INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN ECONOMICS & MANAGEMENT SCIENCES

OPEN ACCESS JOURNAL

Vol 13, Issue 2, (2024) E-ISSN: 2226-3624

Application of Blockchain Technology in Agricultural Product Supply Chain: Cite Space Bibliometric Analysis Based on WOS Database

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To Link this Article: http://dx.doi.org/10.6007/IJAREMS/v13-i2/21784 DOI:10.6007/IJAREMS/v13-i2/21784

Published Online: 21 June 2024

Abstract

The application of blockchain technology in the agricultural supply chain is an emerging field that addresses critical issues of transparency, traceability and sustainability. This study aims to explore the current status and trends in this field through a bibliometric analysis using CiteSpace based on data from the Web of Science (WoS) database. Through the use of CiteSpace, this study identifies key research topics, influential publications and emerging trends in the literature on blockchain technology in agricultural supply chains. The methodology of this study includes co-citation analysis, keyword co-occurrence analysis and cluster analysis to depict the intellectual structure and evolution of this research field. The main findings indicate a growing interest in the integration of blockchain to improve traceability, increase supply chain efficiency and ensure food safety. Key research clusters focus on the challenges of blockchain implementation, case studies of successful blockchain adoption and the impact on supply chain sustainability. This analysis reveals significant gaps in the literature, particularly in the areas of blockchain scalability and regulatory frameworks. The study suggests further research to fill these gaps, emphasizing the need for interdisciplinary approaches and real-world application studies. This study provides a comprehensive overview of the current research landscape and provides valuable insights for researchers and practitioners looking to utilize blockchain technology in agricultural supply chains.

Keywords: Blockchain, Agricultural Product, Supply Chain, Citespace, Bibliometric

Introduction

With the continuous development of blockchain technology, it has become one of the reforming technologies in many fields and is being adopted by many different industries, especially those with backgrounds in banking, supply chain, logistics, etc (Guo et al., 2021). As an emerging enabling technology, blockchain technology provides fundamental conditions for the modernization of agriculture (Chandan et al., 2023). The policies and strategic models for the development of blockchain for agricultural products have different local characteristics

(Akella et al., 2023). Economically developed areas rely on their advantages in business, technology and talents to invest in high standards and starting points to consolidate and lead the new technological revolution and maintain leading development; while economically backward areas make blockchain another strategic choice after the realization of new technologies such as big data and artificial intelligence (Kamble et al., 2020). Therefore, analyzing the principles and operation mechanisms of blockchain for agricultural products, establishing a trustworthy and highly transparent agricultural supply chain, and promoting the development of agricultural product traceability, agricultural product supply chain management and other fields are of great significance to the high-quality development of agriculture.

In addition, in recent years, under special circumstances such as the COVID-19 epidemic, uncertainties in production, consumption and trade in the agricultural commodity supply chain have further deepened, and the development of the agricultural commodity supply chain is still in its infancy (Chandan et al., 2023). These issues prompte to integrate blockchain technology into the agricultural product supply chain to solve existing problems and realize the intelligent development of the agricultural product supply chain through various blockchain technologies (Kowalska & Bieniek, 2022). Blockchain technology integrates, innovates, deepens and interleaves existing advanced digital information technologies such as communication, artificial intelligence, augmented reality and the Internet of Things (Wang & Chen, 2022). The integration of blockchain technology into the agricultural product supply chain can organically integrate the operation of each link of the agricultural product supply chain and combine it with the technology of the Internet of Things to provide a virtual and real simulation platform that accurately meets the needs of the intelligent agricultural product supply chain (Raza et al., 2023). The combined development of blockchain and supply chain will bring emerging technologies into traditional industries, and the agricultural product supply chain strengthened by blockchain will gradually become a new development trend (Lezoche et al., 2020). The previous researches on visual analysis, scholars mostly only researched on "agricultural product supply chain" or "blockchain", and there were relatively few comparative and fusion studies on the intersection of these two terms.

This article uses bibliometric methods to conduct a visual analysis of literature data on the keywords supply chain for agricultural products and blockchain. Based on the concept, characteristics and value of blockchain in conjunction with the characteristics of the agricultural product supply chain field, we closely follow and predict the role of blockchain in agricultural products (Ktari et al., 2022). A combined "blockchain + agricultural product supply chain" and dual-chain operating model is proposed for adaptation and innovation in the supply chain field, focusing on the following three points.

(1) What security guarantees does blockchain provide for the agricultural product supply chain?

(2) In what aspects does blockchain promote the development of agricultural product supply chains?

(3) What problems does blockchain solve in the agricultural product supply chain?

Research Methods and Data Sources

Research Methods

This study uses bibliometric analysis methods, combined with scientific knowledge graphs, and uses data mining, information processing, knowledge measurement, and graphical visualization to represent the scientific research field (Luo et al., 2022). CiteSpace is an information visualization and analysis software developed by Chen Chaomei, which can be used to explore citation networks based on large amounts of bibliometric data (Song et al., 2022). CiteSpace is an important reference for interdisciplinary research, enabling researchers to effectively understand specific research areas, their connections and emerging areas of interest (Wang et al., 2022). Li et al (2023), for example, used CiteSpace to trace the origin of the development of the system and show the latest research topics and the knowledge map of the application of blockchain technology in agricultural product supply chains (Li et al., 2023). Lin et al (2020) used the information visualization software CiteSpace to conduct a bibliometric analysis and display the knowledge structure and hot spots in the application research of blockchain technology in agricultural product supply chains in the form of a knowledge map (Lin et al., 2020). Li et al (2023) used the visualization tool CiteSpace to conduct a bibliometric research analysis to quantify and visualize the pattern and development of research on the combination of blockchain and agricultural product supply chain (Li et al., 2023). These studies show that the use of CiteSpace software can visually represent trends and research priorities at different stages of a research field (Ktari et al., 2022). Therefore, this article employs bibliometric analysis methods and uses CiteSpace 6.1.R6 software to investigate from the perspective of journals, lead authors, institutions, keyword co-occurrence, hot word cluster, blockchain, and core content of agricultural product supply chains. This study aims to clarify the research status, hot spots and limitations of blockchain technology in the application of agricultural product supply chain, and explore the development trends and future research directions of "Blockchain Technology + Agricultural Product Supply Chain".

Data Sources

The Web of Science Core Collection database was selected as the data source for this study due to the inclusion of literature from various disciplines such as engineering, social sciences, medicine, management, and philosophy (Cao et al., 2022). The topic of this study is social media in organizations. After various attempts, the most comprehensive article was found using the search terms TS = ("blockchain" and "agricultural supply chain"). Literature is limited to English articles, and the search time is October 22, 2023. Finally, a total of 166 relevant articles were selected, covering the period from 2018 to 2023. The research plan of this article is shown in Figure 1.

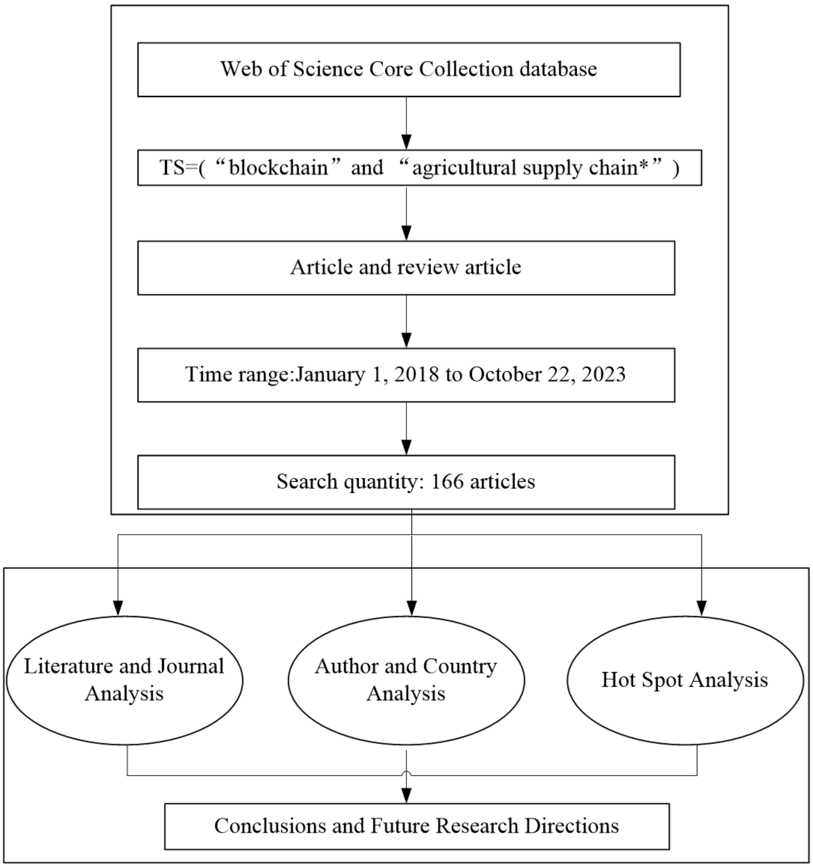

Figure 1. Research road map

Results of the Analysis

Journal Analysis

Overview of Publications

It can be seen from the number of published research documents on the combination of blockchain and agricultural product supply chain that with the application and development of blockchain technology in recent years, relevant documents on the application of blockchain technology in the supply of agricultural products are also emerging. Chains also appeared. and is on an upward trend. According to Figure 2, research can be divided into three stages based on the number of publications: research initial stage, slow development stage and rapid growth stage. Before 2019, there were basically no relevant publications, indicating that blockchain technology was still in its infancy during this period. From 2019 to 2020, with the development of popular technologies such as the Internet and big data, scholars gradually turned their attention to the research of blockchain technology. More and more scholars linked blockchain technology to this topic, leading to a number Slow growth. Publications on the subject. The number of publications has increased rapidly since 2021, indicating the increasing number of applications of blockchain technology in agricultural product supply chains and the growing interest among scientists in the topic. At the same time, a search on the Web of Science found that there are relatively few studies on the application of blockchain technology in agricultural product supply chains, indicating that scientists still have a lot of room to further deepen their research.

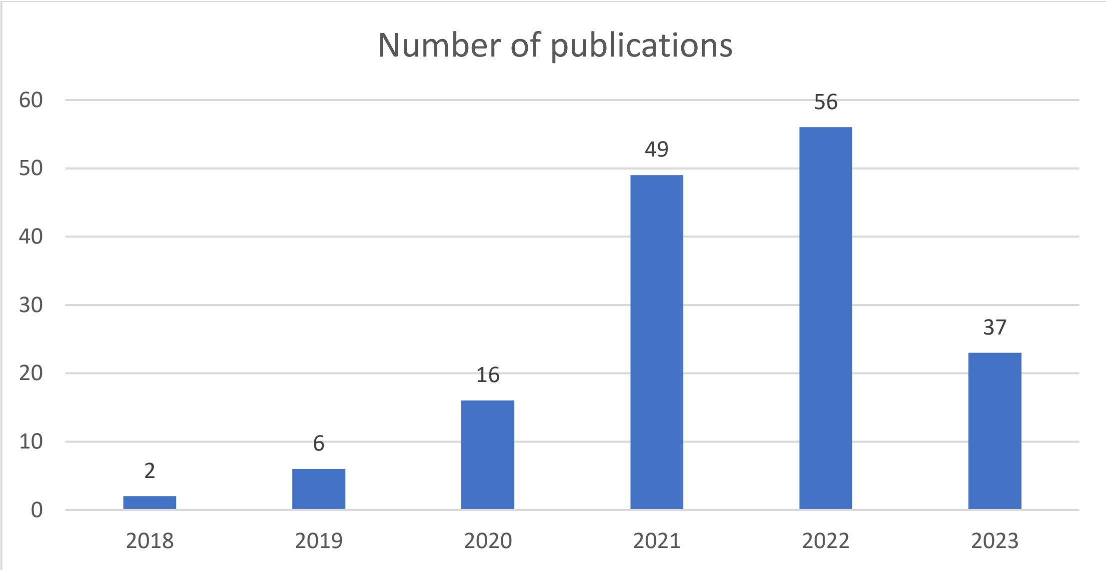

Figure 2. Annual publication statistics of "Blockchain + Agricultural Products Supply Chain". (Note: Statistics are as of 2023)

Analysis of Publishing Journals

Table 1

Major journals for blockchain and agricultural supply chain research

Journals	**Publication**	**Proportion of 166**
Journal of Cleaner Production	11	6.63%
Sustainability	11	6.63%
Leee Access	10	6.02%
Computational Intelligence and Neuroscience	5	3.01%
Computers & Electrical Engineering	5	3.01%
Sensors	5	3.01%
Applied Sciences-Basel	4	2.41%
Agriculture-Basel	3	1.81%
Cmc-Computers Materials & Continua	3	1.81%
Mathematical Problems in Engineering	3	1.81%
Mathematics	3	1.81%
Annals of Operations Research	2	1.20%
Cluster Computing-the Journal of Networks Software Tools and Applications	2	1.20%
Computers and Electronics in Agriculture	2	1.20%
Computers in Industry	2	1.20%
Discrete Dynamics in Nature and Society	2	1.20%
Expert Systems with Applications	2	1.20%
Foods	2	1.20%
International Journal of Environmental Research and Public Health	2	1.20%
Journal of Agribusiness in Developing and Emerging Economies	2	1.20%

Journal of Cleaner Production	2	1.20%
International Journal of Production Economics	2	1.20%
Peerj Computer Science	2	1.20%
Scientific Programming	2	1.20%
Scientific Reports	2	1.20%
Transactions on Emerging Telecommunications Technologies	2	1.20%
Transportation Research Part E-Logistics and Transportation Review	2	1.20%
Web Intelligence	2	1.20%

Journals are platforms on which research areas and results are presented. Table 1 summarizes the journals that have published more than two articles (Miller et al., 2023). It can be seen that most articles on the application of blockchain technology in agricultural product supply chains are published in internationally renowned journals, which shows that the application of blockchain technology in agricultural product supply chains has become a trend in recent years. popular research topics. The top three journals in terms of publication volume are “Journal of Cleaner Production”, “Sustainability” and “Leee Access”. Among them, “Journal of Cleaner Production” has published 11 articles, “Sustainability” has published 11 articles, and “Leee Access” has published 10 articles. Other publishing journals publish fewer research results on the topic of blockchain and supply chains for agricultural products, but are nevertheless important publication platforms.

Analysis of Co-Cited Reference

Literature citations reflect the quality of research, innovation in a particular field, attention and recognition from scholars (Shreya et al., 2023). They help researchers understand hot topics and important milestones in their fields (Song et al., 2022). Through citation analysis of the literature, it is possible to identify influential articles on the application of blockchain technology in the supply chain for agricultural products. The citation rate of an article is considered an important indicator of its research value. Table 2 provides details of the 10 most cited articles. It should be noted that the citation frequency from Web of Science was determined based on 166 selected articles.

Table 2
The details of the top 10 cited articles

No.	Title	Journals	Authors	references	Citation Frequency
1	A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda	Njas-wageningen Journal of Life Sciences	Klerkx, L; Jakku, E and Labarthe, P	(Klerkx et al., 2019)	397
2	Future challenges on the use of blockchain for food traceability analysis	Trac-trends in Analytical Chemistry	Galvez, JF; Mejuto, JC and Simal-Gandara, J	(Galvez et al., 2018)	345

3	Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications	International Journal of Production Economics	Kamble, SS; Gunasekaran, A and Gawankar, SA	(Kamble et al., 2020)	345
4	Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture	Computers in Industry	Lezoche, M; Hernandez, JE; Díaz, MDEA; Panetto, H; Kacprzyk, J	(Lezoche et al., 2020)	260
5	Blockchain-Based Soybean Traceability in Agricultural Supply Chain	IEEE Access	Salah, K; Nizamuddin, N; Jayaraman, R; Omar, M	(Salah et al., 2019)	248
6	Research on agricultural supply chain system with double chain architecture based on blockchain technology	Future Generation computer systems-the international Journal of Escience	Leng, KJ; Bi, Y; Jing, LB; Fu, HC; Van Nieuwenhuyse, I	(Leng et al., 2018)	223
7	A systematic literature review on machine learning applications for sustainable agriculture supply chain performance	Computers & Operations Research	Sharma, R; Kamble, SS; Gunasekaran, A; Kumar, V; Kumar, A	(Sharma et al., 2020)	216
8	From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies, and Research Challenges	IEEE Transactions on Industrial Informatics	Liu, Y; Ma, XY; Shu, L; Hancke, GP; Abu-Mahfouz, AM	(Liu et al., 2021)	183
9	Blockchain-Based Traceability for Agricultural Products: A Systematic Literature Review	Agriculture - Basel	Lv, GJ; Song, CX; Xu, PM; Qi, ZG; Song, HY; Liu, Y	(Lv et al., 2023)	175
10	Blockchain technology adoption barriers in the Indian agricultural supply chain: an integrated approach	Resources conservation and recycling	Yadav, VS; Singh, AR; Raut, RD; Govindarajan, UH	(Yadav et al., 2020)	153

The most cited article among them is the one by Klerkx, Mukherjee et al (2022), which comprehensively discusses the agenda of social sciences in terms of new contributions and future research in various aspects such as digital agriculture, smart agriculture, and agriculture

4.0 (Mukherjee et al., 2022). This work has been accepted, adopted and cited by many scholars. The second most cited paper is that of Dayana et al (2022), which examines the potential of blockchain technology to ensure traceability and authenticity in food supply chains (Dayana & Kalpana, 2022). They conclude that the application of blockchain technology in the field of food safety can be considered a truly innovative and relevant method to ensure the quality of the third step of the analysis process, data collection and management. The third most cited paper is that of Kamble et al (2020), which primarily provides a research overview of achieving sustainable performance in data-driven agricultural supply chains (Kamble et al., 2020). Their research addresses issues such as lack of industrialization, poor management, inaccurate information and inefficiencies in agri-food supply chains (Hu et al., 2021). The sustainability of agricultural supply chains can be driven by IoT, blockchain and big data technologies (Khan et al., 2022). At the same time, these technologies are driving agricultural supply chains towards a data-driven digital supply chain environment (Mukherjee et al., 2022). Based on the findings of the review, an application framework is proposed for practitioners dealing with agri-food supply chains. It identifies supply chain visibility and supply chain resources as key drivers for developing data analytics capabilities and achieving sustainable performance, and identifies future research directions and limitations (Kumari et al., 2023). Several other papers also explored the application of blockchain technology in the traceability of agricultural product supply chains and the influencing factors of blockchain technology on Agriculture 4.0 (Altarturi et al., 2023). Blockchain technology thus has an impact on the long-term development of agricultural product supply chains. These widely cited papers provide guidance for future researchers and provide theoretical and practical significance for the sustainable development of agriculture.

Author and Country Analysis

Author Analysis

The author collaboration network diagram can reflect the author's influence in a specific research field and the cohesion of the collaboration network (Amiri-Zarandi et al., 2022). This section analyzes the main authors through the author collaboration network diagram. The size of the nodes in the graph represents the number of published articles, and the connections between nodes represent the collaborative relationship between authors. The number of published articles is represented as node size, close collaboration between authors is represented as link thickness, and the time of publication is represented as color depth. The density of lines is positively correlated with the intensity of collaboration. Figure 3 shows the formed author collaboration graph, which consists of 150 nodes and 135 lines connections, with a network density of 0.0121. Among them, the nodes representing Raut, Awan and Ahmed are larger in size, indicating that these authors have produced more research results on the application of blockchain technology in agricultural product supply chains. Furthermore, connections between nodes in the graph are relatively sparse, and some nodes are isolated and scattered, indicating limited collaboration among some authors. Overall, blockchain technology is not highly collaborative in the field of agricultural supply chain research; there is no overall trend of collaboration among authors.

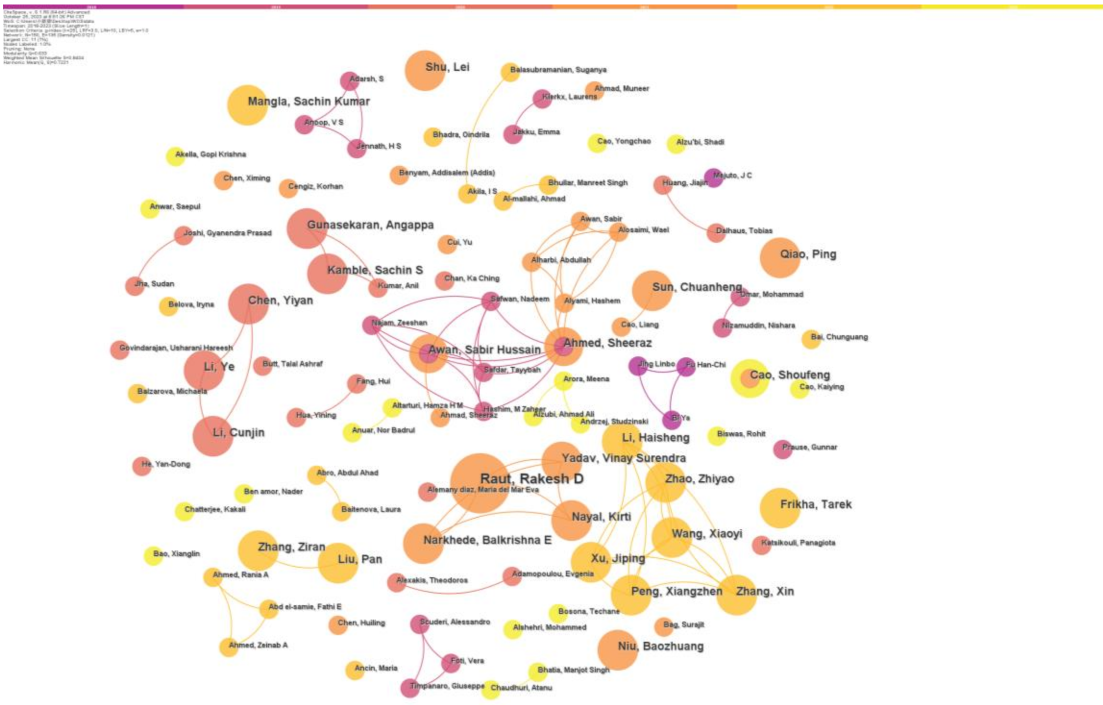

Figure 3. Author network map

Institutional Collaboration Mapping Analysis

It is crucial to analyze the degree of collaboration between different countries, institutions and scientists from the perspective of research organizations (Das et al., 2023). This enables a more in-depth explanation of the research progress of different research organizations in the application of blockchain technology in agricultural product supply chains (Luo et al., 2022). The presentation method of the institutional collaboration map analysis is consistent with the presentation method of the authors' collaboration map. In Figure 4, there are a total of 130 nodes, 97 links, and a density of 0.0121. This shows that there is a relative lack of cross-institutional collaborative research. Each node represents an organization, and the links between nodes represent collaboration between organizations. The color at the top of the institutional network diagram gradually changes from dark to light, from purple to orange, and finally to yellow, representing early research and recent research, respectively. In addition, the color in the middle of the circle represents the earliest year of publication, while the thickness of the color scale corresponds to the number of publications in the corresponding year. Among them, China Acad Social Science, Hubei College Economy, Katholieke College Leuven and Vigo College are the earliest research institutions, Vellore Institute Technology is the new force, and Natl Inst Ind Engn NITIE, Beijing Institute Technology, Henan Agricultural College and Harbin Univ Commerce are the major research institutions.

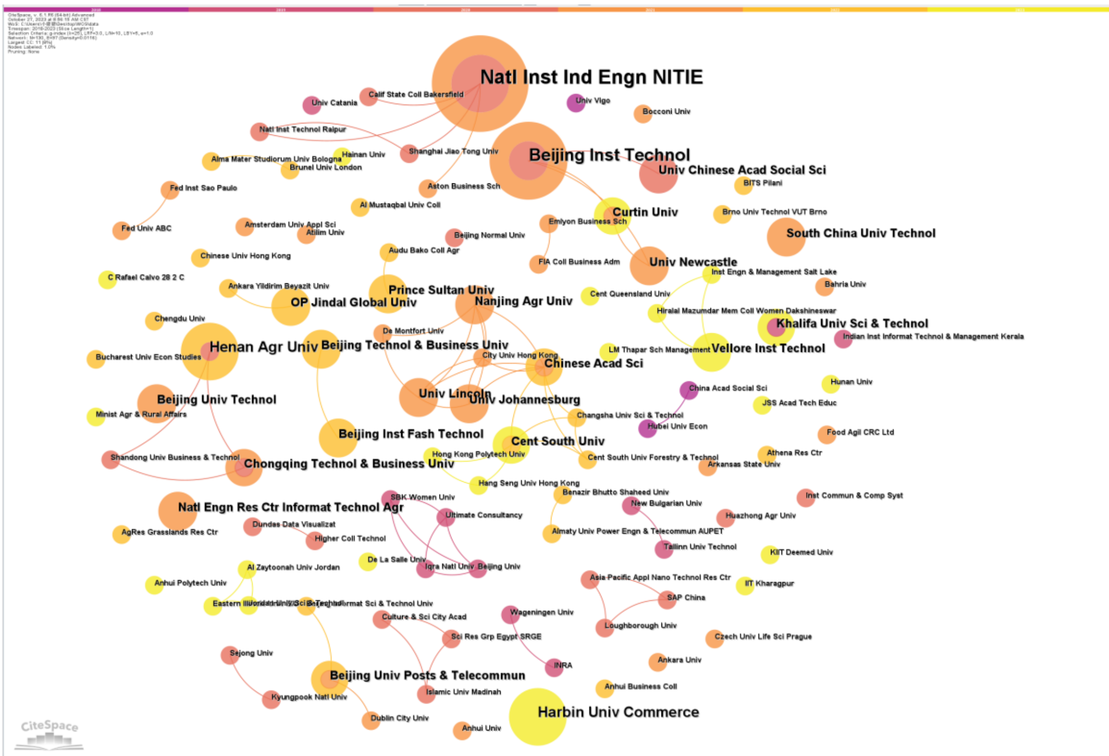

Figure 4. Institutional cooperation map analysis

National Analysis

Based on the results of the CiteSpace National Collaboration Network, the ten countries with the highest number of publications were identified (Xiong et al., 2020). As shown in Table 3, China has the most publications in the Web of Science in quantitative terms with 73 publications. It is followed by India (32 articles), the United Kingdom (15 articles), etc. China has the highest centrality (0.87), followed by India (0.44), Saudi Arabia (0.19), the United Kingdom (0.18), Pakistan (0.13), Australia (0.11) and other countries. Although the number of publications in China is much higher than that in India, considering the number of publications and centrality, India is also relatively advanced in the field of research on the application of blockchain technology in agricultural product supply chains. Therefore, further research should focus on strengthening international cooperation and exchanges to promote the development of research on the application of blockchain technology in agricultural supply chains.

Table 3
Total number of national papers issued

Serial	Count	Centrality	Year	Countries
1	73	0.87	2018	PEOPLES R CHINA
2	32	0.44	2019	INDIA
3	15	0.18	2020	ENGLAND
4	12	0.11	2019	AUSTRALIA
5	10	0.19	2021	SAUDI ARABIA
6	9	0.03	2020	USA
7	8	0.13	2019	PAKISTAN
8	8	0.07	2020	CANADA
9	6	0.07	2019	FRANCE
10	6	0.08	2021	TURKEY

Hot Spot Analysis

Research hotspots are the focus of current research (Sung et al., 2022). These are popular questions or topics that are discussed in a relatively large number of articles and are closely related to each other in a given time period (Wu et al., 2022). The frequency distribution and centrality of keywords in the literature can be used to examine the development trends and research priorities in this area. The Keyword Emergence Map uses keywords to represent the rate of change in the number of co-occurrences, reflecting the basic characteristics of the development and changes of the research frontier (Xie et al., 2022). In this article, CiteSpace software is used to conduct a keyword co-occurrence analysis of the literature on the application of blockchain technology in agricultural product supply chains and identify research hotspots. Since there were few publications on the concept of blockchain before 2018, this article started the statistical analysis in 2018 and created the keyword co-occurrence map of blockchain in agricultural product supply chain application. The time scale is set to 2018-2023 (the literature ends on 2023), the time interval is set to 1, the data extraction object is set to Top50, and the clipping method is Pathfinder (Cao et al., 2022). The result is 212 nodes and 936 links (as shown in Figure 5).

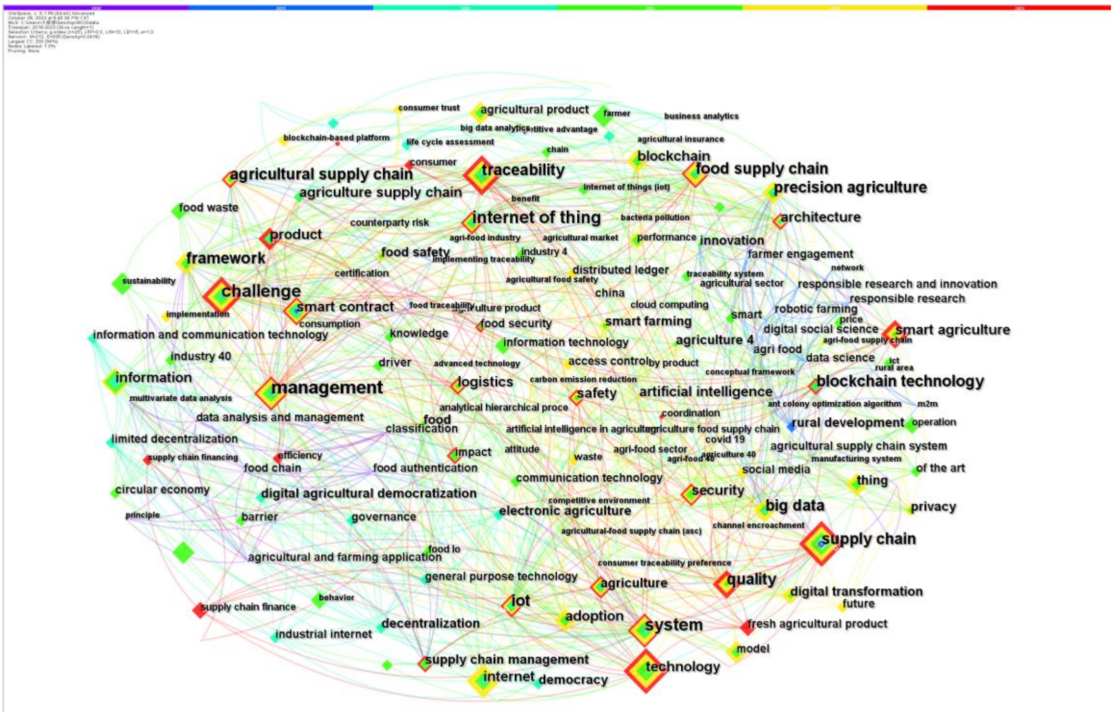

Figure 5. Graph of scientific knowledge co-occurrence of keywords

The frequency in the co-occurrence map is represented by the size of the nodes and the centrality by the thickness of the connecting lines. Centrality refers to the ability to act as an intermediary in the entire relationship network (H. P. Li et al., 2023). It is generally assumed that a node with a centrality greater than 0.1 represents its position important in comparison. According to the statistical results of the software (e.g., Table 4), the keywords with a centrality greater than 0.1 are: management (37), Internet of Things (19), challenge (31), framework (14), agricultural supply chain (11), big data (15), supply chain (58), system (31), blockchain technology (16) (as shown in Table 4). Among them, supply chain is the largest node in the relationship network, which means that it has the highest centrality in blockchain and agricultural product supply chain research, followed by management, challenge, system, Internet of Things, blockchain technology, big data, framework, etc., which means that they play a greater connection and transit role in the whole relationship network and are a hot topic in the field of blockchain technology in the field of agricultural product supply chain research.

Table 4
Statistical table of high-frequency keywords

Serial	Count	Centrality	Year	Keywords
1	37	0.25	2019	management
2	19	0.18	2019	internet of thing
3	31	0.15	2020	challenge
4	14	0.14	2018	framework
5	11	0.14	2019	agricultural supply chain
6	15	0.13	2019	big data
7	58	0.12	2019	supply chain
8	31	0.12	2018	system
9	16	0.11	2019	blockchain technology

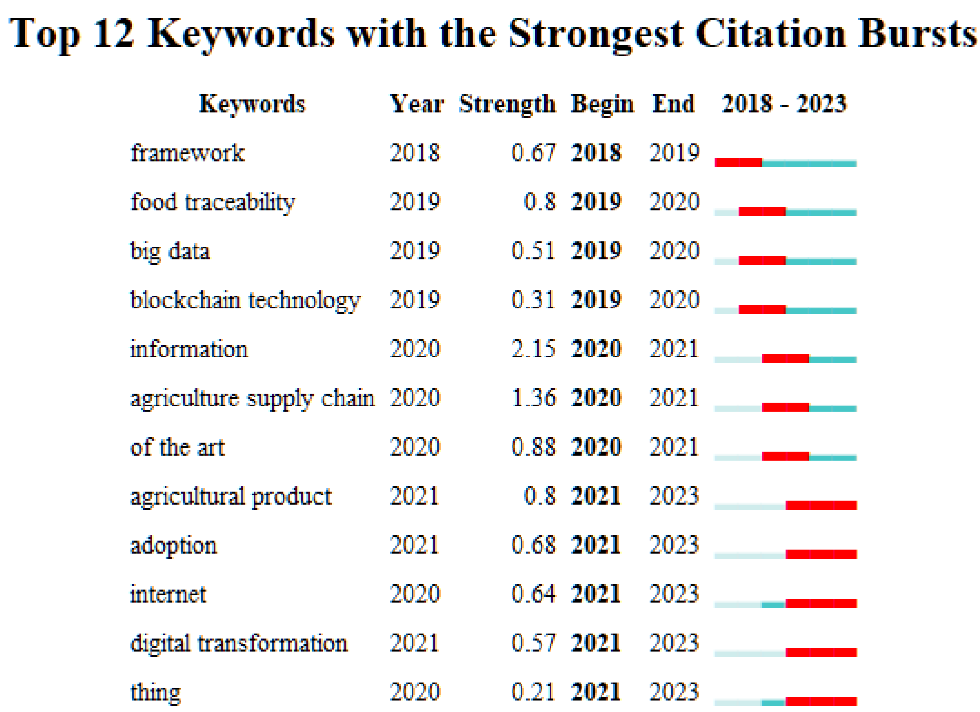

Figure 6. Key words with the Strongest Citation Bursts

The keyword burst map can show the sudden decrease or increase in the number of citations of a document, reflecting a major shift in research hotspots (Chen et al., 2020). To track the hot turning points of blockchain technology in agricultural product supply chain research, the burstiness function of CiteSpace is used to recognize the burstiness of keywords (Gan & Huang, 2022). The analysis of emerging keywords in the field of research on the application of blockchain technology in the agricultural product supply chain (see Figure 6) shows that there are a total of twelve emerging keywords. Each research hotspot has become an explosive trend in a short period of time. Over time, the research hotspots continue to change. Combining the frequency of keywords, centrality and emergencies, it can be seen that the research hotspots of blockchain technology in agricultural product supply chains have evolved from the initial framework and traceability of food, big data, blockchain technology, information, agricultural supply chain, from art, agricultural product, adoption, Internet, digital transformation and thing. From the time when these buzzwords emerged, we can learn about the application of blockchain technology in the agricultural product supply chain, from the initial draft framework to the current practical application. From theory to practice, it embodies the research and development process of blockchain application in the agricultural product supply chain.

Cutting-edge Analytics

Research fronts play an important role in clarifying research directions (Su & Cao, 2023). They relate to potential research questions and a set of emerging dynamic concepts that exist in the field (Yang et al., 2023). The keyword clustering map can summarize the similarities between keyword nodes, cluster nodes with obvious co-word relationships into a category based on data operations, and accurately represent the focus of the research frontier (Hong et al., 2018). (The scientific knowledge map of keyword clustering for blockchain application in agricultural product supply chain is shown in Figure 7).

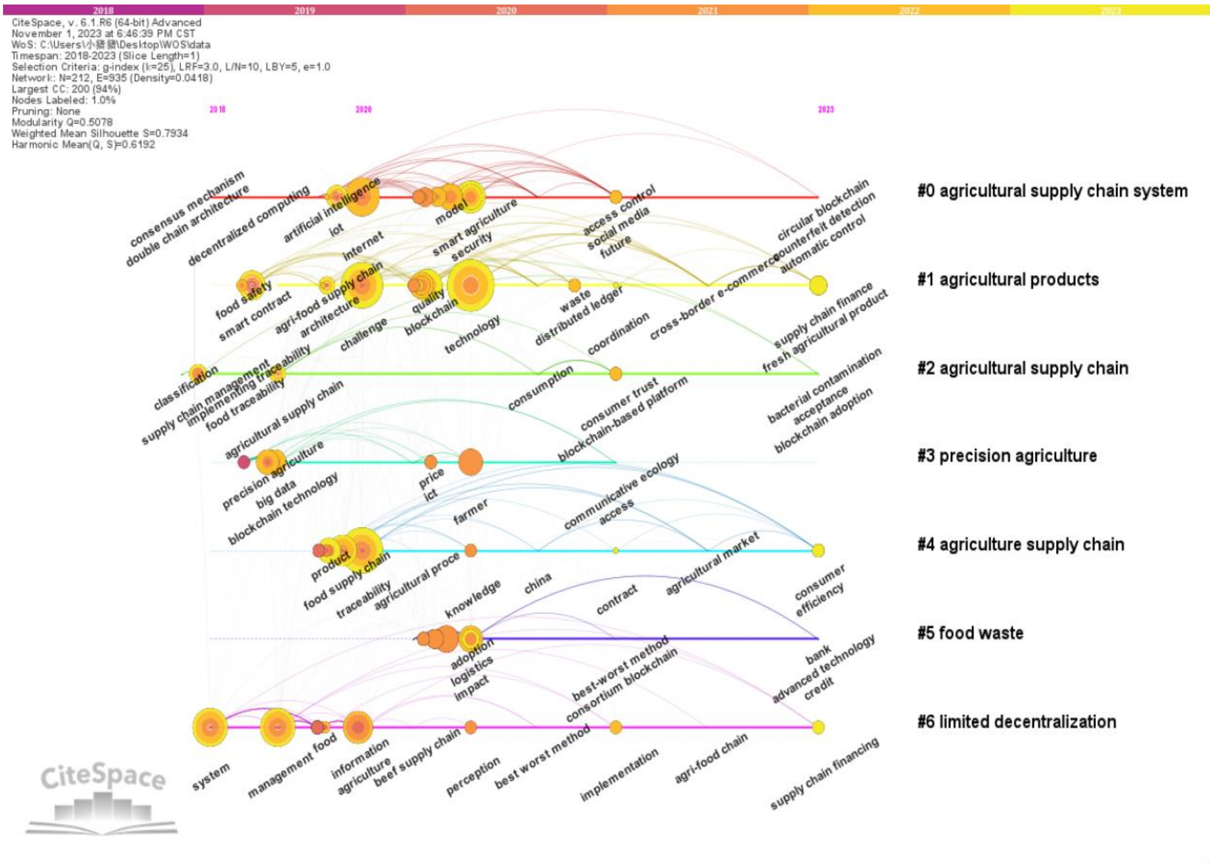

Figure 7. Scientific knowledge map of keyword clustering for blockchain application in agricultural product supply chain (timeline view)

As you can see from Figure 7, the CiteSpace keyword map generates a total of 7 elements, silhouette = 0.718, the clustering is significant and the clustering reliability is high. The research on the application of blockchain in agricultural product supply chains mainly focuses on eight topics: agricultural supply chain system, agricultural products, agricultural supply chain, precision agriculture, agricultural supply chain, food waste, and limited decentralization. (See Table 5).

Cluster#0 , agricultural supply chain system，Key words are agricultural supply chain system (7.6, 0.01); smart farming (5.33, 0.05); internet of things (4.37, 0.05); artificial intelligence (4.06, 0.05); smart agriculture (4.06, 0.05).

Cluster#1 ,agricultural products，Keywords included are agricultural products (7.35, 0.01); production (6.5, 0.05); traceability system (6.5, 0.05); agriculture supply chain (4.97, 0.05); agricultural supply chain (4.97, 0.05).

Cluster#2, agricultural supply chain，Keywords included are agricultural supply chain (8.44, 0.005); blockchain-based platform (5.41, 0.05); blockchain-based platforms (5.41, 0.05); financing risk (5.41, 0.05); offline-online business (5.41, 0.05)。

Cluster#3, precision agriculture，Keywords included are precision agriculture (8.83, 0.005); blockchain technology (6.46, 0.05); blockchain (5.94, 0.05); digital social science (4.7, 0.05); digitalization (4.7, 0.05)。

Cluster#4, agriculture supply chain, Keywords included are agriculture supply chain (9.36, 0.005); pestels (4.08, 0.05); supply chain resources (4.08, 0.05); dematel (4.08, 0.05); third-party logistics service provider (4.08, 0.05)。

Cluster#5, food waste, Keywords included are food waste (8.75, 0.005); agricultural-food supply chain (6.21, 0.05); bank (6.21, 0.05); blockchain technology (6.21, 0.05); impact (6.21, 0.05)。

Cluster#6, limited decentralization, Keywords included are limited decentralization (7.12, 0.01); digital agricultural democratization (7.12, 0.01); electronic agriculture (7.12, 0.01).

Table 5
Keyword clustering information table

Serial No.	Cluster ID	Size	Silhouette	Mean(Year)	ClusterLable	Label (Ellram & Cooper)
1	0	44	0.718	2020	agricultural supply chain system	agricultural supply chain system (7.6, 0.01); smart farming (5.33, 0.05); internet of things (4.37, 0.05); artificial intelligence (4.06, 0.05); smart agriculture (4.06, 0.05)
2	1	43	0.689	2021	agricultural products	agricultural products (7.35, 0.01); production (6.5, 0.05); traceability system (6.5, 0.05); agriculture supply chain (4.97, 0.05); agricultural supply chain (4.97, 0.05)
3	2	24	0.936	2020	agricultural supply chain	agricultural supply chain (8.44, 0.005); blockchain-based platform (5.41, 0.05); blockchain-based platforms (5.41, 0.05); financing risk (5.41, 0.05); offline-online business (5.41, 0.05)
4	3	24	0.919	2019	precision agriculture	precision agriculture (8.83, 0.005); blockchain technology (6.46, 0.05); blockchain

						(5.94, 0.05); digital social science (4.7, 0.05); digitalization (4.7, 0.05)
5	4	23	0.79	2020	agriculture supply chain	agriculture supply chain (9.36, 0.005); pestels (4.08, 0.05); supply chain resources (4.08, 0.05); dematel (4.08, 0.05); third-party logistics service provider (4.08, 0.05)
6	5	22	0.8	2021	food waste	food waste (8.75, 0.005); agricultural-food supply chain (6.21, 0.05); bank (6.21, 0.05); blockchain technology (6.21, 0.05); impact (6.21, 0.05)
7	6	20	0.86	2020	limited decentralization	limited decentralization (7.12, 0.01); digital agricultural democratization (7.12, 0.01); electronic agriculture (7.12, 0.01)

Timeline of Keywords Analysis

To visually represent the development and development trends of keywords in different time periods, the timeline function of CiteSpace is used to create a timeline map of keywords in the application of blockchain technology in agricultural product supply chains, as shown in Figure 8. The time zone visualization of keywords attempts to analyze the research characteristics and research focus of each stage in the field of spatial metaphor research from 2018 to 2023 to dynamically develop from theoretical framework to practical application. Figure 8 is the general time zone diagram of the application of blockchain in the agricultural product supply chain. The abscissa is time. The development of keywords is shown in the time dimension (Zhang et al., 2021). The research trend of blockchain application in agricultural product supply chain is clear and intuitive. There are many documents in a certain time period, indicating that researchers focused on this field at that time (Chen & Yin, 2023). The connection of nodes between time periods indicates the inheritance relationship (Bai et al., 2023). How close the connection between the two time periods is represented by the number of connections. As you can see from Figure 8, there are the fewest nodes in the 2018-2019 time period, namely only System, Framework and Supply Chain Management, and there are few links. This is the first phase of research on blockchain applications in the agricultural product supply chain, 2019 ~ 2021. In 2022, the research on the application of blockchain in the agricultural product supply chain was more in-depth, with a dense distribution of keywords and a wide range of topics. It was an explosive time. After 2022, there will be relatively few research focuses, but the topic continues to attract the attention and interest of researchers, and the research has entered a stable phase. Deepening phase.

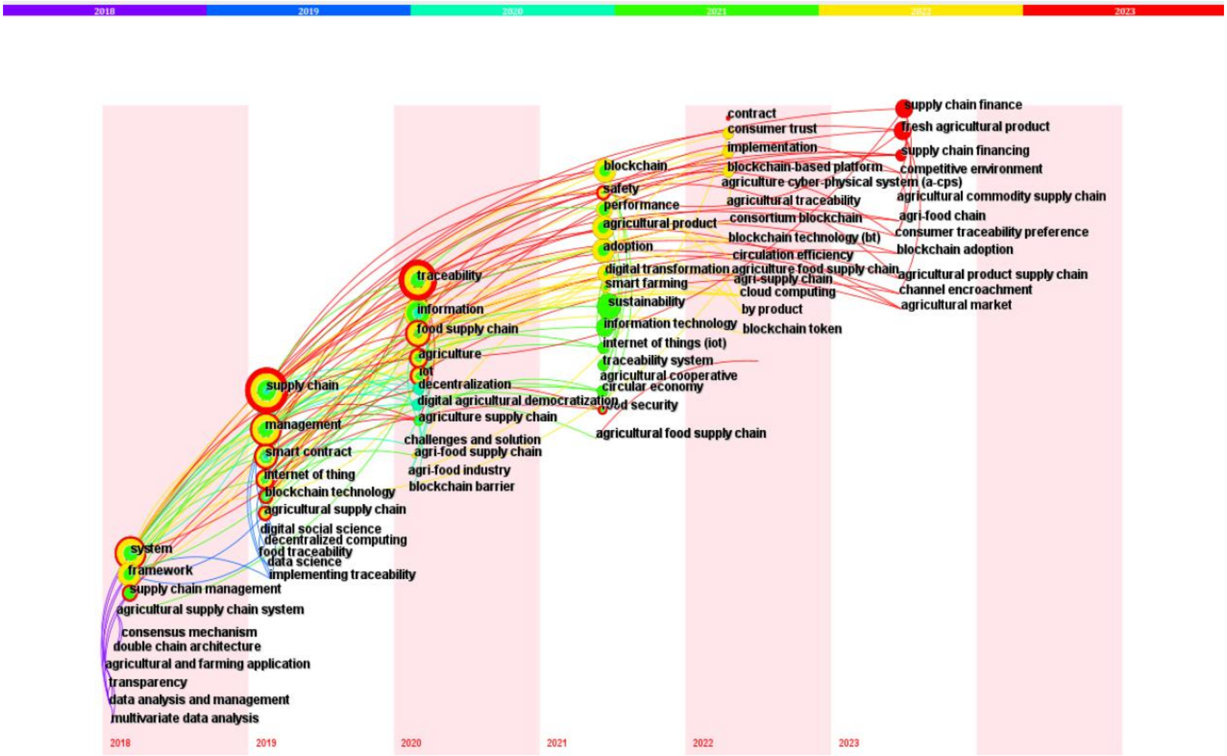

Figure 8 Keywords for research on the application of blockchain in agricultural product supply chain Time-zone diagram

The development and migration of research focuses on supply chains for agricultural products at home and abroad were analyzed. At present, some key technologies of blockchain are being applied in the supply chain of agricultural products. Scholars such as Yang and Zhigang (2021) explained the principle that blockchain can solve the shortcomings and inadequacies of traditional supply chain management and provide new solutions for supply chain development (Yang et al., 2023). Researchers Tan et al (2023) started from reality, explained the advantages of blockchain technology in the agricultural supply chain, and raised some practical challenges (Tan et al., 2023). These related studies provide forward-looking applications for the construction of “blockchain” + “agricultural product supply chain” and effectively promote the digitalization and intelligence of the agricultural product supply chain.

Discussion

(1) Blockchain provides security guarantee for agricultural product supply chain

The supply chain for agricultural products is an issue that is closely linked to people's "vegetable basket" and farmers' "wallet" (Chen & Paulraj, 2004). It is a link of strategic importance for the construction of a socialist economy (Lee et al., 2022). One of the most important keywords in the agricultural product supply chain is "safety", and "freshness preservation efforts", "quality safety" and "food safety" all revolve around it. Blockchain is the most powerful weapon to protect the "safety" of the agricultural product supply chain. Blockchain has the characteristic of "big data" and can store huge data in the entire life cycle of the supply chain, which includes agricultural product trade, warehousing and logistics (Galvez et al., 2018). The completeness of basic information is the prerequisite for achieving "security" in the supply chain for agricultural products (Yadav et al., 2022). In ordinary supply chain logistics, it is difficult to complete and disclose information in all aspects due to various technical barriers such as computer computing power and storage space (Marshall et al., 2022). However, the smart supply chain under the blockchain can perfectly overcome the above problems (Lee et al., 2022). The information in the blockchain can hardly be manipulated, so the information recorded in the blockchain is more authentic and reliable, and can reduce people's distrust and resistance to data without physical form in the Internet era (Marshall et al., 2022). Through the "blockchain" technology of blockchain, the identities and behaviors of all parties in the operation links of the agricultural product supply chain can form corresponding chains, and the data information in each link and dimension can be mutually verified, thereby reducing the number of problems in each link of the supply chain. Possible errors and frauds have greatly improved the "security" of the supply chain, and also contributed to the realization of "information sharing" and "agricultural and supermarket docking" in the agricultural product supply chain.

(2) Blockchain promotes the development of agricultural product supply chain

The nodes of the traditional supply chain for agricultural products are too dispersed, the scale of operations is small and the degree of organization is low (Peng et al., 2022). The overly dispersed producers and traders have not come together to form a large organized collective. The products grown or raised by the farmers are bought from traders or sold directly in the market (Scuderi et al., 2022). There is a lack of planning and a slow response to market changes, leading to supply shortages. Chain organizations are less competitive (Lv et al., 2023). Blockchain can strengthen traditional supply chains and optimize the market system and trading methods for agricultural products through big data forecasting, public opinion polls, policy interpretation and other digital means, helping to create a unified integration of supply chains for agricultural products across the country network.

(3) Blockchain solves the problem of unclear responsibilities in the agricultural product supply chain

Blockchain and big data can clarify the business relationships in each link and fully record the information about the circulating links of the supply chain for agricultural products such as supply contracts, purchase agreements and storage documents, and ensure that each individual behavior and the time of occurrence (Jennath et al., 2019). All are traceable, solving the problem of difficult identification of responsibilities in traditional supply chains and achieving clarity and transparency of responsibilities in the agricultural supply chain.

Conclution

With the gradual adoption of blockchain in agricultural supply chains, academic research in this area has also increased rapidly, setting the stage for a systematic and in-depth analysis of the current state of research in this area. In this context, the article combines bibliometric analysis methods and relies on the WOS core database to analyze in depth the current state of research on blockchain application in the field of agricultural supply chain. With the help of CiteSpace analysis, we constructed a map of keyword coincidence and found that there is an obvious coupling phenomenon between agricultural product supply chain and blockchain. In terms of supply chain security, traceability, smart integration, etc., we conclude that the relationship between the blockchain and the agricultural product supply chain and the opportunities that the blockchain brings to the agricultural product supply chain are very important.

As for future research areas, although the combination of blockchain with agricultural supply chains has already been researched on several levels, due to the late start of this research area, the research is not yet in-depth enough; at the same time, the area of practical application of blockchain in practice has not yet fully started, and the potential challenges still need to be explored. Therefore, there is still a relatively large field of research in this area.

The limitation is mainly reflected in the fact that extensive literature publications did not appear until 2021, which proves that research on supply chains for agricultural products started late. The analysis diagram based on the co-occurrence of keywords is shown in Figure 5. The results of high-frequency co-occurrence of keywords show that research in related fields at home and abroad mainly focuses on traceability systems that improve the quality and safety of agricultural products. There is little research on how they can be concretely implemented and applied, which also serves as a reference for subsequent research areas.

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