 10 most productive research institutions.

Journal (year)	HKPL	KUST	WPI	NITNS	UOHK	SZU	CAS	HKSE	KSU	USG
2017										
2018			1							
2019	4	2	3	1		1		1		1
2020	7	4	3	4	6	2	2	2	3	2
2021	9	10	7	8	4	5	6	6	5	5
2022	1	1			1	2	1		1	1
Total	21	17	14	13	11	10	9	9	9	9

HKPL, Hong Kong Polytechnic University; KUST, Khalifa University of Science Technology; WPI, Worcester Polytechnic Institute; NITNS, National Institute of Technology; UOHK, University of Hong Kong; SZU, Shenzhen University; CAS, Chinese Academy of Sciences; HKSE, Hanken School of Science and Technology; KSU, King Saud University; USG, University System of Georgia.

closely connected with 3 other countries/regions, including the UK, France, and Germany. (ii) The blue cluster has the US as its core and has close ties with Australia, Spain, and other countries/regions. (iii) The green cluster has India as its core and is closely linked with Italy, South Africa, and other countries/regions. (iv) The purple cluster has Canada as its core. (v) The yellow cluster has the United Arab Emirates as its core. The above findings also exhibit a new round of blockchain technology discovery, which has triggered a global research boom that is unlike the First and Second Industrial Revolutions, which were led by one or a few countries/regions. Blockchain technology is the result of national cooperation and can occur in various countries/regions worldwide at the same time.

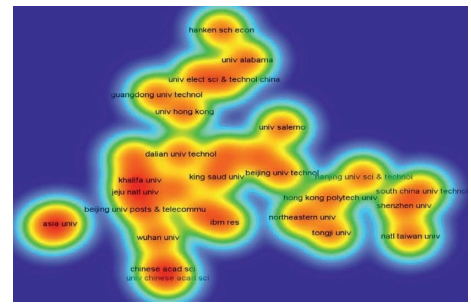

Figure 6: Institutional cooperative network analysis based on a literature coupling with a threshold of 3 articles.

4.5. Research Institutions. On the topic of the application of blockchain technology to supply chain management, we analyzed the top 10 research institutions contributing to this research area, as shown in Table 4. At the macrolevel, all of the articles published by the top 10 contributing institutions were published after 2019, and only the Worcester Polytechnic Institute published an article in 2018. This finding indicates that many research institutions started researching this topic relatively late. These institutions produced very high volumes of literature despite their short research periods. The lead contributing institution is Hong Kong Polytechnic University, which has published 21 articles in the past 4 years. The second highest contributor is the Khalifa University of Science Technology, with 17 articles. Worcester Polytechnic Institute, the third highest contributor, has published 14 articles. These findings indicate that the core research institutions engaged in more in-depth research on blockchain technology applications in supply chain management and produced a large number of high-quality articles in a shorter time.

A single research institution is often unable to break through its own bottleneck when conducting research on blockchain technology as it applies to supply chain management. Cooperation among institutions has become a necessary tool for the deep development of blockchain technology. We used VOSviewer to analyze the network of institutional cooperation and establish a connection between institutions through "bibliographic coupling." The results are shown in Figure 6, which exhibits four major institutional cooperation networks. (i) The largest collaborative network is that, with the Khalifa University of Science Technology as its core, and the common research theme is the integration of blockchain and IOT technology in supply chain management. The main research areas in this network are the intelligent manufacturing, medical, agricultural food, and financial industries. (ii) The second largest institutional cooperation network is that, with the University of Electronic Science and Technology of China as its core, the joint research theme of which is architecture design for blockchain implementation, and the main research areas of which are the transportation and logistics industry and the circular economy industry. (iii) The third largest cooperative network of institutions is that, with Hong Kong Polytechnic University as its core, the joint research theme of which is blockchain technology applied to Industry 4.0, which can solve the COVID-19 pandemic problem; the main research areas of this cooperative network are the e-commerce and supply chain finance fields. (iv) The fourth largest institutional cooperation network is that, with Shenzhen University as its core, its most researched field is the medical industry, and its common themes are the application of blockchain technology in green supply chains and the government's regulation of blockchain technology. Different cooperative institutions have different research fields, content, and methods, the details of which are described in Table 5.

4.6. High Yield Authors and Cross-Citations between Them. In our statistical analysis of the authors of articles on the application of blockchain technology in supply chain management, we found a particularly interesting

Table 5: Four major institutional cooperative networks.

SN	Core institution	Other institutions	CRF	CRT
1	Khalifa University of Science Technology	Chinese Academy of Sciences; Wuhan University; King Saud University; Jeju National University; Beijing university of posts telecommunications, etc.	Intelligent manufacturing industry [31–34]; medical industry [35–38]; agricultural food industry [39–42]; financial industry [43–45]	Fusion of blockchain and IOT technology [46–50]
2	University of Electronic Science and Technology of China	University of Hong Kong; Hanken School of Economics; Guangdong University of Technology; University of Alabama system	Transportation and logistics industry [51–55]; circular economy industry [56–58]	Architecture design for blockchain implementation [59–63]
3	Hong Kong Polytechnic University	Tongji University Nanjing University of Science Technology; Northeastern University China	E-commerce field [64–66]; supply chain finance field [67–69]	Blockchain technology applied to industry 4.0 [70, 71]; blockchain technology solving the COVID-19 pandemic problem [72, 73]
4	Shenzhen University	South China University of Technology; National Taiwan University	Medical industry [74–76]	Green supply chain [77, 78]; government regulation [79, 80]

SN, serial number; CRF, common research field; CRT, common research topics.

Table 6: Top 10 authors and their information (based on the corresponding author).

Author	TNPPCA	TNPPAA	Issuing unit	Research direction
Jayaraman, R	9	15	Khalifa Univ.	Computer science; engineering; telecommunications
Choi, TM	5	10	Natl Taiwan Univ.; Hong Kong Polytech Univ.	Operations research & management science
Sarkis, J	4	12	Worcester Polytech Univ.; Hanken Sch. Econ.	Science & technology - other topics; environmental sciences & ecology
Yaqoob, I	4	7	Khalifa Univ.	Computer science; engineering; telecommunications
Tanwar, S	4	5	Nirma Univ.	Telecommunications
Nandi, S	3	3	Appalachian State Univ.	Science & technology - other topics; environmental sciences & ecology
Gunasekaran, A	2	5	Calif State Univ.	Operations research & management science
Li, X	2	4	Hong Kong Polytech Univ.	Construction & building technology; engineering
Bai, CG	2	3	Univ. Elect Sci & Technol. China	Engineering operations; research & management science
Luo, SY	2	3	Shenzhen Univ.	Business & economics; engineering; operations research & management science

TNPPCA, total number of papers published as a corresponding author; TNPPAA, total number of papers published as any author.

phenomenon. Jayaraman, *R*, Salah, K, Omar, *M,* and other authors formed a research group and copublished numerous articles as cofirst authors. Therefore, to fully reflect the authors' contributions to blockchain technology as it applies to supply chain management, we counted the number of publications based on the corresponding authors. Table 6 shows the top ten authors in terms of their contribution rates. The author with the most publications was Jayaraman, *R*, who published 15 papers, 9 of which as a corresponding author. This finding indicates that individual authors were relatively thorough in their research on the application of blockchain technology in supply chain management. The main research content was as follows: (i) traceability of the supply chain with blockchain technology, including the traceability of medical drugs [81, 82] and soybeans [83], and (ii) blockchain smart contracts [84–86]. Choi, TM, whose research was very broad, ranked second in terms of the number of posts, applied blockchain technology to finance, logistics, e-commerce, health care, etc. The 3rd-ranked author was Sarkis, *J*, whose research focused on blockchain technology and sustainable supply chains [87, 88]. We identified the top 10 authors in terms of contribution rate, each with its own research focus and direction. We used VOSviewer to plot the cocitation analysis between authors, as shown in Figure 7. This plot shows that the cross-citation level among authors with a high contribution rate was very low. The top ten contributing authors had very few cross-citations with other authors. This finding further verified our view that, in the field of blockchain technology as it applies to supply chain management, authors with high contribution rates tend to engage in their own "unique" research.

4.7. Highly Cited Papers and Cross-Citations between Them. The number of citations of a paper reflects its recognition by peers and its importance in a certain research field. In the research field of blockchain technology, as it applies to supply chain management, the ten articles with the highest number of citations are shown in Table 7. Overall, three of these ten articles were published in 2018, and five were published in 2019. The most frequently cited article (590 times) was "blockchain technology and its relationships to

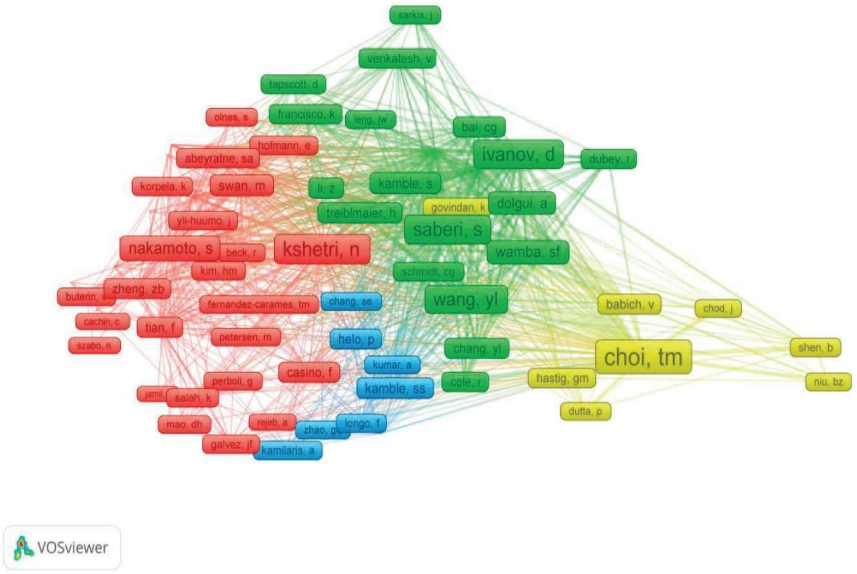

Figure 7: Co-citation analysis atlas among high-contributing authors with a citation threshold of 20.

Table 7: Top 10 most frequently cited papers.

Title	First author	Year	TC	TC/year
Blockchain technology and its relationships to sustainable supply chain management	Saberi, S.	2019	590	147.5
Blockchain's roles in strengthening cybersecurity and protecting the privacy	Kshetri, N.	2017	186	31
Understanding the blockchain technology adoption in supply chains-indian context	Kamble, S.	2019	178	44.5
The rise of blockchain technology in agriculture and food supply chains	Kamilaris, A.	2019	165	41.25
Making sense of blockchain technology: how will it transform supply chains?	Wang, Y.	2019	164	41
A novel blockchain-based product ownership management system (POMS) for anti-counterfeits in the post supply chain	Toyoda, K.	2017	159	26.5
The mean-variance approach for global supply chain risk analysis with air logistics in the blockchain technology era	Choi, *T.*	2019	138	34.5
Research on agricultural supply chain system with double chain architecture based on blockchain technology	Leng, *J.*	2018	138	27.6
Blockchain in logistics and supply chain: A lean approach for designing real-world use cases	Perboli, *G.*	2018	132	26.4
Blockchain practices, potentials, and perspectives in greening supply chains	Kouhizade, *M.*	2018	126	25.2

The total number of citations

sustainable supply chain management" [87], written by Saberi, S, with an average of 147.5 citations per year. The research topic of this article is how blockchain technology can contribute to sustainable supply chain development. Realizing the sustainable development of green and low-carbon supply chains with the help of blockchain technology is one of the focuses of future research. The focus on this area was brought about by a series of factors, including political and economic factors as well as the need for environmental protection. Kamilaris et al. [89] and Leng et al. [90] studied the application of blockchain technology in agricultural supply chains, while Choi et al. [91] and Perboli et al. [92] studied the integration of blockchain technology in logistics supply chains. To verify whether the top ten most frequently cited papers also had a high degree of cross-citation, we used VOSviewer to perform an analytical mapping of the cross-citations, as shown in Figure 8. There are cross-citations among Saberi et al. [89], Choi et al. [93], and Wang et al. [93] in the top ten most highly cited papers, but their degree of cross-citation is not high. Overall, most of the papers with a very high degree of cross-citation were published in 2021 and 2022; these include Kouhizadeh et al. [94], Casino et al. [95], Liu et al. [96], Kayikci et al. [97], and Wamba et al. [98]. This finding suggests that new authors in the field of blockchain technology application in supply chain management prefer to read the articles of their predecessors and then innovate based on their reading.

Question 3: what are the research hotspots of blockchain technology applied to supply chain management (based on keyword clustering analysis)?

The keywords of an article summarize the research content, method, and field of the article. We used VOSviewer to analyze the 591 articles on the application of blockchain technology in supply chain management by keyword clustering according to (i) keyword frequency, (ii) keyword affinity, and (iii) whether the keywords belonged to

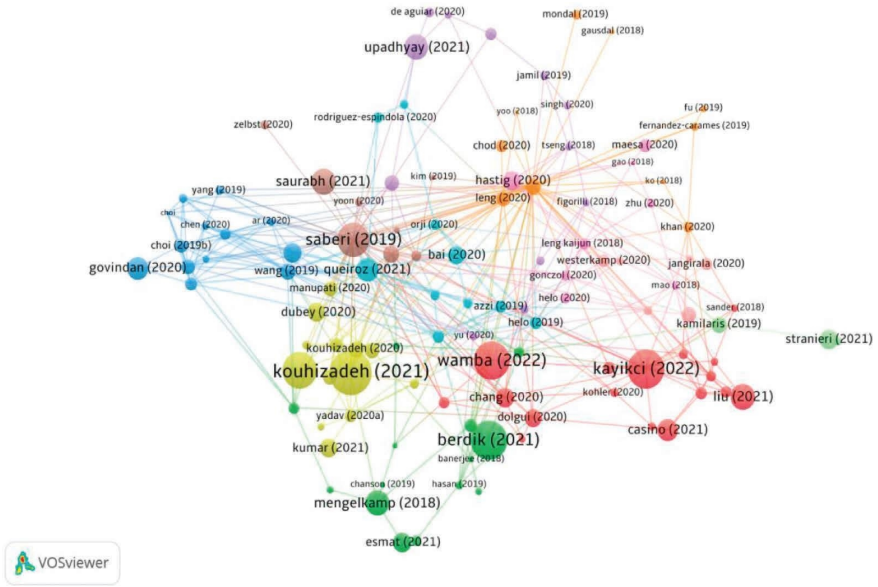

Figure 8: Co-citation analysis atlas is among the most frequently cited papers with a citation threshold value of 20.

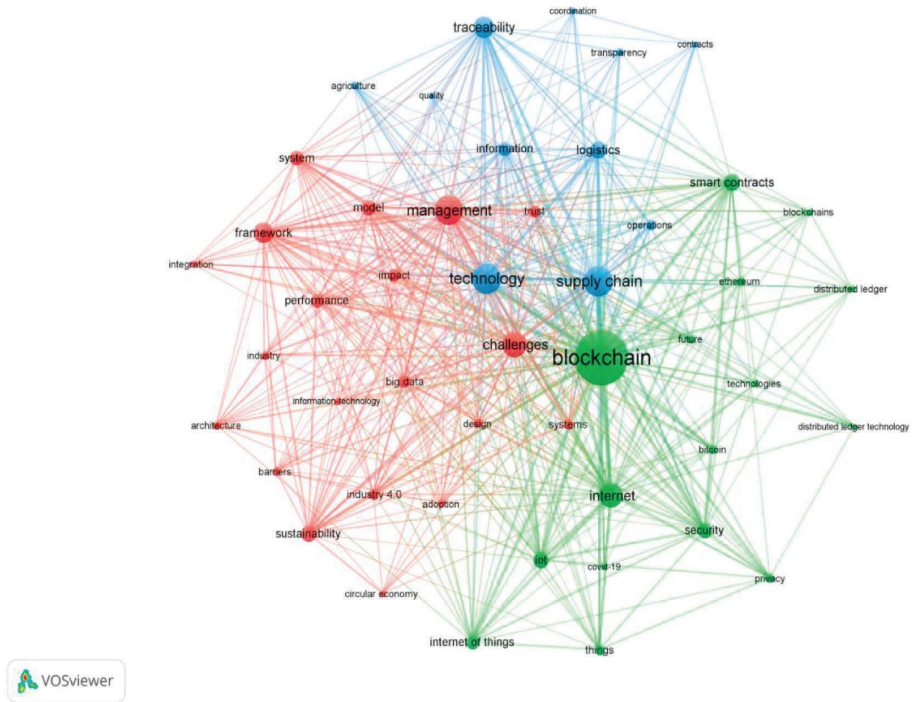

Figure 9: Co-occurrence network analysis of author keywords with a threshold value of 10 occurrences.

the same cluster. Since scholars have been studying the application of blockchain technology in supply chain management for only a short time, the research content is rather scattered. To better capture the research hotspots and thus cluster the keywords, we set the minimum number of keyword occurrences to 10 and obtained a keyword cooccurrence map, as shown in Figure 9. The hotspots of blockchain technology as it applies to supply chain management can be divided into three major clusters for analysis: (i) "blockchain" as the core of the green cluster, (ii) "supply chain" as the core of the blue cluster, and (iii) "management" as the core of the red cluster.

4.7.1. "Blockchain" as the Core of the Green Cluster. In the green cluster category, the keyword "blockchain" is the core. The three keywords that were most closely related to it and that appeared in the largest proportion were "Internet," "smart contracts," and "security." It could be seen that the research hotspots of scholars on green clusters focus mainly

on the following. (i) "Blockchain and Internet": in fact, scholars were more interested in studying the integration of blockchain technology with the Internet and the IoT to jointly improve the overall efficiency of the supply chain; examples include Sultan et al. [99], Banerjee [100], Azizi et al. [101], and Zhang et al. [102]. (ii) Regarding "blockchain smart contracts," Omar et al. studied their application in supply chain procurement management [103] and inventory management [86]. Other scholars studied the application of blockchain smart contracts in supply chain gaming (Giovanni [104] and Grida et al. [105]). (iii) Regarding "blockchain and security," some scholars (Jiang et al. [106] and Zulkifli et al. [107]) argued that blockchain technology ensures the security of information transfer in the supply chain. Another group of scholars (Bakiras et al. [108] and Shahzad et al. [109]) argued that blockchain technology as it applies to supply chain management continues to have security vulnerabilities, such as being subject to cyberattacks. Therefore, blockchain technology is a double-edged sword, and thus, its application and popularity still face many challenges.

4.7.2. "Supply Chain" as the Core of the Blue Cluster. In the blue cluster, the keyword "supply chain" is the core. The three keywords that are most closely related to it and have the largest occurrence proportion are "technology," "logistics," and "traceability." It could be seen that the research hotspots of scholars on the blue cluster focus mainly on the following. (i) "Supply chain and technology:" the research theme of this paper is the application of blockchain technology in supply chain management, so the keyword "technology" appeared more frequently and was closely related to "supply chain." The technology in the sample literature referred mainly to blockchain technology, so we do not repeat it here. (ii) Regarding "supply chain and logistics," many scholars believe that logistics are subordinate to the supply chain and that supply chain management is the conceptual extension and expansion of logistics management. The supply chain includes logistics, capital flow, and information flow. Some scholars have studied blockchain technology for green logistics or green supply chain services (Kouhizadeh et al. [110] and Diniz et al. [111]), while other scholars have studied the application of blockchain technology in the logistics of products derived from e-commerce (Gao et al. [112] and Chen et al. [113]). Other scholars have studied blockchain and logistics finance or supply chain finance (Li et al. [114]). (iii) The topic "supply chain and traceability" examines how the introduction of blockchain technology enables the timely traceability in the supply chain. A large number of scholars have studied the application of blockchain technology in food supply chain traceability (Demestichas et al. [115] and Tharatipyakul et al. [116]), textile supply chain traceability (Ahmed et al. [117] and Agrawal et al. [118]), and pharmaceutical supply chain tracing (Uddin et al. [119]). In addition, a small group of scholars studied blockchain to improve the transparency of the supply chain through traceability (Sunny et al. [120]).

4.7.3. "Management" as the Core of the Red Cluster. In the red cluster category, the keyword "management" is the core. The three keywords that are most closely related to it and have the largest occurrence proportion are "challenges," "framework," and "sustainability." It could be seen that the research hotspots of scholars on the red cluster focus mainly on the following. (i) "Management and challenges:" most scholars believe that the application of blockchain technology in supply chain management is a matter of both opportunities and challenges (Chang et al. [121], Ahmad et al. [122], and Pd et al. [123]). Other scholars believe that blockchain technology introduces profits into supply chain management (Hackius et al. [124] and Katsikouli et al. [125]). A few scholars have studied the challenges of the digital transformation of supply chains (Rauniyar et al. [126]). (ii) Regarding "management and framework," the framework design of the application of blockchain technology to supply chain management is a hot research topic for scholars. Moreover, Wang et al. [127] and Rodrigues et al. [128] researched the abovementioned theoretical framework, while Wang et al. [129] and Vu et al. [130] researched the system framework. Additionally, Shoaib et al. [131] and Boutkhoum et al. [132] researched the ensemble framework. (iii) Regarding "management and sustainability," Esmaeilian et al. [133] studied blockchain technology to help achieve sustainability in supply chains, and Bickel et al. [134] studied how blockchain technology can achieve the sustainable development of supply chains by promoting a circular economy.

Question 4: what are the innovations and breakthroughs in different years (based on keywords and burst detection words analysis)?

4.8. Research Innovations and Breakthroughs Based on the Timeline. We used CiteSpace, V.5.8. R3, to perform keyword clustering analysis on the target literature and drew a timeline-based keyword cooccurrence map, as shown in Figure 10. The results show that the clustering module value was $Q = 0.7265$ and that the clustering means profile value was $S = 0.9237$, which clearly demonstrates the credibility of the clustering results. Figure 10 shows the core keywords for each year. To further study the shift in research hotspots each year, we used CiteSpace to determine the top 20 burst detection words, as shown in Table 8. Considering the core keywords and burst detection words together, we conducted a research trend analysis by year. Considering that the time span of the target literature was from 2017 to 2022, that the number of studies in 2017 was very small, and that the time span of the available literature in 2022 was short, 2017 and 2022 were excluded. We selected four full years (2018, 2019, 2020, and 2021) for the research trend analysis. After systematic analysis, we found that scholars have gone through a "discovery-acceptance-question-improvement" process for the application of blockchain technology in supply chain management research.

4.8.1. Analysis of the Research Innovations in 2018: Discovery. Table 8 shows that the burst detection words in 2018 were "origin" and "technology," which were also the core

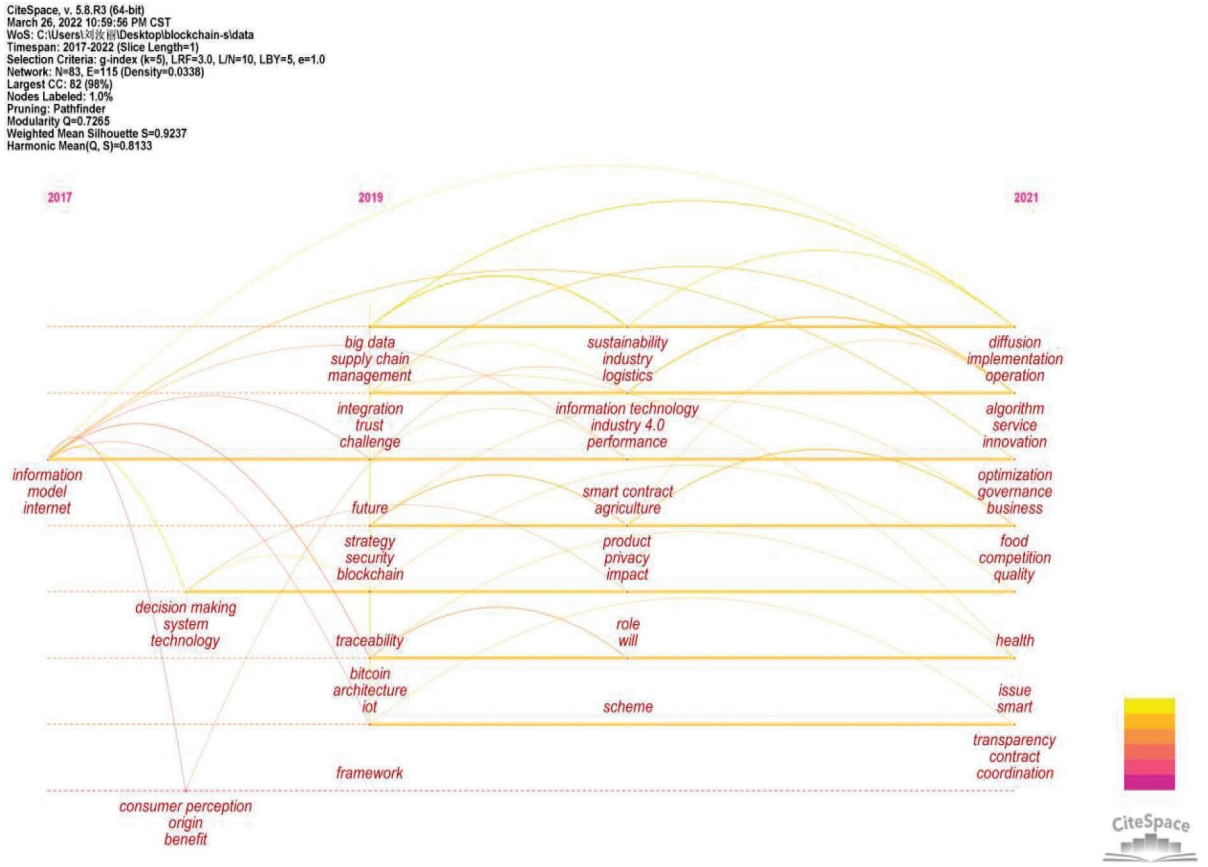

Figure 10: Timeline-based co-occurrence map with a threshold value of 5 occurrences.

Table 8: Top 20 keywords with the strongest citation bursts.

Keywords	Year	Strength	Begin	End	2017–2022
Technology	2017	1.61	2018	2019	
Origin	2017	1.35	2018	2018	
Green	2017	0.99	2018	2018	
Internet	2017	3.19	2019	2019	
Framework	2017	1.31	2019	2019	
Quick response	2017	1.23	2019	2019	
Antecedent	2017	1.16	2019	2019	
User acceptance	2017	1	2019	2019	
Integration	2017	1	2019	2019	
Acceptance model	2017	1	2019	2019	
Security	2017	0.92	2019	2019	
Risk	2017	1.7	2020	2020	
Uncertainty	2017	1.28	2020	2020	
Capability	2017	0.9	2020	2020	
Smart contract	2017	0.85	2020	2020	
Mutual authentication	2017	0.85	2020	2020	
Impact assessment	2017	0.85	2020	2020	
Competition	2017	0.96	2021	2022	
Transparency	2017	0.96	2021	2022	
Health	2017	0.85	2021	2022	

keywords in 2018, as shown in Figure 10. In 2018, blockchain technology, as it applies to supply chain management research, began to be studied. Kouhizadeh et al. [110] explored the potential and prospects of blockchain technology applications. Scholars started to apply blockchain technology to supply chain management in various industries and made some initial explorations: Cartier et al. [135] in the gem industry, Mao et al. [136] in the agricultural industry,

Figorilli et al. [137] in the wood industry, and Ko et al. [138] in the manufacturing industry. The other two core keywords in 2018 were "consumer perception" and "benefit." Blockchain technology solves the information asymmetry problem for supply chain stakeholders, among which customers are certainly one type. Mao et al. [139], Sander et al. [140], and Kumar et al. [141] studied how blockchain technology could establish an information trust mechanism among supply chain stakeholders. A few scholars also studied green supply chains during the year, which were analyzed in the previous section and thus are not repeated here. Up until 2018, scholars made some preliminary explorations regarding blockchain technology being applied in supply chain management and discussed its novelty, putting forward some expectations and visions for its future development.

4.8.2. Analysis of the Research Innovations in 2019: Acceptance. Table 8 shows that there was a burst detection word, "Internet," in 2019, along with the core keywords "IoT" and "big data." This finding demonstrates that many scholars were working on blockchain technology along with other advanced technologies (including the Internet, the IoT, and big data) for supply chain management in 2019 [100]. The burst detection word "security" [106] is elaborated in Section 4.8.1, while the burst detection word "framework" [121] is described in Section 4.8.3. Two other burst detection words for 2019 were "quick response" and "user acceptance." The rapid response, high information sharing, timely traceability, and other services of the supply chain have greatly improved customer satisfaction (Tijan et al. [142]), making logistics services more in line with consumer expectations (Narayanaswarni et al. [143]). "Integration" appeared as both a core keyword and a burst detection word in 2019, indicating that supply chain integration was a research focus in that year. According to Ferdous et al. [144], Tsang et al. [145], and Rahmanzadeh et al. [146], blockchain, as a breakthrough technology, enables a high level of supply chain integration. In that year, blockchain technology was applied more broadly, and a large number of scholars emerged to study the application of blockchain technology in supply chain management in many industries. Blockchain technology was applied to cross-border trade by Chang et al. [147], the food industry by George et al. [148], maritime trade by Yang et al. [149], the medical industry by Mackey et al. [150], and the automotive industry by Sharma et al. [151]. In 2019, scholars made many meaningful explorations on the research theme of the application of blockchain technology in supply chain management, replicating its successful application in the supply chain in one industry to many other industries.

4.8.3. Analysis of the Researchinnovations in 2020: Question. The number of articles on blockchain technology, as it applies to supply chain management, surged in 2020, with 164 articles. The core keywords of that year, "smart contract" and "sustainability," are described in Section 4.8. One burst detection word for 2022 was "impact assessment," while "impact" was the core keyword for that year. Farooque et al. [152] suggested that blockchain technology could greatly improve the effectiveness and efficiency of product lifecycle assessment in the supply chain. Moreover, Kohler et al. [153] and Longo et al. [154] assessed the impact of blockchain on the food supply chain, while Zarour et al. [155] assessed the impact of blockchain on the healthcare supply chain, proving that the impact of blockchain technology on the supply chain had been further expanded. The advantages of blockchain technology as a distributed ledger that applies to supply chain management are well known, but some scholars have questioned whether the high level of information sharing in the supply chain leads to uncertainty risks such as those related to personal privacy leakage. The two words revealed by the burst detection to have the greatest intensity in 2020 were "risk" and "uncertainty," while "privacy" was the core keyword of that year. According to Lu et al. [156], individual privacy in the supply chain is not adequately protected. Yu et al. [157] suggested that personal privacy disclosure is one of the most serious challenges in blockchain technology applications. The illegal disclosure of private user data can cause damaging consequences (Zhang et al. [158]). Therefore, it is necessary to establish a personal privacy protection plan (Gao et al. [159]). However, the application of blockchain technology is a double-edged sword. On the one hand, blockchain technology reduces the risk of the circulation of poor-quality goods in the supply chain, according to Erokhin et al. [160], and on the other hand, information sharing in real time allows for the unreserved disclosure of personal privacy (De Aguiar et al. [161] and Choi et al. [162]). In 2020, as blockchain technology matured, it was used in more industries: the agricultural industry by Iqbal et al. [163] and Lin et al. [164], industry 4.0 by Chang et al. [165], and smart cities by Makhdoom et al. [166]. In 2020, scholars began to reflect on whether there are some safety hazards in the excessive use of blockchain. Being questioned is a sign of the more mature application of blockchain technology in supply chain management research. Only by breaking through this bottleneck can we usher in improved development.

4.8.4. Analysis of the Research Innovations in 2021: Improvement. In 2021, the highest number of research publications related to blockchain technology as it applies to supply chain management was found compared to the previous five years. Although the application of blockchain technology has been questioned, the practical need for such an application further highlights its importance. The keyword with the highest burst detection intensity in 2021 was "transparency," a term that also appears as a core keyword in Figure 10. On the one hand, as Park and Li [167] found, the improvement of supply chain transparency depends on blockchain technology, which can achieve the traceability of products in the supply chain. On the other hand, Yang et al. [168] suggested that high transparency contributes to supply chain sustainability. "Health" was another burst detection word in 2021, and the core keywords associated with it were "food," "quality," and "service." Food safety is closely related

Table 9: Analysis of the study trends in four years.

	2018
BD and CK	Origin, technology, consumer perception, benefit, green, etc.
Research field	Gem industry [135], agricultural industry [137], wood industry [162], and manufacturing industry [138]
Research hotspot	Potential and prospects of blockchain technology [110], application of blockchain technology, trust mechanism of supply chain stakeholders [139, 140], and green supply chain
Research method	Lean approach [92] and operations' research [141]
	2019
BD and CK	Internet, IoT, big data, security, framework, challenges, quick response, user acceptance, integration, supply chain management, etc.
Research field	Cross-border trade industry [147], food service industry [148], sea transportation industry [149], medical industry [150], and automotive industry [151]
Research hotspot	Blockchain and IoT, Internet, big data technology [100], supply chain security [106], supply chain framework [121], quick response and user acceptance [142, 143], and supply chain integration [144–146]
Research method	Mean-variance approach [91] and game [152]
	2020
BD and CK	A smart contract, sustainability, risk, uncertainty, privacy, impact assessment, impact, agricultural, industry4.0., etc.
Research field	Agriculture [163, 164], industry 4.0 [165], and smart city industry [166]
Research hotspot	Blockchain and smart contract [104], supply chain traceability [115, 120], lifecycle assessment [153, 154], circulation risk of inferior quality goods [160], and risk of privacy disclosure [156–159]
Research method	Fuzzy analytic network process (ANP)-modified total interpretive structural modelling (TISM) approach [183]
	2021
BD and CK	Transparency, health, food, quality, service, competition, coordination, etc.
Research field	Financial industry, pharmaceutical industry, textile industry, and food industry [169–172]
Research hotspot	Supply chain transparency [167, 168], blockchain ensures food supply chain security, data encryption [175–178], privacy computing [179, 180], and coordinate and supply chain competitiveness [181, 182]
Research method	Quantum approximate optimization algorithm [173] and mixed-integer programming model [174]

BD and CK: burst detection words and core keywords.

to people's health, a fact that has been shown to be especially true in recent years. People worldwide have suffered impacts from COVID-19 to some extent (Yang et al. [169]), which has further stimulated the demand for high-quality food (MF et al. [170]). Blockchain technology undoubtedly provides a better shopping experience for consumers in the food supply chain, who can enjoy services such as food traceability (Collart et al. [171]) and rapid responses (Dey et al. [172]). On the one hand, the application demand for blockchain technology in supply chain management is increasing, and on the other hand, the application of blockchain technology has been questioned because of the risk of information disclosure. Therefore, scholars have optimized blockchain technology and reapplied it to supply chain management. We can see two related keywords in Figure 10: algorithm and optimization. Some scholars have proposed certain improvement schemes. For example, El et al. [173] proposed an improved quantum approximate optimization algorithm model based on blockchain technology to improve the scalability and reduce the cost of smart logistics, while Xia et al. [174] proposed a mixed-integer programming model based on blockchain-enabled fleet sharing. Other scholars have tried to protect data in the supply chain by means of data encryption (Ma et al. [175], Peng et al. [176], Li et al. [177], and Zhao et al. [178]) or privacy computing (Feng et al. [179]). Improved blockchain technology makes supply chains more competitive. As such, "competition" was not only a burst detection word but also the core keyword in 2021 and is closely linked to the keyword "coordination." Blockchain technology coordinates the relationship between supply chain members, according to Xu et al. [180], and their cooperation makes the whole supply chain more competitive (Niu et al. [181] and Chen et al. [182]). Therefore, the encrypted reapplication of blockchain technology should be the focus of future research.

We summarized the research field, research hotspot, and research method from 2018 to 2021 by year. The details are shown in Table 9.

5. Discussion

In this study, we aim to conduct a detailed analysis of 591 target articles by exploring the logicality and correlation between these massive disordered documents. We search the research context, hot spots, trends, and future directions of the research on blockchain technology applied in supply chain management. The four research questions raised in this study have been effectively solved.

5.1. Comparison between This Research Method and Traditional Research Methods. The traditional research literature

typically uses a single visualization software. We combined the advantages of CiteSpace and VOSviewer to demonstrate the coupling between documents. We performed the most detailed systematic research and comparison work to provide the most useful information. In addition, we conducted a detailed analysis of the distribution characteristics of the sample studies in terms of countries/regions, institutions, journals, and subject areas and described the literature in terms of citations, cross-citations, funding support, and high-yield authors. More importantly, we analyzed the core keywords, burst detection words, research fields, research hotspots, and research methods in detail for each year and showed the research trends. To ensure the timelines of the study, our research includes the latest relevant studies.

5.2. Core Country/Region and Institutional Cooperation Networks Contribute Greatly. Although blockchain technology for supply chain management has not been studied for long, the number of publications by a single author is very high, and this research topic has formed a significant network of country/region and institutional collaborations. There are five country/region cooperation networks, which are centered on China, the US, India, Canada, and the United Arab Emirates. There are four major institutional cooperation networks, which are centered on the Khalifa University of Science Technology, University of Electronic Science and Technology of China, Hong Kong Polytechnic University, and Shenzhen University. Each country/region and institutional network has its own research focus. The above works have made great contributions to the application of blockchain technology in supply chain management.

5.3. Three Hotspots of Blockchain Technology as It Applies to Supply Chain Management Research. This study of 591 papers on the application of blockchain technology in supply chain management revealed three major research hotspots. (i) The research focus of the green cluster, with "blockchain" as its core, is as follows: the integration of blockchain technology with the Internet and IoT technology serves to improve the overall efficiency of the supply chain, the application of blockchain smart contracts in the supply chain, and the challenge of the popularization of blockchain technology. (ii) The research focus of the blue cluster, with "supply chain" as its core, is as follows: the application of blockchain technology in the logistics field, and the ways in which blockchain technology permits the supply chain to be transparent and traceable. (iii) The research focus of the red cluster, with "management" as its core, is as follows: the opportunities and challenges, as well as the framework design of blockchain technology in supply chain management. Supply chain sustainability through the use of blockchain technology is also included.

5.4. Research Innovations and Breakthroughs Based on the Timeline. There are similarities and differences in the research innovation and breakthrough points of different years. Blockchain technology, as a distributed ledger, builds a supply-chain-based trust mechanism, as such technology was a common topic in each study year and, thus, could not be avoided. In addition, blockchain technology helps improve the transparency of the supply chain. Therefore, it can enable timely information sharing and product traceability in the supply chain, which was another studied topic. In 2018, scholars studied the potential and prospects of blockchain technology, trust mechanisms for supply chain stakeholders, and green supply chains. In 2019, supply chain security, the supply chain framework, supply chain challenges, and supply chain integration became the focus of scholarly research. Moreover, in 2020, blockchain smart contracts were one of the most important pieces of content of previous studies. The circulation risk of inferior goods and the risk of privacy disclosure in the supply chain became the research innovation point of that year. In 2021, scholars focused on how blockchain technology could ensure the security of the food and pharmaceutical supply chains. At the same time, the use of blockchain technology to enhance the competitiveness of the supply chain became another research hotspot that year. During these four years, we found a phenomenon: from 2018 to 2021, scholars focused on the research topic of the application of blockchain technology in supply chain management, going through a of discovery, acceptance-questioning, improvement process.

We conducted a systematic bibliometric analysis of the application of blockchain technology in supply chain management and obtained very detailed research results, which reasonably answered 10 research questions proposed in this study. The findings are consistent with the current situation of the COVID-19 global pandemic. The application of blockchain technology in supply chain management is not only a theoretical concept, it has found many successful cases in practice around the world. The research conclusions of this study provide useful information for subsequent scholars in carrying out future research, providing theoretical support for enterprises in the supply chain in the implementation of blockchain technology. Moreover, these findings provide a meaningful reference for the government in the formulation of relevant policies on the application of blockchain technology in supply chain management.

6. Conclusions

As a blast technology, blockchain technology has greatly improved the transparency, traceability, and rapid response capability of supply chains. Moreover, it has played a large role in achieving sustainable supply chain development. This study uses a systematic literature review to elaborate on the application of blockchain technology in supply chain management. Based on 4 clear research questions, we set appropriate search criteria, and 591 studies are selected as research objects.

6.1. For Question 1. We conclude that computer science information systems are the most important subject area. Future research will be more inclined to the area of environmental protection. People's Republic of China is the

country with the highest output of papers. Funding from financial institutions has a certain positive significance for the output of papers in a country/region. The top three journals in terms of output contribute significantly to this field of research.

6.2. For Question 2. Cooperative relationships among different countries/regions, which can be clustered into five cooperation networks, exist. There is a strong coupling relationship between research institutions, forming four major institutional cooperation networks. The productive author tends to choose a very narrow direction to perform thorough research. Most papers with a higher number of total citations were published in 2019, but the cross-citation phenomena of such papers were more frequent in 2021 and 2022.

6.3. For Question 3. Based on VOSviewer, all the keywords are visually coupled and clustered into three research hotspots. (i) The research focus of the green cluster, with "blockchain" as its core. (ii) The research focus of the blue cluster, with "supply chain" as its core. (iii) The research focus of the red cluster, with "management" as its core.

6.4. For Question 4. Using CiteSpace to perform timeline-based keyword atlas analysis, we find that scholars have gone through a "discovery-acceptance-question-improvement" process for the application of blockchain technology in supply chain management. According to the intensity and duration of burst detection words in different years, we draw three key points for future research: (i) blockchain technology should be used to restructure and optimize the high-end food and medical cold chain supply chains, (ii) blockchain technology should be used to enhance the cooperative relationship between supply chain members and the overall competitiveness of the supply chain, and (iii) blockchain encryption technology should be innovated to reduce the risk of information and privacy leakage in the supply chain.

The research in this study has limitations. Firstly, we select the WOS as the literature source and ignore many other studies, which may cause us to ignore some important information about blockchain technology as it applies to supply chain management. Secondly, in the screening of the research sample, some literature that is only weakly related to the topic of blockchain technology as it applies to supply chain management is manually removed, which leads to some subjectivity in the results. Finally, blockchain technology, as it applies to supply chain management, is an emerging field that is developing very fast, and more scholars are expected to join this research and contribute more findings to this field.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by (i) Cigarette Order Sorting Green Packaging Technology Research and Overall Development of Simulation Project (project no. 80026091801) and (ii) Scientific Research project of Hunan Provincial Department of Education "Research on in Nuencing Factors of Shared Express Packaging Recycling" (project no. 20C1036), and (iii) Loudi Social Science Evaluation Committee Project "Study on the path selection of high quality development of Loudi County economy" (project no. 202105A).

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