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Review

Blockchain-Enabled Cross-Border E-Commerce Supply Chain Management: A Bibliometric Systematic Review

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Abstract: Driven by the internet-based advanced information technologies and logistics channel improvement, the cross-border e-commerce industry keeps an increasing trend in Chinese industrial market. Blockchain, as an empowered technology, contributes to the management innovations for industrial sectors. The blockchain technology, due to its transparency, visibility, and dis-intermediation characteristics, helps to improve operations management of cross-border e-commerce supply chain by innovative industrial applications. However, practical applications of the blockchain technique-enabled cross-border e-commerce sector are still in their infancy and still at the proof-of-concept stage. This paper presents a systematic review on blockchain-enabled cross-border e-commerce supply chain management by employing a bibliometric data-driven analysis. All relevant publications from the Web of Science database from 2013 to 2021 were collected as the research samples. Besides, the VosViewer is adopted to conduct the network and co-word study by visualizing collaborative relationships of sampled literatures. Results show that the blockchain technique has substantial applications in the field of cross-border e-commerce supply chain, whose contributions mainly focus on cross-border e-commerce platform, supply chain operations, and data governance and information management. Academic researchers and industrial managers can promote innovative management practices in cross-border e-commerce supply chain by adopting blockchain. Moreover, we hope this study serves as a future direction for both researchers and engineers on leveraging blockchain to improve the supply chain management performance of the cross-border e-commerce.

Keywords: blockchain; cross-border e-commerce; supply chain management; bibliometric analysis

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1. Introduction

With the rapid development of digital transformation and internet-based technology, there is an increasing trend of online shopping, contributing to the booming development of the e-commerce industry. The cross-border e-commerce facilitates access to products and worldwide service, and it has become a prevailing consumption form in the Chinese market, driven by the diversified e-commerce platform, modern logistics distribution systems, and effective operations management [1,2]. An important feature of cross-border e-commerce is the worldwide network; regardless of place, one can participate in electronic shopping. However, there are still some inevitable obstacles hindering the development of cross-border e-commerce due to the discrepant cultures and habits, and the fast delivery to online consumers is one of the crucial factors for further development of cross-border e-commerce due to time-consuming international logistics [3,4]; The long-distance transportation is usually time-consuming for cross-border e-commerce business [5]. The effective supply chain management innovation practices contribute to performance improvement of cross-border e-commerce due to effective operations management [6–9]. It will be regarded as a triumph for cross-border organizations that have a developed logistics network and a high efficiency distribution system [6,10–12]. For the cross-border supply chain management, the trust problem is a key issue due to multiple participants. Due to the discrepancies in terms of cultures, legal provisions, and consumption habits of different countries and regions, it is difficult to establish a stable and reliable alliance for all participated parties [13]. With the technological development and the changing consumer awareness, the core of competition in cross-border e-commerce has changed from the basic attributes of goods, such as quality and cost, to the after-sales service ability of merchants to customers, namely the service ability of the supply chain [14–19]. To improve the performance and efficiency of cross-border e-commerce, efficient management of the segmental elements of business flow, logistics, and capital flow should be integrated efficiently. The development of management service capacity of the supply chain is based on these three sectors and their effective interactions [20]. Blockchain technique, as a crucial technology enablement, could significantly improve the efficiency of supply chain management by innovative management practice and further promoting the development of cross-border e-commerce [21]. Therefore, there is great significance and research value in studying the relevant literature of blockchain technology enabling cross-border e-commerce supply chain management for exploring the development status and further exploring problems.

The transparency, visibility, and dis-intermediation characteristics of blockchain motivate its prevailing applications in industrial sectors during the digital transformation and Industry 4.0 period [22–24]. Blockchain is an open distributed ledger, and all the information recorded in the blockchain is open and transparent. This feature contributes to establishing a mutual trust trading network, solving security problems in the trading process, and assisting the realization of mutual trust among all parties of the supply chain. However, the current application of blockchain in the supply chain is far from reaching this level even though it has great potential application opportunities from a theoretical viewpoint [11,25,26].

As a mainstream technology, blockchain technology has been widely used in all walks of life and industrial sectors [27–29]. It is regarded as a strategic frontier technology in China, which has been the focus of academic researchers and industrial managers. Blockchain technology can effectively solve the problem of information opacity and information asymmetry, as well as effectively protect the security of operational data. It plays a significant role in promoting innovative development and regional transformation, and there is a vast amount of papers addressing blockchain industrial applications [30]. However, as far as the current research status is concerned, there is little research focusing on the integration of blockchain technique in the e-commerce supply chain area to the-state-of-the-art of the knowledge. This study aims to conduct a systematic review analysis on blockchain-enabled cross-border e-commerce supply chain management based on the collected sample references. Firstly, the related published papers from Web of Science were collected, and 19,062 papers were identified for further review analysis. Furthermore, the bibliometric analysis using VosViewer software was performed to explore blockchain-enabled applications in cross-border e-commerce supply chain management from the viewpoint of country, journals, and hot research topics. The main contributions and theoretical underpinnings of this study are to help to disclose the blockchain technology applications in cross-border e-commerce supply chain by performing a comprehensive review analysis and a bibliometric study. This paper aims at providing systematic understanding and theoretical insights for further blockchain-based management practice innovation in cross-border e-commerce.

The rest of this paper is structured as follows. Section 2 presents the theoretical background of cross-border e-commerce and blockchain technology. The research data, research methods, and research framework adopted are proposed in Section 3. Section 4 discloses the results and visualization of the collected samples and explores the development trend of blockchain and cross-border e-commerce supply chain management. Section 5 describes the management enlightenment and theoretical contribution of this study. Section 6 provides the conclusions. Finally, we end this paper with research limitations and future research opportunities.

2. Theoretical Backgrounds

This section describes the theoretical background of the blockchain technique and its application in the cross-border e-commerce supply chain area.

2.1. Blockchain Technique Background

2.1.1. Consensus Mechanism

The consensus mechanism determines the rules of block generation in the blockchain and completes the verification and confirmation of transactions in a short period of time, ensuring decentralized trust issues. It guarantees the honesty of each node, the robustness of the system, and the fault tolerance of the ledger [9]. The prevailing consensus mechanisms mainly include PoW (Proof of Work), PoS (Proof of Stake), DPoS (Delegated Proof of Stake), and PBFT (Practical Byzantine Fault Tolerance).

The PoW consensus algorithm is based on the principle that all participating nodes perform calculations and compete for the rewards of generating new blocks and bitcoins, with the node that takes the least amount of time to solve becoming the master node [31,32]. It can reduce malicious node attacks, tamper with data, and improve the security of the blockchain [33].

The competition concept of PoS algorithm is similar to PoW, and PoS reduces the search space to an acceptable range. By introducing the concept of "currency age", the competition of computing power is transformed into the competition of equity. It aims at saving computing power, preventing malicious attacks from nodes, and maintaining the stable operation of blockchain [32]. Although the PoS mechanism can, thus, shorten the time required to reach consensus, it still essentially requires nodes in the network to perform mining operations. Therefore, it does not fundamentally solve the problem that the PoW mechanism is difficult apply in the commercial field.

The DPoS consensus algorithm introduces the electoral system in PoS [34]. At the same time, compared with PoS, DPoS does not consume computing power, which can improve the verification speed. There are two types of nodes in DPoS, namely, normal nodes and trusted nodes. Each node selects trust nodes through a democratic vote process. In the election process, each node can participate in the voting, which can avoid the generation of the main node tending to the high-interest node [35]. However, such voting does not directly represent the practical complex voting situation in the real world. Xu et al. [36] designed an improved DPoS consensus mechanism based on fuzzy sets, which can explain the voting model more intuitively. Although DPoS reduces cost and time compared with PoW and PoS, the consensus process of DPoS is easily centralized, resulting in a small number of nodes controlling the election process, which will threaten the security and accuracy of the DPoS election process [37]. In addition, the consensus mechanism is dependent on tokens that are not adopted in many commercial applications. Therefore, the consensus mechanism cannot perfectly solve the application of blockchain in business.

PBFT is characterized by removing the mortgage with our rights and reducing the consumption of competitive resources, which can reduce the cost of malicious nodes, and reduce the impact of malicious nodes on the consensus. Furthermore, it can also improve the fault tolerance [38,39]. The point-to-point communication of PBFT solves the problem of poor scalability of the other mechanisms, which inevitably increases the communication cost. Constructing multi-layer PBFT to form sub-consensus can reduce the cost, but multiple sub-consensus increases the system reaction time and causes a long delay [40].

Apart from the above-mentioned four consensus mechanisms, the PoC (Proof of Activity) and PoA (Proof-of-Authority) are often addressed in the literature. Each of these mechanisms has its own advantages and disadvantages, and it is necessary to make a reasonable choice by considering their advantages and disadvantages in the practical application.

2.1.2. Hash Algorithm

The principle of the hash algorithm is to turn a piece of information into a fixed-length binary value, called the hash value [41]. The hash value could be obtained by the input function, which could be used to test whether the data is complete or not. The hash algorithm can be used to ensure the authenticity and invariance of ledger data, and the process of converting input data to fixed-length by hash algorithm is irreversible [42].

Yang et al. [43] designed a new Dohashi algorithm, which can effectively replenish the shortcomings of the network flow scheduling optimization algorithm by conflict probability reduction and query performance improvement. Zhou et al. [44] established a multi-pattern matching algorithm based on the double hash algorithm, which improved the time efficiency.

2.1.3. Smart Contract

It is extremely costly to keep a contact from being broken by inserting contract terms into hardware and software. The concept of smart contracts has been put forward for a long time, but it was applied to industrial practices until the prevailing booming development of blockchain technology [45]. A smart contract in a blockchain is a script stored in the blockchain, and it runs automatically without any interference from the signer of the contract [46]. The capabilities of smart contracts allow them to be associated with areas such as insurance, health care, and smart cities [47]. Vo et al. [48] developed a blockchain smart contract-based micro-insurance quotation solution to facilitate insurance companies to manage and analyze pay-as-you-go auto insurance data. Hamamreh et al. [39] discussed the security and feasibility of accessing electronic health records based on intelligent contracts in the field of health care. Kuo et al. [49] applied smart contracts to address healthcare privacy protection while leveraging blockchain technology to improve interoperability between institutions and national healthcare delivery capabilities. Yang et al. [50] adopted blockchain technology to study current security and privacy deployment strategies for e-government in smart city environments, disclosing the feasibility of applying smart contracts as an alternative to real contracts. Lazaroiu et al. [51] built a smart city model based on the blockchain and IoT platform, and smart contracts are employed to conduct autonomous distributed management of community power grids and smart meter technology. In addition, the advantages of smart contract transaction information, such as traceability and irreversibility, make it widely used in the supply chain field. Natanelov et al. [52] proved that blockchain smart contracts could minimize supply chain operation risks and reduced cash flow cycles in traditional supply chain financial models. Salah et al. [53] adopted blockchain and smart contracts to improve the transaction reliability and operational efficiency in the agricultural supply chain.

2.2. Recent Trends in Cross-border E-commerce Supply Chain Management

With the continuous development of Internet-based techniques and digital transformation, cross-border e-commerce has gradually developed [54]. It brought a wider variety of goods and enlarged the range of choices for domestic consumers. In the last few years, cross-border e-commerce exportation has become a new economic and trade growth point in the Chinese market [5]. To promote the rapid development of cross-border e-commerce, innovative management practices are studied and conducted regarding the supply chain activities, including production, warehousing, logistics, customs declaration, distribution, marketing, and other processes [38,55–57]. The operational management practices and innovations have motivated the continuous improvement of the e-commerce supply chain management, including strategic pricing, supply chain network optimization, delivery strategy, and lean management through strategic contact and mechanisms [19,34,35,41,58]. With the gradual formation of cross-border e-commerce supply chain, the principal competition part of cross-border e-commerce is transforming a single subject to the supply chain. In addition, the transaction process and logistics process of cross-border e-commerce are also gradually becoming more open and more transparent in the global environment [59].

The e-commerce payment, as a typical application scenario, has proven to be an effective innovation in the blockchain-enabled cross-border e-commerce sector, which helps with improving the trustworthiness of the transaction process, the encryption of customer data, and the tracing of the product supply chain. The payment system is an important link in the process of e-commerce transaction. The payment gateway in the current payment system usually requires authentication, which will increase the cost of e-commerce transactions. The public key, private key, and digital signature technologies in the blockchain technology can ensure the security of electronic payment, and the operating cost is reduced at the same time [60].

With the booming development of cross-border e-commerce, security is considered to be one of the key issues restricting the development of e-commerce [61]. It is of great significance to promote e-commerce so that the public will build a solid transaction with great trust. It is easy to cause customer privacy disclosure or information modification once the platform is attacked [62]. The decentralized technology of blockchain can solve these problems mentioned above. In blockchain-based systems, the data update of all nodes is synchronous and consistent, and all blocks are connected in chronological order [63]. Therefore, blockchain technology can effectively ensure the stability and security of platform data [55].

The trust issue has become one of the difficulties in the development of cross-border e-commerce. Due to the characteristics of cross-border e-commerce transactions, it requires close cooperation and mutual trust among supply chain participants [25]. However, the cultural and legal differences among different nations leads to a lack of trust. Ronaghi developed a model to test the maturity of blockchain in the agricultural supply chain [64].

3. Research Design

The systematic review analysis is performed in this study by employing a bibliometric analysis. This section presents the research design of this study, and the blockchain-empowered cross-border e-commerce supply chain management has been profoundly explored and discussed to help to better understand the blockchain-driven integration applications.

3.1. Data Collection

The previous publications related to blockchain and cross-border e-commerce supply chain management are collected to be the research samples. The Web of Science is crucial for accessing global academic information [65]. In order to further understand the development trend of blockchain in the field of cross-border e-commerce, this paper selected the core database of Web of Science as the database [66]. It includes more than 1300 authoritative and high-quality academic journals from around the world in the fields of natural sciences, social sciences, biomedicine, arts, and humanities. Furthermore, it easily tracks the origin and history of research documents or the latest developments in a field on the Web of Science. A total of 19,062 research papers published from 2013 to 2021 were searched using "blockchain", "cross-border e-commerce", and "supply chain management" as the keywords.

3.2. Bibliometric Study

Bibliometric analysis is a quantitative analysis method based on mathematical statistics, which is considered a common method for structural overview of the research field. It takes the external characteristics of literature as the object, and analyzes the structure, quantitative relations, and changing trends of collected publications. To explore the research hotspot and trends in a certain field, the systematic review and bibliometrics analysis are conducted regarding main ideas theoretical basis [66,67]. Bibliometrics analysis has been applied to different industry sectors, which effectively helps to explore the development status and overall trend of this field. Therefore, this paper tries to disclose the development trend of blockchain technology and its application in cross-border e-commerce supply chain management by employing a bibliometric analysis. Visualization analysis is performed with the help of VosViewer software, free Java-based software developed by the Technical Research Center of Leiden University in the Netherlands in 2009 [68–70]. The complicated interactions of objective items could be depicted and reflected through the similarity definition realized by the VosViewer mapping technology. The similarity matrix of n order is generated by collecting all similarity elements. Suppose the similarity element between two items is Similarity (X, Y), which means the correlation intension of two items. The X and Y mean the two objective items, and it is non-negative, namely $Similarity(X, Y) \geq 0$. The similarity formula has symmetry characteristics, that is $Similarity(X, Y) = Similarity(Y, X)$. It means there is no similarity or overlap between the X and Y items when $Similarity(X, Y) = 0$. The purpose of the VosViewer technology is to reflect the similarity between each pair of items in a two-dimensional space based on their spacing distance as accurately as possible [71]. It is often used in literature analysis and measurement, and has a powerful graphical display ability, which can vividly show the complex cross-over and evolutionary relationship between knowledge groups.

3.2.1. Co-Word Analysis

Co-word analysis was proposed by Turner et al. (1988) and Callon et al. (1991) in the 1980s [72,73]. It is used to analyze the research status of a certain field and has strong advantages and credibility, which includes factor analysis, strategy analysis, and network analysis. Co-word analysis is a content analysis method, which mainly selects a large number of common keywords in the literature and makes hierarchical clustering of these representative words based on them, so as to reveal the relationship between these words and the research trends of the disciplines represented by them. Co-word analysis has great applicability in different fields due to its advantage in finding overlapped research. To help better understand this topic, the VosViewer analysis is employed to draw a keyword co-occurrence network diagram to explore the evolution of blockchain technology, contributing to summarizing the overall development trend and future research opportunities [72,74].

3.2.2. Network Analysis

Social network analysis originated in the 1950s, which was initially applied to psychology study, and later widely used in sociology, economics, anthropology, and other fields, is an important part of data mining of objective literatures. Its principle is to regard the analyzed object as a set of social actors and their relations. The network of keywords, related literature, and countries are categorized and analyzed by exploring the set relationship between nodes in the network [75,76]. Through the network analysis, we can judge the diversified development of the application of blockchain in different fields. Furthermore, through the co-occurrence matrix of high-frequency feature words construction, the development trend and research hotspots can be investigated [73]. It can effectively fill the deficiencies in the details mining of sample information statistics, and the typical literature are selected for in-depth analysis from the collected samples and carry out research from both micro and macro perspectives.

3.3. Research Framework

This paper performed and bibliometric analysis by addressing the collected literature on blockchain and cross-border e-commerce supply chain management from 2013 to 2021. The research framework is designed as shown in Figure 1. Firstly, the theoretical background of blockchain and cross-border e-commerce supply chain management is presented to elaborate the recent research trends. It is found that blockchain technology can enable the development of cross-border e-commerce, especially the payment and supply chain management of cross-border e-commerce. Then, the bibliometric analysis is employed to disclose the complicated visualizations and interactions of blockchain-enabled cross-border e-commerce supply chain through the VosViewer software. The research findings and research themes are summarized. Finally, the visualized analysis diagram is elaborated to analyze the potential blockchain-enabled cross-border e-commerce supply chain management, so as to more profoundly explore the trend of cross-border e-commerce supply chain.

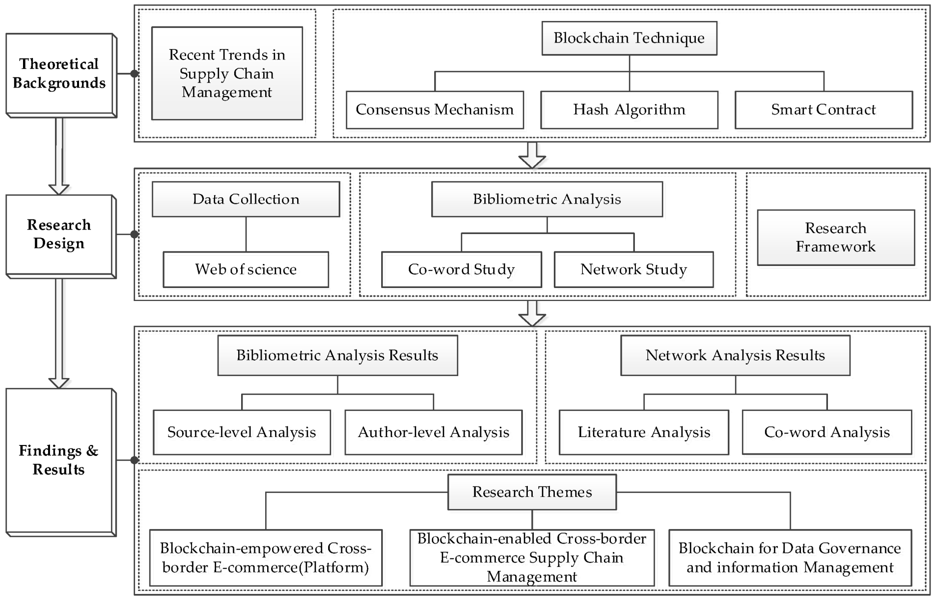

Figure 1. Research framework.

4. Findings & Results

4.1. Overview Analysis Results

4.1.1. Source-Level Analysis

In order to analyze academic research papers about blockchain, we selected the related papers from the core database of Web of Science by searching "blockchain", "cross-border e-commerce", and "supply chain" keywords [77]. There are 19,062 references collected in this bibliometric analysis. We found that academic research about blockchain has occurred since 2013, keeping an increasing tend until 2021. As can be seen from Figure 1, although studies on blockchain began to appear in 2013, the number of studies was pitifully small in the following two or three years. Since 2016, the number of relevant studies has grown rapidly, and the fastest growth is from 2018 to 2021. The distribution of collected research articles is shown in Figure 2. We can speculate that blockchain is developed with the emergence of new data such as the Internet of Things and big data, which is related to the characteristics of blockchain technology [78]. We also find that the large-scale research and application of blockchain is related to the emergence of some new technology. Figure 3 shows the number of publications on blockchain in recent years. Figure 3 shows the top 10 journals including research papers. The top three publications were *IEEE Access*, *Lecture Notes in Computer Science*, and *Sustainability*. The number of publications is more than 110, which have become the hotter journals in this field. Through the depicted diagram, we find that the research directions of journals include computer science, business economics, communication, telecommunications, mathematics, government law, and so on. This shows that the research about blockchain has been gradually extended from the research about technology to the research on application of blockchain in different fields.

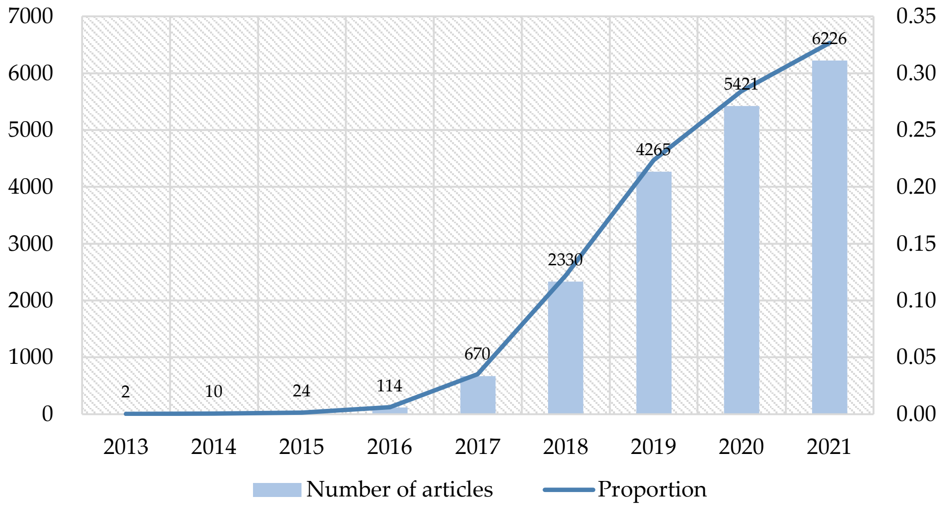

Figure 2. Distributions of research publications.

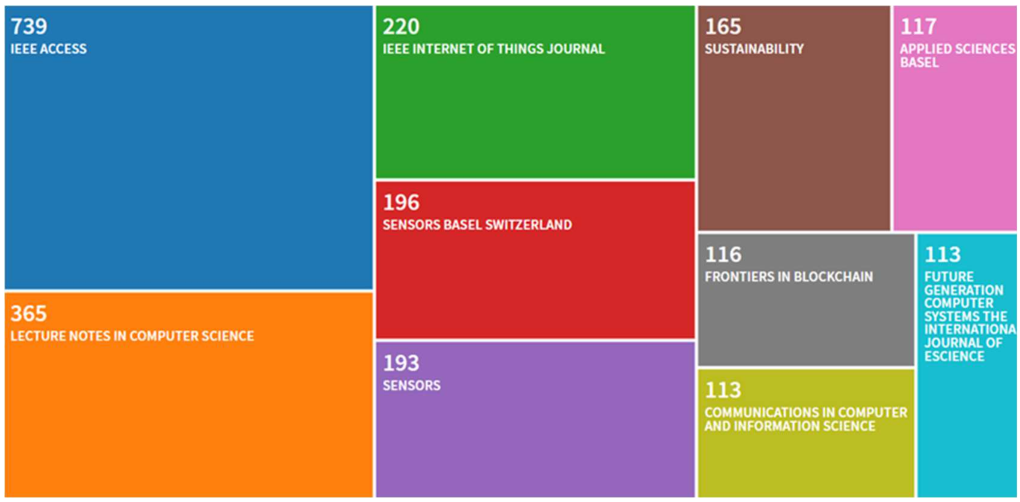

Figure 3. Top 10 journals in terms of the number of publications included.

From Figure 3, we can see that the journals publishing blockchain research are mainly *IEEE Access* and *Lecture Notes in Computer Science.* Both are engineering-oriented journals, obviously contributing to the development of blockchain study. Furthermore, there are also many related references published in the *Sustainability* journal, contributing to this research promotion. However, it is surprising that a large number of articles on blockchain have not been published in the management journals of supply chain and logistics area. The logistics operations and innovative supply chain management are considered to have great potential for blockchain applications, and a large number of papers will be published in these two journals in the future.

4.1.2. Author-Level Analysis

The institutional funds and the top 10 fund institutions with most publications in related areas are depicted in Table 1. As can be seen from Table 1, among the top 10 fund institutions, the top three are respectively from China, Europe, and the United States. Furthermore, the number of records in China far exceeds that of the United Stated and Europe, illustrating that China has paid much more attention on blockchain technology and its applications than other countries.

Table 1. Top 10 institutional funds of sample publications.

Institutional Funds	Papers
National Nature Science Foundation of China (NSFC)	2040
European Commission	411
Fundamental Research Funds for the Central Universities	296
National Key Research and Development Program of China	286
Ministry of Education Culture Sports Science and Technology Japan (MEXT)	116
Japan Society for the Promotion of Science	108
China Postdoctoral Science Foundation	103
Beijing Natural Science Foundation	98
Natural Sciences and Engineering Research Council of Canada (NSERC)	97
UK Research Innovation (UKRI)	96

Table 2 presents that the top 15 countries in blockchain research based on the number of publications. China exhibits its predominance in production and influence with 4007 papers, followed distantly by the USA and India. India has less than half as many publications as the USA. The worldwide distribution of blockchain publications shows that academic research on blockchain is being published in all regions of the world.

Table 2. Top 15 countries in blockchain-related research.

Country	Papers
China	4007
USA	2957
India	1266
England	1033
Australia	955
South Korea	784
Germany	733
Canada	738
Italy	707
UK	530
France	493
Spain	485
Japan	461
Russia	442
Saudi Arabia	430

Figure 4 draws a collinear diagram of the keywords for the collected literature samples, where items = 86 and Links = 1177. The item indicates that the number of nodes is the number of keywords, and the number of links is the number of connections between nodes (excluding the number of repetitions). The larger the circle, the more nodes are connected to that node. However, the number of links does not include the number of repeated associations, which cannot more accurately represent the relationship between nodes. Therefore, we conduct co-occurrence analysis through total link strength, which is the total number of connections between nodes (including the number of repetitions), and the larger the circle, the more total connections.

It can be seen from Figure 4 that in the relevant research of blockchain, China's total link strength = 1799, which is the country with the most cooperation. Followed by the United States with total link strength = 1619, followed by India, Australia, Canada, Germany, and other countries. It is not difficult to find that the development and application of blockchain technology has attracted the attention of countries around the world. Various countries are increasing their investment and striving for innovative development of blockchain technology. Therefore, blockchain technology is regarded as one of the strategic technologies for future development by various countries, especially China and the United States.

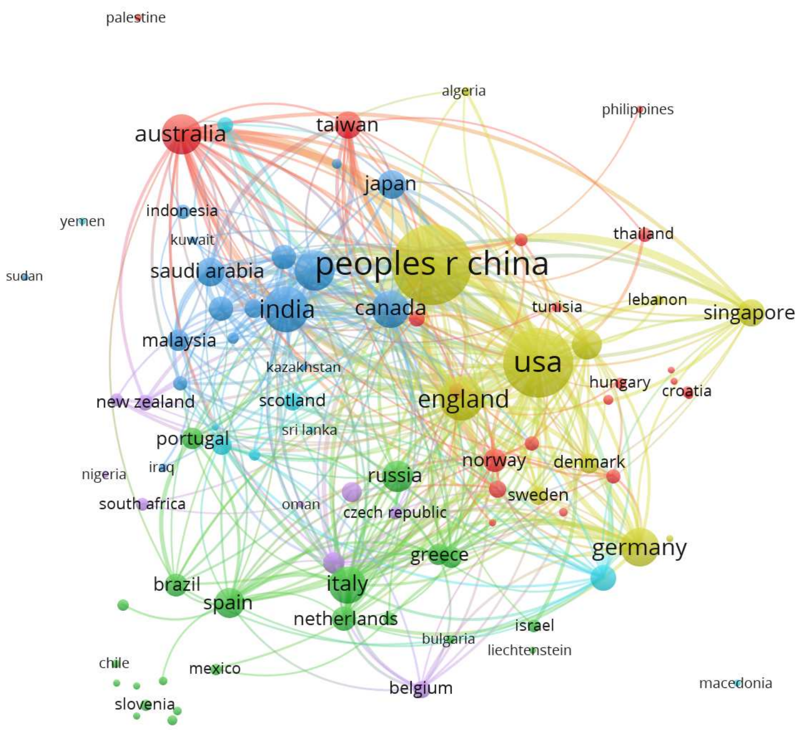

Figure 4. Analysis of cooperation in different countries on blockchain research.

4.2. Network Analysis Results

4.2.1. Literature Analysis

Table 3 presents the top 19 high cited papers in blockchain research. According to the highly cited papers, the mainstream research direction was excavated. Most of these articles discuss the application of blockchain in various aspects. Blockchain has great development prospects in supply chain, agriculture, and other fields. The role of blockchain is examined in achieving key SCM goals for enterprises by establishing a framework [79]. The combination of blockchain and the Internet of Things will drive major changes across multiple industries, as well as the development of new business models and distributed applications [80]. Furthermore, blockchain has been applied in the chemical industry, energy, and healthcare area, but there is still a small amount of literature on blockchain-enabled cross-border e-commerce and the potential future trends. Through the statistical analysis on the high cited literatures from 2013 to 2021, we observed that blockchain has proven to be an effective driver for innovative practices of different sectors, especially for the integration with Internet of Things and the data science area [43]. At the same time, the relationship between blockchain technology and future development is also the focus of the field of study.

Table 3. Highly cited papers in blockchain-related research.

Item	Journal Name	Theme	Source	Total Citations
1	*IEEE Access*	Blockchains and smart contracts for the Internet of Things	[80]	1131
2	*International Journal of Production Research*	Industry 4.0: State of the art and future trends	[81]	545
3	*Future Generation Computer Systems-The International Journal of eScience*	IoT security: Review, blockchain solutions, and open challenges	[82]	508
4	*International Journal of Web and Grid Services*	Blockchain challenges and opportunities: A survey	[83]	486

Table 3. *Cont.*

Item	Journal Name	Theme	Source	Total Citations
5	*PLoS ONE*	Where is current research on blockchain technology?—A systematic review	[84]	471
6	*IEEE Communications Surveys and Tutorials*	Bitcoin and beyond: A technical survey on decentralized digital currencies	[85]	454
7	*Applied Energy*	Designing microgrid energy markets a case study: The Brooklyn microgrid	[86]	379
7	*Harvard Business Review*	The truth about blockchain	[87]	372
8	*IEEE Transactions on Industrial Informatics*	Enabling localized peer-to-peer electricity trading among plug-in hybrid electric vehicles using consortium blockchains	[88]	343
9	*IEEE Transactions on Dependable and Secure Computing*	Security and privacy in decentralized energy trading through multi-signatures, blockchain and anonymous messaging streams	[89]	341
10	*Journal of Medical Systems*	Healthcare data gateways: Found healthcare intelligence on blockchain with novel privacy risk control	[90]	331
11	*Future Generation Computer Systems-The International Journal of eScience*	On blockchain and its integration with loT. Challenges and opportunities	[91]	310
12	*International Journal of Production Research*	Blockchain technology and its relationships to sustainable supply chain management	[57]	304
13	*International Journal of Information Management*	The role of blockchain in meeting key supply chain management objectives	[79]	303
14	*IEEE Internet of Things Journal*	Blockchain meets IoT: An architecture for scalable access management in IoT	[92]	294
15	*Renewable & Sustainable Energy Reviews*	Blockchain technology in the energy sector: A systematic review of challenges and opportunities	[93]	292
16	*IEEE Transactions on Industrial Informatics*	Consortium blockchain for secure energy trading in industrial Internet of things	[94]	286
17	*IEEE Access*	MeDShare: Trust-less medical data sharing among cloud service providers via blockchain	[95]	257
18	*Applied Energy*	Blockchain technology in the chemical industry: Machine-to-machine electricity market	[96]	240
19	*Journal of The American Medical Informatics Association*	Blockchain distributed ledger technologies for biomedical and health care applications	[97]	239

4.2.2. Co-Word Analysis

Based on the 18,537 keywords collected by the authors, we drew a co-word analysis diagram as shown in Figure 5. As a content analysis technology, co-word analysis can effectively display the co-occurrences of keywords in data sets and reveal the network relationship structure. The co-word analysis is based on the proposed formula $T = \left(-1 + \sqrt{-1 + 8I_1}\right)/2$, where I_1 represents the number of words with frequency 1, and T denotes the minimum frequency value of high frequency words [98]. The T index is used to distinguish the high frequency and low frequency words, and the T value calculated in this study is 67. Therefore, we chose keywords with more than 67 occurrences as the analysis content to ensure the effectiveness of the network diagram [68].

The VOS clustering algorithm is adopted to perform clustering analysis by VosViewer. In order to better reflect the research hotspots, nodes with an occurrence frequency greater than 67 were selected for clustering analysis, and a total of four clustering groups were obtained. In Figure 6, the larger the node of the keyword, the higher the frequency of occurrence. The color of the node represents the research hotspot of a certain stage, and the line of each node represents the flow of knowledge, which transitions from purple to yellow according to the chronological order. The purple node represents 2019, and the yellow represents after 2020.

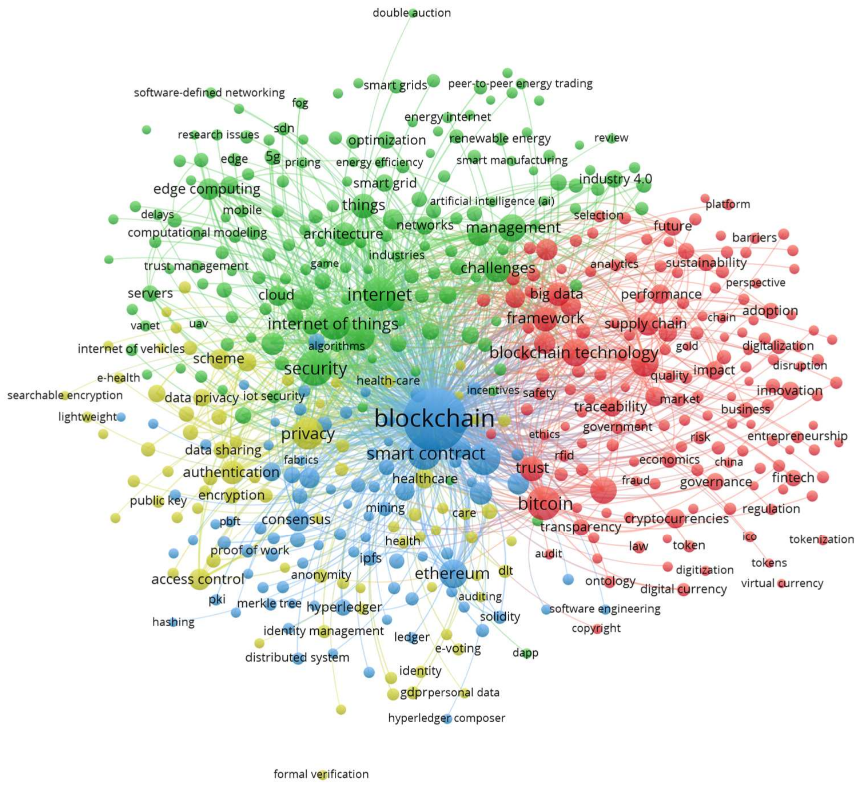

Figure 5. Co-occurrence of keywords by author-keywords.

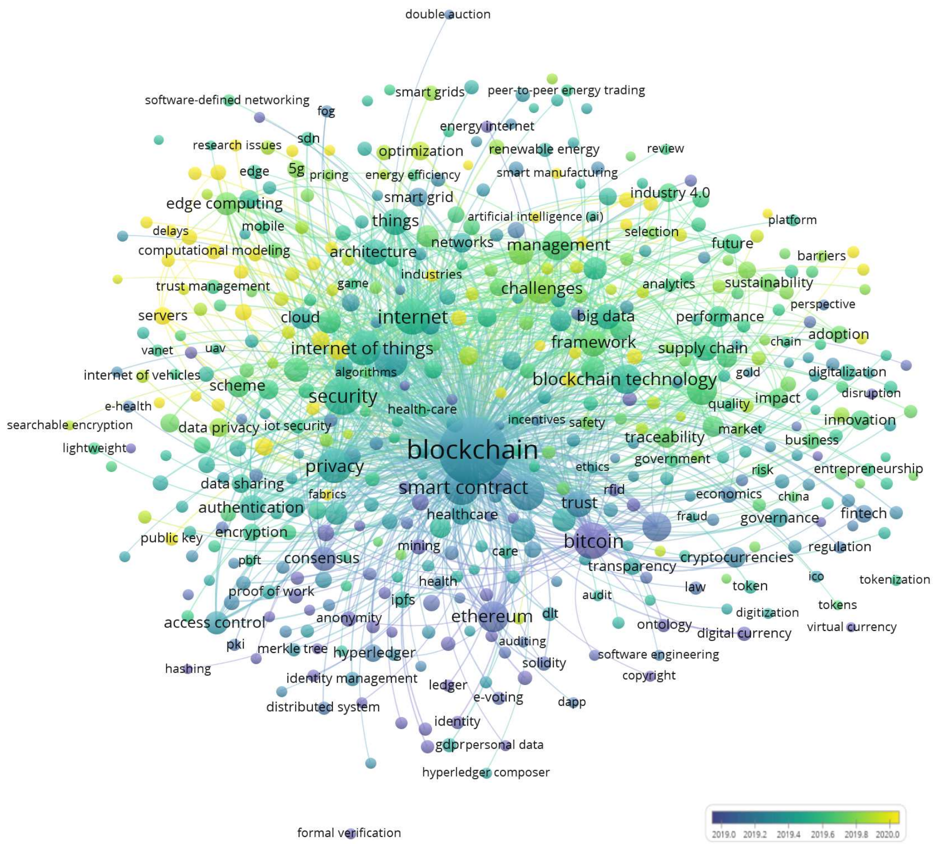

Figure 6. Overlay visualizations by author-keywords.

Cluster 1 shows the industrial applications of blockchain technology in different sectors, including big data, AI, logistics, monitoring, and supply chain, etc.

Based on the characteristics of decentralization and immutable data, blockchain has a wide application prospect in many fields. For example, blockchain facilitates realizing the transparent information of logistics processes, so that both consumers and businesses can trace the dynamic information, greatly improving the efficiency of information flow. Furthermore, blockchain technology makes the products traceable in the supply chain, ensuring the confidentiality of all participants. The blockchain technology helps establish a convincing network with complete trust mechanism in the supply chain.

Cluster 2 shows the combination of blockchain and other emerging technologies, including cloud computing, edge computing, IOT, distributed database, federated learning, machine learning, and smart grid, etc. Blockchain is considered to be one of the most promising emerging technologies. Due to its particularity, blockchain technology can be combined with the Internet of Things to process all kinds of data more quickly.

Cluster 3 is mainly characterized by blockchain features in protecting personal information and improving transparency, involving access control, encryption, privacy protection, identity management, etc. Due to its openness and immutable nature, blockchain technology helps the researcher better build a shared and secure cyberspace.

Cluster 4 focuses on the concept and usefulness of bitcoin, and bitcoin technologies, such as consensus-algorithm, hashing algorithm, and anonymous bitcoin consensus-algorithm. Blockchain technology is not mature at present, and its blocks can only store a limited amount of information, which is also one of the reasons for restricting the development of blockchain technology.

We found that most of research between early 2019 and April 2019 were about blockchain technologies, with subjects such as consensus mechanisms and smart contracts. From April to August 2019, the focus of the studies shifted to the integration and application of other technologies, for instance, the Internet of Things, supply chain management, personal privacy protection, cloud computing, data sharing, traceability, and so on. In 2020, research had moved into industrial applications in different sectors, such as person analysis, services, resource management, trust management, smart city, public key, and Industry 4.0.

4.3. Research Themes

The bibliometric analysis of blockchain development trends reveals that blockchain is more closely studied in logistics management, supply chain management, information management, and data governance. This section focuses on analyzing the research trends of blockchain technology in cross-border e-commerce, supply chain management, information management, and data governance, and exploring the different roles of blockchain technology in practical application scenarios.

4.3.1. Blockchain-Empowered Cross-Border E-Commerce

Cross-border e-commerce platforms have the natural advantage of integrating domestic and international suppliers, intermediate service providers and consumers [42]. The emergence of cross-border e-commerce has changed China's traditional international trade model and made the flow of cross-border goods more convenient. However, in the course of the rapid development of cross-border e-commerce, some problems that are difficult for e-commerce platforms to break through have also emerged, such as the leakage of consumers' personal information, credit risk of cross-border payment, loss of goods and untraceable product information, etc. Among them, credit assessment of participants is considered to be the biggest obstacle to online transactions. Blockchain technology can help e-commerce platforms to solve these problems due to its characteristics of decentralization and openness and transparency. In the survey, we found that the application of blockchain in e-commerce is mainly in logistics and improving the security of the transaction process [99]. Blockchain technology provides reliable information for involved participants to help achieve effective scheduling and planning [32].

The cross-border e-commerce platform security is a typically extended practice of blockchain technique. E-commerce platform is a centralized service platform, which has a large amount of customer personal information. Once the information is leaked or tampered, it will cause huge losses. Blockchain is an open book, in which all information is transparent. Each block contains all the contents of the previous block and is arranged in chronological order. Therefore, it is difficult to tamper with the information. Blockchain can ensure the integrity of information to some extent [100]. Another problem that hinders the development of e-commerce is the transaction risk. Blockchain technology in the asset trading and payment process can effectively solve this challenge and ensure the security of the transaction process [101]. Current cross-border e-commerce transactions have problems such as fraud and credit risk. Most cross-border e-commerce payments are made through the medium of third-party banks and financial institutions. The commercial banks on both sides must clear and settle each payment before transferring it to the central bank for approval. Cross-border electronic payment has many problems such as long cycle time, high liquidation cost, low efficiency, and complex process. The cross-border e-commerce payment system based on blockchain technology can enhance system security and national supervision, assisting in realizing direct transactions between buyers and sellers [89]. The design ideas of the cross-border e-commerce payment system based on blockchain technology are as follows: Firstly, according to the transparency of blockchain technology, the new payment system can solve the identity authentication problem of the parties to transactions on the Internet and improve the efficiency of the entity identity authentication of the original payment system. Secondly, the distributed ledger makes every payment transaction traceable and improves the security of the transaction process. Thirdly, the decentralized characteristics of blockchain technology can improve the payment efficiency of cross-border e-commerce payment systems, simplify the payment process, and improve the rate of capital transfer. The Ripple protocol, as a new protocol for international settlement, is widely used in distributed cross-border e-commerce payment systems due to blockchain technology adoption. The Ripple's cross-border e-commerce payment system is associated with its network through a gateway, facilitating the real-time payment for financial settlement institutions and banks. It is achieved through the Ripple network, thus enabling global, real-time, and decentralized cross-border payments.

The traceability and delivery security assurance of cross-border e-commerce goods are other blockchain-enabled capabilities. Even though cross-border e-commerce has been rapidly developed due to the convenient transportation conditions and "one-belt-one-road" construction, there still exist problems in "one kilometer out of the factory" and "the last kilometer". The "one kilometer from the factory" refers to the process from the production of products to the logistics transportation system. "The last mile" refers to the terminal delivery of goods, and this process has the problem of goods being misrepresented or lost. The asymmetric encryption technology in blockchain can solve the above problems. The manufacturing side holds the private key, and the transportation side holds the public key, which can effectively ensure the information protection of consumers. In addition, the digital signature technology in blockchain can help solve the problem of goods being falsely claimed or lost, promote accountability, and ensure the interests of consumers.

Finally, the authenticity and traceability of product information is another typical industry application of blockchain in cross-border e-commerce. Previous studies have found that safety issues caused by untraceable food not only harm consumers and businesses, but also it is time consuming to resolve issues due to the lack of visibility in the supply chain [45]. The blockchain applications in cross-border e-commerce products traceability are mainly reflected in ensuring the authenticity and traceability of product information. The authenticity of product sources can help to track down and investigate products, avoid selling fake products, and ensure the authenticity of cross-border products. However, a huge amount of data will be generated, and a powerful database is needed to collect, store, and manage the data, which is convenient to provide data support for product traceability. Due to its unique technology, blockchain can update information in real time and optimize the traceability system of cross-border products. From the collected literatures, we find that it is prevailing for blockchain application in the field of Internet of Things (IoT), which can combine IoT and blockchain technology to record the information of all involved participants during different business stages of cross-border e-commerce. Through the information block, the information of different stages can be traced in series to form a complete data chain. Blockchain can obtain reliable information about the origin of goods and communicate it to consumers, which can improve the market competitiveness of enterprises [102]. In this way, the data in blockchain can not only provide information services for platforms, manufactures, and consumers, but also ensure the effective traceability and quality control capability of cross-border products.

4.3.2. Blockchain-Enabled Cross-Border E-Commerce Supply Chain Management

Supply chain management aims at minimizing the cost of the entire supply chain by coordinating the supplying process involving suppliers, manufacturers, and distributors [103]. Blockchain technology is widely regarded as an innovative model to promote sustainable development of global supply chains [12,34]. The blockchain-based innovations conducted help to improve operational performance and energy efficiency of the cross-border e-commerce supply chain [11]. In addition, it can also increase trust degree among the chain members and improve the operational efficiency of logistics, thus effectively contributing to the construction of sustainable supply chain management [57]. The integration applications of blockchain and supply chain management has been demonstrated to be a great triumph in practical case studies [104], and it has been recognized and advocated by several scholars [35,105]. The use of blockchain technology in the supply chain can improve supply chain transparency and accountability mechanisms by enhancing supply chain resilience [43,106]. In addition, blockchain technology has great value for global supply chains and cross-border transactions [107]. The bibliometric study reveals that blockchain can improve supply chain efficiency in several industrial scenarios. In order to understand more specifically the effect of blockchain in each link, we analyzed the application of blockchain in cross-border e-commerce supply chain management from three links: procurement, manufacturing, and distribution.

To reduce supply chain risks, suppliers need to be evaluated on criteria that should take into account, in addition to cost, the supplier's attitude toward environmental and social issues [79]. The collected data for decision-making of participants is usually structured, and the integration of this data requires behavioral analysis of suppliers' deliveries, warehousing, and transportation models. Moreover, the distributed ledger formed by each block allows for cross-regional confirmation of data due to the decentralized mechanism of blockchain. The blockchain-based transparent information platform can be established between the platform and merchants for public inquiry at any time to ensure the transparency of information and urge suppliers to further improve product quality and provide better services to customers. In the process of enterprise production, the consumer demand is gradually changing from mass production to personalized customization. Traditional production is large-scale batch production, which also leads to serious homogeneity of products, with single shape and design. However, the application of a new generation of digital technology allows some products to be adjusted according to the changing needs of users. Under the environment of industry 4.0, many manufacturing enterprises are seeking to optimize the structure, transform, and upgrade. By strengthening the effective sharing of information and resources in organizations, manufacturing enterprises can be promoted towards intelligent, integrated, lean, and flexible production.

Supply chain flexibility refers to the flexibility of operations management to better meet customer needs and achieve the economic goals pursued by the company. Supply chain flexibility not only allows for quick response to unexpected events, but also greatly reduces supply chain risk by reducing response time and losses. Blockchain technology brings automatic organization of production to the supply chain, automatically matching demand and supply according to the information exchange between upstream and downstream, which contributes to the upgrading and transforming of the manufacturing process in a smart way. The blockchain technology platform can ensure access to effective control between a large number of devices, which facilitates to the coordination between machines and humans. It changes the operation mode of traditional supply chain, which needs to rely on one core enterprise to promote the collaborative operation of the supply chain. Industry 4.0 suggests that the operation mode of enterprises should be decentralized. Siemens is famous for adopting digital model solutions and establishing Internet of Things operating system in enterprises to customize digital transformation solutions for customers. The internet-based industrial platform promotes the integration of mass manufacturing and personalization through efficient supply chain management by involving consumers' requirements. However, the integration of the Internet and industrial chain is not perfect at present, mainly in the following two aspects. Firstly, the application of blockchain technology on the Internet faces performance and regulatory challenges. Secondly, in the process of promoting smart manufacturing, there are many demands for low latency landing in end-use scenarios. These are the bottlenecks for the application of blockchain technology in industrial Internet.

Finally, the application of blockchain in the distribution chain. Traceability of goods in the supply chain is very important. The traceability of the whole process tends to be possible due to the blockchain adoption. Supply chains are becoming more and more complex, which may lead to trust issues in some processes for some sensitive commodities, such as pharmaceuticals. The national policy regulates that it needs full traceability of the origin and processing of some critical products. Blockchain technology can reliably record every shipment in the supply chain. This traceability extends from the extraction of raw materials, all the way to the completion of the final customer's purchase. The added value is another possible competitive advantage of blockchain technology in supply chain management. The increased transparency and traceability not only increase the advantages for supply chain companies, but also create more trust in the product among consumers, increasing customer satisfaction and brand loyalty, attracting more consumers.

4.3.3. Blockchain for Data Governance and Information Management

With the philosophy of circular economy and circular supply chain having been put forward, enterprises in the supply chain regard environmental sustainability as one of the significant contents of operation management. The goal of supply chain governance is to make enterprises in the supply chain take environmental responsibility to ensure safe, green, and clean production through effective data governance. The analysis by co-word analysis reveals that blockchain has been applied in the field of big data. By 2021, a quarter of the world's largest publicly traded companies are expected to have established digital trust based on blockchain technology, according to IDC. At present, the demand for data mainly includes data accessibility and data format consistency. The data recorded in blockchain technology can be open to different objects, and the encryption technology of blockchain can also ensure the privacy and safe storage of data. In addition, the collected data can also play a very important role in providing personalized services for customers. In the process of data collection, how to ensure the reliability and security of data is an important aspect to be considered. In addition, blockchain technology can help data to promote the re-innovation of production, sales, and after-sales service. However, the blockchain technology faces challenges in terms of low latency at this stage. Therefore, the next blockchain technology needs new mechanisms to achieve efficient processing of large amounts of data and quick consensus, to meet the smart applications.

In addition, blockchain can also play an important role in information management. The supply chain is composed of suppliers, manufacturers, retailers, and consumers. The traditional supply chain usually relied on core enterprises to connect the upper and lower parts of the supply chain. However, the core enterprises had a limited grasp of the upstream and downstream of the supply chain, and it was difficult to obtain the data of the whole supply chain network. As a result, it is difficult for core enterprises to effectively integrate the capital flow, information flow, and logistics upstream and downstream of the supply chain, leading to the phenomenon that the management ability cannot keep up with the management demand. However, by building an information resource sharing platform with blockchain technology and effectively integrating all stakeholders, the information can be effectively integrated between upstream and downstream, reducing information delay and improving the information utilization rate.

Scholars have addressed the blockchain-driven information management in the supply chain [108]. The emergence of information resource sharing platform can make enterprises from the past "passive production" to "active production", changing the production relationship between enterprises and consumers. The traditional chain structure of "supplier-manufacturer-wholesaler-retailer" may be overturned, and the barriers between different links will be broken. The supply chain based on blockchain is more inclined to develop to the "network" structure. Blockchain not only acts as a decentralized database, but also enables relevant stakeholders to monitor the performance of the entire supply chain. Under the Industry 4.0 era, Internet of Things and intelligent cyber physics systems are adopted in industrial plants for data collection and recording. The blockchain integrated application potentials need to be developed by combining with the Internet of Things, cloud computing, big data analysis, and other technologies. Blockchain technology can trust the collected data at a low cost, and the collected data can be analyzed massively through artificial intelligence and cloud computing to dig deeper for information. In this process, both structured and unstructured data are usually included, and the growth of this data is usually exponential. Therefore, blockchain technology can promote the operation efficiency of cross-border e-commerce supply chain through enabling information management and transformation of industry information.

5. Implications to Theory and Practice

5.1. Implications to Theory

From the perspective of taxonomy, this paper conducts quantitative bibliometric research on the existing literature of blockchain in cross-border e-commerce supply chain management. It provides systematic understanding and theoretical insights for the innovative applications of blockchain-enabled cross-border e-commerce management practice. Moreover, the paper fills the relevant research gaps on the potential impact of blockchain on cross-border e-commerce supply chain management, while enriching the innovative cross-border e-commerce development by providing potential industrial applications and research opportunities.

5.2. Implications to Practice

This research is conducive to actively adopting and employing blockchain in cross-border e-commerce, facilitating the promotion of the cross-border e-commerce industry by a systematical analysis of blockchain enabling cross-border e-commerce. Specifically, the related themes are addressed regarding blockchain enabling cross-border e-commerce platform, cross-border e-commerce supply chain management, and data integration information management. The practical implications are introduced from the aspects of enterprises, government, industry, and academic specifically.

In term of organizational enterprises, blockchain facilitates data sharing and business process optimization of the e-commerce supply chain. The cross-border e-commerce enterprises can develop blockchain-based innovations to promote the relevant application of supply chain management. Additionally, cross-border e-commerce businesses may employ the blockchain technology to solve issues in specific scenarios, such as promoting paperless bills and optimizing financing processes. For national governments, related regulations should be made to encourage blockchain technology adoption in the cross-border e-commerce. Relevant policies are formulated to accelerate the integrated application of blockchain technology in the supply chain. For the industrial plants, the different industries may apply blockchain to solve the problems of information credibility, false financing, and repeated financing in cross-border e-commerce business, and the transaction efficiency would be improved in complex transaction scenarios involving multiple parties. In addition, this paper also provides inspiring research ideas for researchers engaged in the cross-field of blockchain and cross-border e-commerce, and it discloses directional inspiration for those who would understand the in-depth application of blockchain in the cross-border e-commerce supply chain.

6. Conclusions

This paper aims to analyze the application status of blockchain technology in cross-border e-commerce supply chain management by analyzing relevant literature on blockchain-enabled cross-border e-commerce supply chain management. Firstly, based on the literature review of cross-border e-commerce supply chain management and the bibliometric analysis, we found that the technical features of blockchain can effectively solve the challenges of cross-border e-commerce platforms and supply chain management. Secondly, relevant literature was collected through the Web of Science database, and the bibliometric analysis was adopted to analyze the trend of the development status of blockchain and cross-border e-commerce supply chain management.

We found that research related to blockchain has increased recently, and the research hotspots in recent years mainly focused on the Internet of Things, supply chain, intelligent community, cloud computing, chemical industry, aviation, and other fields. In addition, we focused on analyzing the research trends of blockchain technology in cross-border e-commerce, supply chain management, information management, and data governance. The significant role of blockchain technology in segmental process of cross-border e-commerce supply chain was also addressed to assist developing innovative management practices. We also found that blockchain could help cross-border e-commerce to solve some existing difficulties, such as customer information security, efficiency of commodity logistics and distribution, and authenticity and traceability of product information. By promoting the application in the procurement process, manufacturing chain and distribution chain, the specific roles of blockchain-empowered cross-border e-commerce supply chain area were discussed and highlighted to help better discover the potential innovation opportunities.

In addition, this study also reveals some theoretical enlightenments and practical significances. The blockchain technology can help cross-border e-commerce supply chain to carry out flexible management and efficient allocation of resources by innovative management practices.

7. Research Limitation and Future Research

This study has some limitations. Firstly, the bibliometric approach was adopted to analyze and explore the development trend of blockchain technology in cross-border e-commerce supply chain. The review study mainly relies on previous published references, and the qualitative interview research study is also necessary to help better understand this area. In addition, the smart big data-based mining approach and intelligent analysis framework can also be developed to help understand the current research status and potential future development trend of the blockchain-empowered cross-board e-commerce sector. Secondly, the data collection time set in this paper is limited to June 2021, and the literature after this period is not included in the scope of the study. The selection of the database was based mainly on the Web of Science database, and literature collection from other databases was not considered. The multiple data sources and different databases with other languages could also be taken into account for data samples, which assists in achieving more convincing and comprehensive results.

With the development of the cross-border e-commerce industry, the traditional technology model cannot meet the growing demands of e-commerce platforms. Blockchain technology, owing to its technical features, can alleviate the logistics, cross-border payment and product traceability problems faced in cross-border commodity transactions. Blockchain's empowerment on cross-border e-commerce platforms can not only improve logistics efficiency, but also contribute to the sustainability achievement of the cross-border e-commerce industry with higher efficiency. Although the application of blockchain has great potentials, the large-scale application and implementation has not been fully implemented. Most of the blockchain research applications are still in the pilot phase. There are many reasons for the existing technical limitations of blockchain. For its transparency and un-changeability, it needs more computing power since the latter block records all the data of the previous block in practical application scenarios. In addition, block-chain has been widely studied in the field of finance, tracing from primary industry to agricultural products, and in the field of new technologies such as Internet of Things and big data in the tertiary industry. In the future, we hope that we can increase the cooperative research between blockchain and the typical application scenarios in different sectors. At the same time, we also hope to develop new technologies on the basis of existing technologies in the future to overcome the shortcoming of existing blockchain technologies.

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