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Mapping the Knowledge on Blockchain Technology in the Field of Business and Management: A Bibliometric Analysis

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ABSTRACT Blockchain technology is gaining momentum in business and management (B&M) field for its decentralization, automation, unalterability and traceability. Yet, despite such a wide range of applications, there is little literature that integrates the history and evolution of blockchain. To this end, this study combines science mapping and bibliometric analysis of 696 articles published between 2015 and 2021 obtained from the Web of Science Core Collection database. By drawing the reference co-citation map, bibliographic coupling map and co-word map with CiteSpace and VOSviewer tools, we identify the foundational themes, current status, and future research directions of blockchain literature in B&M. The results indicate that the blockchain research evolves from decentralized transaction and smart contract, and future research is focusing on the role of blockchain in financial risk management, organizational structure and the digital transformation of society.

INDEX TERMS Business and management, blockchain technology, bibliographic coupling, co-citation analysis, co-word analysis, science mapping.

I. INTRODUCTION

What is blockchain? As a disruptive innovation technology, blockchain is attracting more and more attentions around the world [1]. In essence, blockchain is a data structure and concatenated transcript of content that is connected and protected by cryptography [2]. During the past decade, blockchain technology has expanded from the 1.0 stage in the field of cryptocurrency, payment transaction system, clearing and settlement to the 2.0 stage in the whole field of business, management and its relevant field, and possess the potential to further develop to the broader 3.0 stage application scenarios such as health care, public service, education, social interaction and justice [3].

Since the advent of blockchain technology, disciplines such as computer science [4], engineering [5], finance [6], [7], operation management [8], and many others [9] are actively integrating with blockchain and have made significant contributions, which produces abundant relevant literatures. Among the many subareas of blockchain research, potentials and applications of blockchain in business and management (B&M) constitute an important part. Existing bibliometrics studies have investigated and addressed the impact of blockchain [10]–[13] and [14], however, there are still some limitations. For instance, Niknejad *et al*. [10] and Müßigmann *et al*. [11] only focused on the blockchain technology application in the food and agriculture sector and supply chain management, but ignored the integration of B&M, which is currently one of the most intensive areas under the research of blockchain; Merediz-Solà and Bariviera [12] subjected to methodological limitations based on analysis of a single software, the VOSviewer, which limited the analysis scope of the literature; Miau and Yang [14] targeted in author productivity in blockchain research but failed to consider other aspects such as reference and keywords. The literatures needs to be synthesized so that would help to address the following research questions (RQs).

RQ1: What are the foundational themes of blockchain research in the B&M have been explored in the existing literature? (past)

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RQ2: What is the current status of the research on blockchain technology in the B&M and its related disciplines? (present)

RQ3: What hotspots and trends can be addressed in future research? (future)

In order to overcome the limitations of earlier studies and answer the aforementioned questions, this paper uses the method of knowledge mapping to make a panoramic presentation of blockchain research and explore past advances, current trends, and future directions of blockchain research in the field of B&M by using CiteSpace and VOSviewer tools.

The rest of the paper proceeds as follows: Section II introduces our research methodology, including method selection, process of data collection and preprocessing, and software. Section III introduces the general contents of bibliometrics. Section IV to VI are analysis parts, in which co-citation analysis is used to answer ''what are the foundational themes of blockchain research'', bibliographic coupling is adopted to investigate the current status of blockchain research and co-word analysis is applied to find out the hotspot and future trend of the associated and underlying research. Finally, the conclusions, limitations and future research prospects are discussed in Section VII.

II. METHODOLOGY

A. METHOD SELECTION

Literature review in management research is undergoing a transformation from pure qualitative description to the combination of qualitative and quantitative [15]. Compared with meta-analysis and systematic literature review, bibliometric analysis is more suitable for both quantitative and qualitative analysis of large sample literature data [16], [17]. Bibliometric analysis organically combines disciplines including, but not limited to mathematics, statistics, graphics through techniques of data mining, processing, measurement and mapping to obtain graphical expressions of internal relations such as knowledge framework, structure, interaction and crossover [18], and becomes more and more popular among scholarly papers in leading academic journals [19]–[21] and [22]. The prevailing popularities and effectiveness of bibliometric method greatly lays in its capability of presenting the status quo of publications, research fields or schools, research hotspots and trends of research topics in a comprehensive way [23] and [24].

B. DATA SOURCE AND CODIFICATION PROCESS

The collection and selection of sample literature are performed in the following four steps. Firstly, we target the source of literature from the Social Science Citation Index (SSCI) and Science Citation Index Expanded (SCI-Expanded), which originated from the Web of Science Core Collection (WoS) database. Secondly, we choose 2015-2021 as the time span of the sample literature, considering the fact that the two words in ''Chain of block'' as introduced by Nakamoto [2], which is the first publication that described the concept of bitcoin and its underlying data structure, then two words were merged to become ''Blockchain'' in the year of 2015; For the search term, we adopt topic-based information retrieval method and retrieves literatures of ''Blockchain'' in Title, Abstract, Author Keywords and Keywords Plus, and published in English, resulting in 6844 articles (retrieved on Dec. 9th, 2021). Thirdly, we further refine the literatures based on category and document type: only literature of articles or review articles that belong to one of the five categories (Management, Business, Operations Research Management Science, Economics and Business Finance) were selected, which yields 780 articles. Finally, we systematically read the title, abstract and body of the retrieved literature together, eliminating the literature that was not relevant to the research topic of this paper (in the case of inconsistent elimination opinions, other team members were included into the discussion to ensure the reliability of the rejection). After the series of database positioning, literature time span, keyword confirmation, category and document type restriction, cleaning and refining, manual proofreading and duplicates removing, 696 articles were obtained as the final pre-processed sample that are to be analyzed by this study.

C. SOFTWARE

CiteSpace,[1] developed and maintained by Chen [18] and his team with Java language, is able to realize multi-period dynamic citation analysis, visual description of knowledge graph, automatic clustering, multiple parameter adjustment and other functions [18]. Compared to other visualization software, CiteSpace has unique and advanced features of pruning and burst. The pruning function can remove 'branches and leaves' according to different algorithms while retain the main content, and the burst function can be used to detect emergencies [25]. In addition, researchers can also see if the mapping result is valid and convincing by inspecting the numerical information in the upper left corner of the map [26].

VOSviewer[2] is a visualization tool developed by Van Eck and Waltman [27], which focuses more on the visual presentation of literatures [28], [29]. It uses VOS mapping technology to produce better structured maps than multidimensional scaling [27]. One of the strengths of VOSviewer is that it adjusts the labels of display according to the algorithm, therefore making it a great tool for co-occurrence visualization [30].

III. BIBLIOMETRIC ANALYSIS

Bibliometric analysis generally includes three parts: co-citation analysis (past), bibliographic coupling (present) and co-word analysis (future) [16]. Co-citation analysis is used to identify the foundational themes of blockchain research; bibliographic coupling is to explore the current

[1] Version 5.7.R5.
[2] Version 1.6.16.

TABLE 1. Top 10 cited journals of blockchain research in B&M.

Rank	Journal	Citation
1	International Journal of Production Research	1482
2	International Journal of Production Economics	840
3	Technology Forecasting and Social Change	716
4	International Journal of Information	579
5	Transportation Research Part E: Logistics and Transportation Review	565
6	Supply Chain Management: an International Journal	547
7	IEEE Access	527
8	Management Science	509
9	Journal of Cleaning Production	545
10	Production and Operations Management	428

Note: Citations refers to a measurement provided by VOSviewer.

TABLE 2. Top 10 cited authors of blockchain research in B&M.

Rank	Author	Citation
1	T. Choi	359
2	S. Nakamoto	282
3	N. Kshetri	203
4	D. Ivanov	194
5	S. Saberi	155
6	M. Swan	149
7	Y. Wang	134
8	D. Tapscott	134
9	M. Queiroz	112
10	V. Buterin	110

Note: Citations refers to a measurement provided by VOSviewer.

TABLE 3. The top 3 pivotal node literature of blockchain research in B&M.

Author(s)	Journal	N_F	N_C	N_D
Saberi *et al*. [40]	International Journal of Production Research	114	0.04	36
Kshetri [41]	International Journal of Information Management	88	0.22	55
Iansiti & Lakhani [42]	Harvard Business Review	84	0.01	7

Note: N_F represents Note Citation Frequency; N_C represents Note Betweenness Centrality; N_D represents Note Degree. All three indicators are given by CiteSpace

status of blockchain research; and co-word analysis is to find out the hotspots and future trends of the research. In this study, we combine both qualitative (country/region, institution, journal, author) and quantitative (word) indicators to show the breadth and depth of the research field of blockchain.

IV. CO-CITATION ANALYSIS

A. CITED JOURNALS

A total of 15,500 journals were analyzed in this section, which are categorized according to the related field(s) into five categories (Figure 1 (a)). The first category belongs to the field of economics and finance (in Red), such as *The Review of Financial Studies*, in which the discussion focuses on how the blockchain facilitates and affects the transformation of existing traditional financial systems such as the settlement and clearing systems, as well as how it maintains market equilibrium through its related applications such as smart contracts[6], [31]. The second category is the field of operation research management science (in purple and light blue), such as *Management Science and Production and Operations Management*, which focuses on the application of blockchain technology in supply chain management [32], [33]. The third category is the strategy and innovation management (in yellow and dark blue), such as *Strategic Management Journal and Technology Forecasting and Social Change*, in which more attentions are paid to the capability of firms empowered by the blockchain technology and its impact on firm innovation and strategic choice [34]. The fourth category is the business review (in orange) such as *Harvard Business Review*, *MIT Sloan Management Review* and *California Management Review*, which mainly discusses how blockchain changes organizations and even the entire ecosystems [35], [36] and [37]. The fifth category is the information engineering (in green) such as *IEEE Access* and *IEEE Transactions on Engineering Management*, which discusses trust-less sharing and decision support via blockchain [38], [39].

In addition, some journals published a large number of papers, which could mainly be attributed to the fact that they launched Special Issues on blockchain research. For example, *Management Science* held a special issue named "Blockchains and Crypto Economics" in the 2nd issue of 2021. *IEEE Transactions on Engineering Management* hosted a special issue titled "*Blockchain Ecosystem*" in 2019 (Table 1).

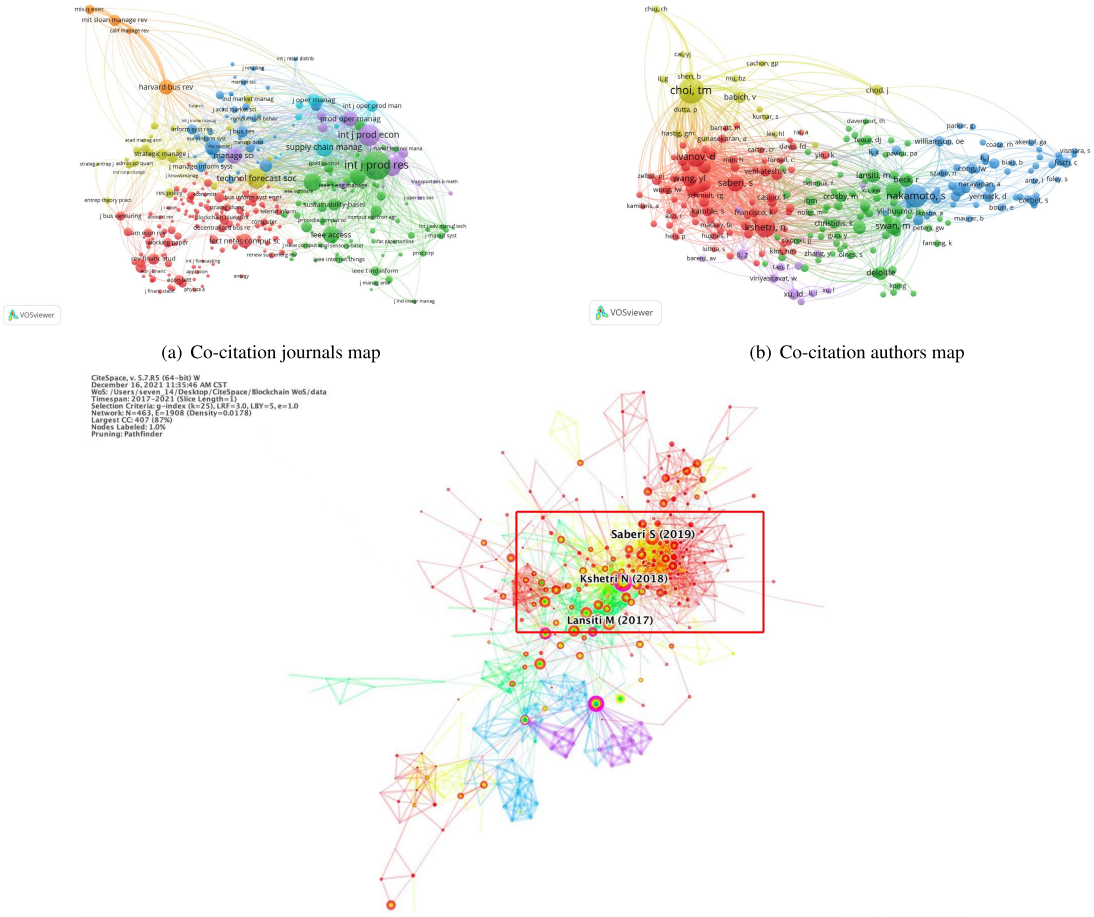
B. CITED AUTHORS

In this section, we analyzed a total number of 25,776 authors. Table 2 presents the top 10 cited authors of blockchain in B&M. As we can see from Figure 1 (b), Choi is the author who has the largest number of citations in the field of blockchain, which reflects the significant influence of him (see by the size of the circle in the figure). Owing to the publication of the first bitcoin paper, Nakamoto also occupies an important position in the field of blockchain. Kshetri, Ivanov, and Saberi are important in the field because of their earlier papers on blockchain, discussing future research directions in the field.

C. CITED REFERENCES

In this part, 38,307 references are analyzed. These cited references are mainly divided into three parts: The first part is represented by Nakamoto [2] and Lakhani and Iansiti [42], the second part is represented by Kshetri [41] and the third part is represented by Saberi *et al*. [40]. For better analysis, we used the pruning function of CiteSpace and set relevant parameters,[3] yielding Figure 1 (c). We focus on these indicators: Note Citation Frequency (N_F), Note Betweenness

[3]The "Time Slicing" is set from 2017 to 2021, the "Years Per Slice" is 1 year, take "Reference" as the "Node Types", the "Selection Criteria" is "g-index", and the "pathfinder" is used as the modified algorithm to pruning.



(a) Co-citation journals map

(b) Co-citation authors map

(c) Co-citation references map generated by CiteSpace

FIGURE 1. Co-citation map.

Centrality (N_C), Note Citation Burst (N_B) and Note Degree (N_D). N_F represents the contribution of node literature, which is reflected by the size of the node in Citepace: the nodes with larger size represent higher cited [43]. N_C is used in CiteSpace to discover and measure the importance of node literature in the network, which is represented by the purple circle around each node: thicker circles correspond to higher Betweenness Centrality. N_B is used in CiteSpace to show the explosion of node literature in the network, which is reflected by the red circle around each node: thicker circles corresponds to higher Citation Burst. N_D is used to jointly measure the importance of node literature.

Table 3 shows the specific information of the top three pivotal node literature (referring to the red box in Figure 1 (c)). The first two literatures focus on the relationship between the blockchain and supply chain management: Saberi *et al*. [40] made a detailed analysis of the potential application of blockchain technology and smart contract in supply chain management, and further explored how blockchain can solve the problem of sustainable development of global supply chain; Kshetri [41] examined how blockchain may impact key supply chain management goals such as cost, quality, speed, reliability, risk reduction, sustainability and flexibility, based on evidence of the use of blockchain in supply chain activities. The third paper discusses the business transformation that blockchain will bring. Lakhani and Iansiti [42], according to the characteristics of blockchain, put forward an analysis framework that better guided managers to implement the blockchain build activities of the organization (such as allowing employees to participate in the activities for understanding the blockchain and to invest on the construction of blockchain related facilities). The framework not only guides managers but also provides direction for everyone, as we will eventually be affected by the blockchain sooner or later.

These three articles bring out two of the most discussed aspects of blockchain research, one is the ''operation management'' (such as supply chain, supply chain management and supply chain finance), since chain involves a large number of upstream and downstream enterprises that are unwilling to disclose information, in which case the blockchain technology can perfectly solve the problems of identity authentication, privacy protection, trust asymmetry and traceability in the supply chain. The other one is the ''business transformation'', in which the blockchain technology is an important part of digital transformation, producing advantages for both small businesses and large enterprises. In lights of its

TABLE 4. The cited references clusters information of blockchain research in B&M.

Cluster ID	Cluster label	Cluster size	Sihouette
#0	Supply chain management integration	95	0.750
#1	Food supply chain	91	0.814
#2	Financial service	57	0.839
#3	Initial coin offering	46	0.963
#4	Business model	27	0.875
#5	Client use	22	0.951
#6	Online platform	22	0.967
#7	Things ecosystem	20	0.946
#8	Covid-19 pandemic	17	0.959
#9	Emerging literature	8	0.990
#14	Sustainable environmental goal	2	0.989

Note: Sihouette represents the degree of similarity among cluster members, and the higher the value, the higher the degree of similarity among cluster members.

capability of achieving better organization results, higher productivity and more effective governance, the blockchain may become more and more popular among large companies and partners in the future.

D. CITED REFERENCE CLUSTERING ANALYSIS

The clustering [4] of blockchain literature in B&M is obtained and showed in Figure 2. According to the relevant parameters of the network displayed in the upper left corner of the figure, ''Modularity Q'' (Q-value) is 0.6076 (greater than 0.5), which indicates that the network is reasonably divided into multiple loosely coupled specialties. ''Weighted Mean Silhouette S'' (S-value) is 0.8561 and is used to describe the average homogeneity of these clusters. A value greater than 0.7 indicates that each cluster is highly homogeneous [18]. Table 4 shows the specific information of clusters showed in Figure 2. According to the cluster size, the top three clusters are ''Supply chain management integration'', ''Food supply chain'' and ''Financial service''. But one can observe from Figure 2 that the highly cited literature and citation burst nodes are concentrated in the cluster of ''Supply chain management integration'', ''Financial service'', ''Business model'' and ''Client use''. It shows that these four clusters are the most active directions that attracted the most attentions from scholars, which will be further discussed in the next paragraph.

First (Cluster #0), with regard to the blockchain technology application under supply chain situation, scholars have discussed a lot about the relationship between blockchain and supply chain, supply chain finance, and supply chain management. For example, Yli-Huumo *et al*. [44] discussed how blockchain impacts key supply chain management objectives, clarified the various mechanisms by which blockchain helps achieve supply chain objectives with particular emphasis on the role of the Internet of Things in blockchain-based solutions, and the extent to which blockchain can be deployed to verify the identity of individuals and assets. Through interviews, field research, semantic analysis and other methods, Wang *et al*. [45] understood how executives diagnose problems existing in blockchain application and discussed how blockchain changes supply chain practice. Second (Cluster #2), blockchain is powering the development of financial services. Tapscott [46] believed that the ''power'' of blockchain owned by firms comes from the continuous investment in blockchain technology and its patents. The applications of blockchain do not only extend to cryptocurrency, but also the financial industry, such as banks, which are vigorously engaged in the field of blockchain and actively deploying blockchain-related applications. Hyvärinen *et al*. [47] developed and evaluated a prototype blockchain-based system designed to eliminate tax fraud due to forged documents and inadequate international information exchange between tax authorities, and to improve the transparency of dividend flows. Third (Cluster #4), blockchain changes existing business models in three levels: the first level is the currency and payment system (blockchain 1.0: currency); the second level is the monetary market and financial applications (blockchain 2.0: contracts); the third level is beyond the category of monetary and financial market outside of the application (blockchain 3.0: justice applications and coordination) [3]. While blockchain has been used in many industries, such as banking, financial markets, insurance, voting systems, leasing contracts, and government services, its use in accounting and assurance has not been fully explored. Dai and Vasarhelyi [48] provided an initial discussion of how blockchain can enable a real-time, verifiable and transparent accounting ecosystem, arguing that blockchain has the potential to produce a more accurate and timely automated assurance system. Fourth (Cluster #5), blockchain upends the balance between communities. The lower costs, greater liquidity, more accurate records and transparent ownership provided by blockchain may have a potential impact on managers, institutional investors, shareholders, auditors, and other parties involved in corporate governance, among which the balance of power may be broken [49].

V. BIBLIOGRAPHIC COUPLING

In this part, we analyze 196 sources, 2,066 authors, 1,067 organizations and 70 countries/regions. The bibliographic coupling maps of literature sources, authors, organizations and countries/regions are showed in Figures 3 (a) through 3 (d), respectively, with the minimum literature citation of 5. Table 5 is the ranking of literature sources, authors, organizations (institutions) and countries/regions according to the Total Link Strength (TLS). TLS measures the strength of the extant links of a researcher or article with other researchers and articles [50], [51], which is influenced by the number of thresholds that we choose. At present, the coupling strengths between sources is mainly focused on supply chain management and technological innovation. Among these sources, journals such as *International Journal of Production Research* and *Technology Forecasting and Social Change* have published a large number of studies on blockchain and its application, making great contributions to the field of blockchain. Other journals such as

[4]The cluster labels were extracted from titles.

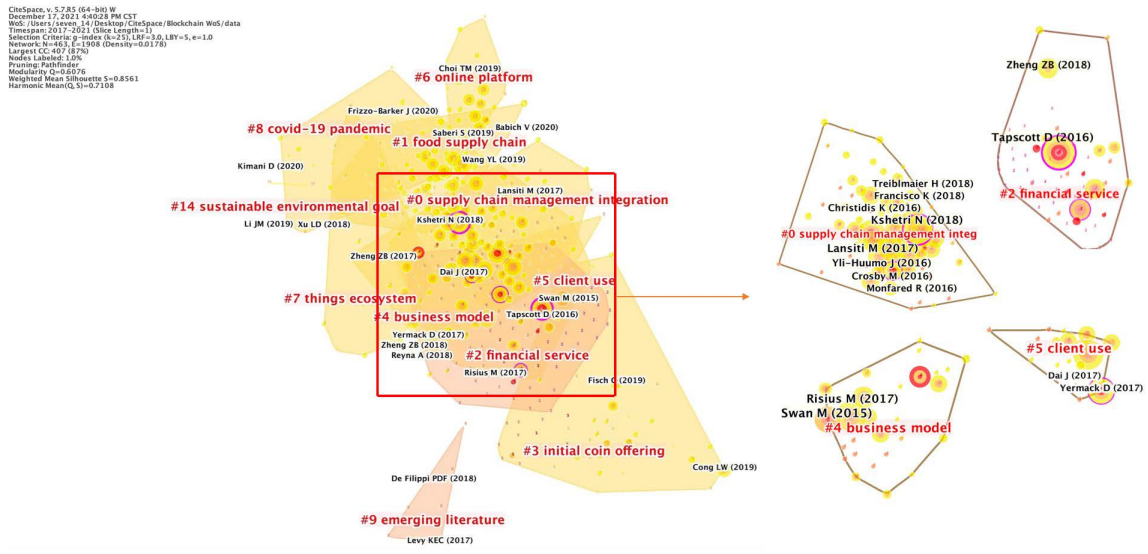
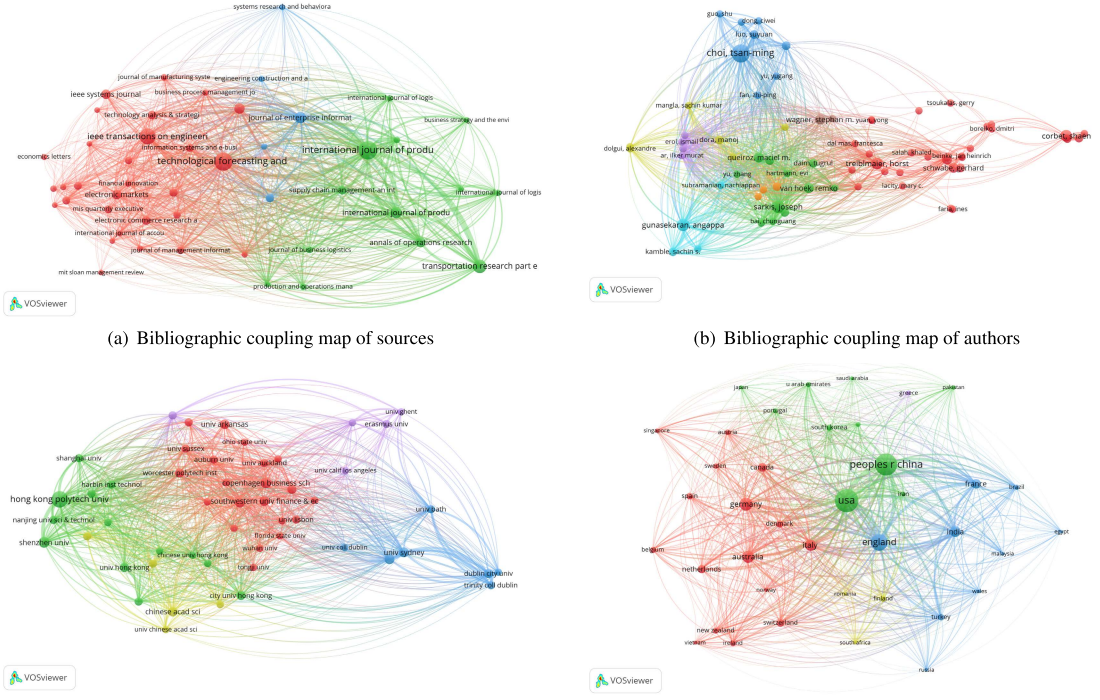


FIGURE 2. The cited references clusters map of blockchain research in B&M.



(a) Bibliographic coupling map of sources

(b) Bibliographic coupling map of authors

(c) Bibliographic coupling map of organizations

(d) Bibliographic coupling map of countries/regions

FIGURE 3. Bibliographic coupling map.

IEEE Transactions on Engineering Management have also published a lot of blockchain-related literature. For the coupling strengths between the authors, it is worth noting that T. Choi is the most published author in the blockchain field, while IM. Ar, I. Erol, IT. Medeni, I. Peker, and A. Gunasekaran have collaborated on many papers and made a great contribution to the blockchain field as well. For the coupling strengths between organizations and countries/regions, most of the countries/regions all over the world are actively involved in the conversation about blockchain technology: the United States, England and China made the most significant contributions to the field, while other countries/regions such as Germany, France and Italy in Europe, India in Asia, and Australia in Oceania are also actively working to contribute to blockchain research in B&M.

VI. CO-WORD ANALYSIS

Keywords are natural language words that express the topic concept of the document. The collection of keywords of a large number of academic research results in a long-time span can reveal the overall content characteristics of the research results in this field, the internal relationship between the

TABLE 5. Top 10 bibliographic coupling of contributing sources, authors, organizations and countries/regions.

Rank	Source	Author	Organization	Country/Region
1	International Journal of Production Research (20931)	J. Sarkis, Worcester Polytechnic Institute (4901)	Hong Kong Polytechnic University (4151)	United States (107594)
2	Technology Forecasting and Social Change (15490)	T. Choi, National Taiwan University (4083)	Worcester Polytechnic Institute (2561)	England (92279)
3	Journal of Enterprise Information Management (10489)	A. Gunasekaran, Penn State Harrisburg (3793)	Shenzhen University (2147)	China (87821)
4	International Journal of Production Economics (9771)	M. Kouhizadeh, University of Rhode Island (3419)	Dublin City University (2079)	India (51584)
5	Transportation Research Part E: Logistics and Transportation Review (8144)	M.M. Queiroz, Universidade Paulista (3405)	EM Lyon Business School (1914)	Germany (44658)
6	Annals of Operations Research (7178)	S.F. Wamba, Toulouse Business School (3167)	University of Sydney (1824)	France (41362)
7	Supply Chain Management: an International Journal (7014)	I.M. Ar, Ankara Yildirim Beyazit University (2897)	Nanjing University of Science and Technology (1803)	Australia (36439)
8	IEEE Transactions on Engineering Management (6605)	I. Erol, Ankara Yildirim Beyazit University (2897)	Copenhagen Business School (1786)	Italy (34098)
9	Production Planning & Control (5543)	I.T. Medeni, Ankara Yildirim Beyazit University (2897)	Modul university Vienna (1748)	Turkey (21356)
10	Experts Systems with Applications (4266)	I. Peker, Gumushane University (2897)	University of Bath (1735)	Denmark (16695)

Note: In parentheses is TLS (Total Link Strength).

research contents, and the development context and direction of academic research [52]. In this section, we use CiteSpace and VOSviewer to extract keywords of blockchain literature for co-word analysis and reveal the hotspots and trends of blockchain research.

A. KEYWORDS CO-OCCURRENCE ANALYSIS

In this section, VOSviewer software is used to co-occurrence keywords.[5] For each of the 244 keywords, VOSviewer calculates a link strength score associated with it. The default target is the keyword with the greatest link strength, and the final result of the keyword co-occurrence network is shown in Figure 4 (a). Table 6 gives the detailed information of clustering results. Cluster 1 (in red) is mainly about the study of bitcoin and other digital currencies. Since Nakamoto (2008) put forward the concept and trading system of bitcoin, related issues of decentralization, pricing and financial regulatory governance have emerged and formed a complete system. Cluster 2 (in green) mainly refers to blockchain, which is the underlying technology of bitcoin that is favored by research for its security and privacy protection features. Cluster 3 (in dark blue) discusses the impact of blockchain on industry, as the birth of blockchain makes possible the era of industry 4.0 based on intelligent manufacturing and big data. Cluster 4 (in yellow) focuses on the discussion of blockchain technology as a dynamic capability to achieve interorganizational value co-creation in an open innovation technology environment. Based on the resource-based view theory, Cluster 5 (in purple) discusses the competitive advantages brought to firm and impact to organizational outcomes from the blockchain technology as a unique technological resource. Cluster 6 (in light blue) mainly discusses the impact of blockchain technology on supply chain management, including the prospection of framework and future challenges. Cluster 7 (in orange) is about blockchain technology bringing changes to accounting and auditing of firms.

As can be seen from Figure 4 (a), there are many intersecting and overlapping areas among clusters 3, 6 and 7, which means that blockchain technology and smart contracts can be combined with big data, the Internet of things and machine learning to solve many problems in the supply chain, while bringing huge challenges at the same time. Clusters 4 and 5 are very close, suggesting that the absorptive capability of firms to blockchain technology can greatly affect organizational outcomes such as innovation and financial performance. However, partial cluster 2 is scattered on the graph and far from the center, indicating that the current research is

TABLE 6. The clusters information of terms co-occurrence.

Cluster ID	Color	Number of terms	Representative terms
#1	Red	53	Bitcoin; cryptocurrency governance; decentralization; fintech; uncertainty; volatility; ICO; even study; risk
#2	Green	47	Blockchain; system; smart contract; security; privacy; IoT; machine learning; DLT; model; optimization; internet
#3	Dark blue	41	Big data; artificial intelligence; industry 4.0; sustainability; framework; logistics; resilience; capability; operations
#4	Yellow	34	Adoption; dynamic capabilities; strategy; ecosystem; governance; value co-creation; open innovation
#5	Purple	27	Performance; competitive advantage; digitalization; management; resource-based view; traceability; trust
#6	Light blue	24	Blockchain technology; network; platform; pricing; supply chain; coordination; contracts; competition
#7	Orange	17	Technology; information; patent analysis; auditing; accounting

[5]The binary counting was selected as the counting method,"Type of analysis" is "co-occurrence", "Unit of analysis" is "All keywords", and "Minimum number of occurrences of a keyword" is 5, so 244 of the 3101 keywords meet the threshold.

TABLE 7. The keywords clusters information of blockchain research in B&M.

Cluster ID	Cluster label	Cluster size	Sihouette
#0	Business practice	32	0.893
#1	Digital transformation	31	0.893
#2	Spatio-temporal coupling task	29	0.942
#3	Surfing blockchain wave	29	0.954
#4	Mean-variance approach	28	0.952
#5	Supply management	27	0.942
#6	Smart contract	22	0.954
#7	Synchronization management	21	0.946
#8	Performance evaluation criteria	18	0.885
#9	Ripple effect	18	0.929
#10	Future research agenda	17	0.929
#11	Cryptocurrency market	17	0.962
#12	Smart metering system	17	0.917
#13	Big data analytics	14	0.97
#14	Citizen utilities	12	0.936
#15	To-peer transactive energy exchange	10	0.986
#16	Blockchain token	6	0.995

Note: Sihouette represents the degree of similarity among cluster members, and the higher the value, the higher the degree of similarity among cluster members.

not enough to mine and optimize the blockchain model and algorithm.

Furthermore, we analyze the keywords co-occurrence from the time dimension and Figure 4 (b) is obtained. According to the time progress color bar in the bottom right corner of Figure 4 (b), the dark blue represents keywords that showed up earlier, while the yellow represents the ones that appear later. As is shown in Figure 4 (b), except for partial cluster 1, 5 and some small clusters, most of the words are relatively recent and focused on blockchain technology and its impact to innovation and management.

B. KEYWORDS CLUSTERING AND HOTSPOT ANALYSIS

In order to investigate the intellectual structure of blockchain-related research hotspots, we adopt keywords clustering analysis and set the relevant parameters[6] in CiteSpace. The clustering visualization atlas of keywords is drawn, as shown in Figure 5. The synthesized network has a Q-value of 0.8127 and a S-value of 0.9352, which can be considered as very high, indicating that the clustering view is significant and convincing. As can be seen from Table 7, the Sihouette score of each cluster is sufficiently high. By sorting out cluster information and combining the content of existing literature, it can be found that the hotspot of blockchain research mainly focuses on three subject areas: finance and risk management, organizational structure and digital transformation, and Machine learning and artificial intelligence.

[6]The selection of "Time Slicing" and "Years Per Slice" are same with Figure 1 (d), take "keyword" as the "Node Types", the "Selection Criteria" as "g-index", and the "pathfinder" and "pruning the merged network" are used as the modified algorithm to pruning, the cluster labels were extracted from titles.

1) FINANCE AND RISK MANAGEMENT

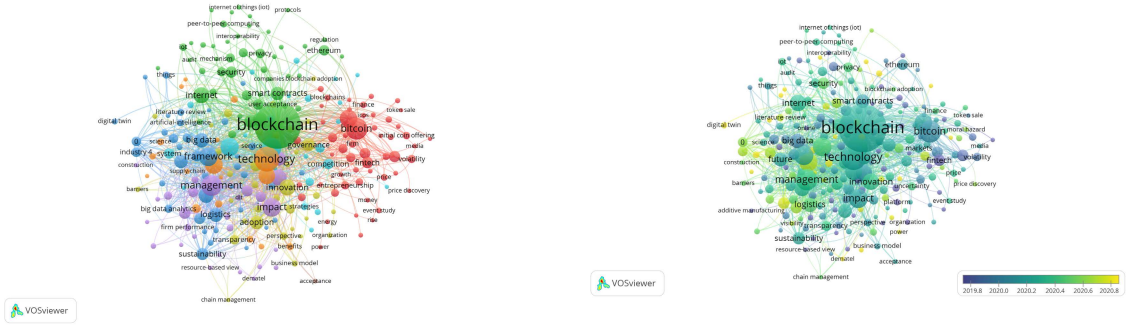
Finance has been an initial and important field for the application of blockchain technology. Many researchers have explored the possibility of the application of blockchain technology in various financial scenarios [53]. For example, Cong *et al*. [54] argued that centralized mining pools for risk sharing will not have a disruptive impact on decentralized mining based on blockchain technology due to cost settings and energy consumption, and these conclusions also provided information for other consensus protocols and organizations. Treleaven *et al*. [55] argued that blockchain can simplify financial services and business processes through two core parts: distributed ledger technology and smart contracts. Hofmann *et al*. [56] discussed the application of blockchain technology in supply chain finance, which is simplified without the need for trusted third parties. Fu and Zhu [57] applied blockchain to solve fraud problem and provided specific information in supply chain endogenous risk management.

2) ORGANIZATIONAL STRUCTURE AND DIGITAL TRANSFORMATION

The rapid development and update of blockchain technology play a crucial role in economic transformation and social development, as well as will have profound effects on the nature of firms. Tapscott and Tapscott [58] believed that blockchain will change the organization and management of firms from the two aspects of reducing transaction costs and obtaining external resources, and even completely destroy the traditional and centralized model. Treiblmaier [59] established a research framework based on four economic theories (principal agent theory, transaction cost analysis, resource-based view and network theory) to discuss how blockchain changed supply chain management. Griggs *et al*. [60] researched the digitization of healthcare systems and discussed about how to use smart contracts to remotely monitor patient secure.

3) MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

Since the birth of machine learning, its theory and technology are developing rapidly, and its application fields are also expanding. The combination of machine learning, artificial intelligence and blockchain technology has also received wide attention from scholars. Tanwar *et al*. [61] combined machine learning algorithms with blockchain to improve the accuracy of data analysis results. Outchakoucht *et al*. [62] proposed a dynamic and distributed policy for the access control of the Internet of Things. Meanwhile, the combination of machine learning, especially reinforcement learning algorithms, provides the possibility of dynamic optimization and self-adjustment for the policy. Singh *et al*. [63] had developed an Internet of Things architecture based on blockchain and artificial intelligence, providing an efficient way to merge blockchain and artificial intelligence. In addition, the authors evaluated the proposed architecture from both qualitative and quantitative aspects, and the results from both aspects showed



(a) Keywords co-occurrence network visualization

(b) Keywords co-occurrence overlay visualization

FIGURE 4. **Keywords co-occurrence visualization.**

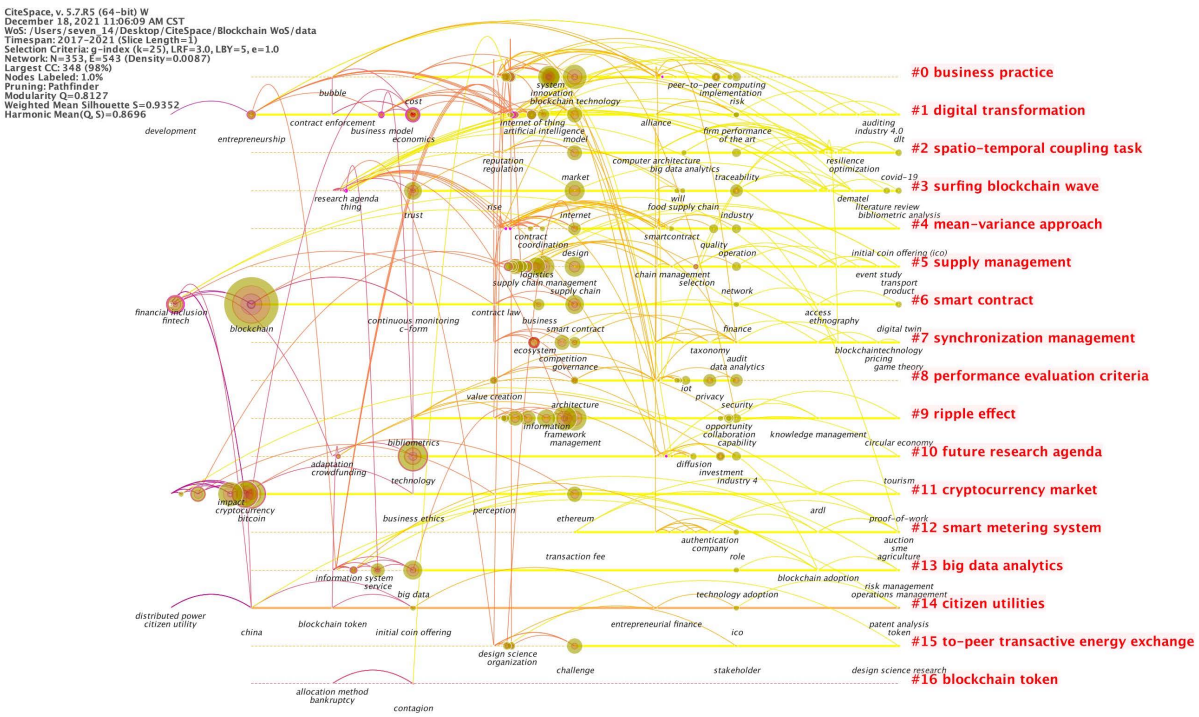


FIGURE 5. **The keywords clusters map of blockchain research in B&M.**

that the proposed architecture performs better than existing Internet of Things architectures.

C. KEYWORDS BURST AND TREND ANALYSIS

In order to better understand the changes of blockchain research in different periods, we adopt the method of emergent word analysis to identify the evolution of blockchain research. Bursty Term [7] is a keyword with a sudden increase in the contribution of word frequency in different time periods [64]. The higher the degree of sudden emergence, the more prominent the academic attention of the keyword. Therefore, by tracking the change of emergent words, we can better find the changing trend of the topic in the research field of different periods. Therefore, in CiteSpace, we draw the top 18 keyword atlas of Bursty Rate.[8] In Figure 6, the time period of keyword emergence is highlighted in red. In the ''Begin'' and ''End'' columns, the specific years of keyword emergence initiation and termination are identified. By analyzing the map of emergent words, it is found that the research trend of blockchain in China is generally divided into three phases.

The first phase, 2017-2018. Keywords in this period are ''bitcoin'', ''cryptocurrency'', ''fiat currency'', ''payment system'', ''Internet finance'' and so on. Because of bitcoin, ethereum and other cryptocurrencies have taken the world by storm, many big banks set up various working groups on

[7]Bursty terms analysis and high frequency keywords analysis are based on keywords, the difference is: high frequency keywords is a whole historical period in the research field, reflects the research focus in the field on the whole, while burst terms reflect the hot focus in a certain period of time, at different times of the hot research topic may change.

[8]Bursty rate refers to the change rate of word frequency detected by Kleinberg algorithm used by CiteSpace software. The more burst nodes a cluster contains, the more active the domain will be. Therefore, the level of the burst term rate to a certain extent can reflect the level of attention to the burst terms.

FIGURE 6. Top 18 keywords with the strongest citation bursts of blockchain research in B&M.

legal digital currency and blockchain research, put forward the goal of publicly issuing digital currency in the social background, and explored the development of blockchain research [65]. The academic community generally believed that the traditional monetary system was not able to meet the needs of the payment system brought by the digital society and began to explore the content and path of digital currency and Internet finance based on the underlying technology of blockchain [3], [66].

The second phase, 2018-2019. With the rise of digital currency and Internet finance, as well as the deepening of people's understanding of blockchain technology, the research field of blockchain began to expand during this period, and researchers focused more on the (sharing) economic field [67], [68]. On one hand, in terms of research subject, distributed ledger technology allows each node in blockchain-based applications to record a complete ledger without the help of a third party, which means that the participants have changed from single party to peer-to-peer network [69]. On the other hand, in terms of research content, blockchain had been applied to all walks of life, such as cross-border logistics, insurance and governance, attracting more scholars' attention and gradually became a research hotspot. Simply put, blockchain economy had become a consensus of blockchain research.

The third phase, 2019-present. Through the ''disintermediation'' and ''decentralization'' characteristics of blockchain technology, the organization can be transformed from a closed system into an open ecosystem that can integrate global resources [70], [71]. Practitioners around the world are actively exploring the innovation and implementation of blockchain applications in organization [72], [73]. At the same time, with so many applications, blockchain has become a new field in which policy makers and regulators urgently need to strengthen their regulatory and governance capabilities. Scholars discussed the improvement path of the blockchain governance framework and the important role of blockchain in regulatory technology, proposed that the social should establish and improve the blockchain governance system based on the multi-dimensional governance needs of blockchain, and vigorously develop the regulatory technology with blockchain as the core technology [74], [75].

VII. CONCLUSION

This paper combines the science mapping and bibliometric analysis to explore the history and evolution of blockchain research in the WoS database by using CiteSpace and VOSviewer tool. By drawing the reference co-citation map, bibliographic coupling map and co-word map, we have revealed the foundational themes of blockchain research, pointed out its current status, and discussed the hotspot issues and further research directions. The conclusions are as follow:

- In response to the first research question, top 10 journals, authors and top 3 publications were recognised as the leading contributors to the subject area, as well as 4 foundational themes of blockchain research in the existing literature. The results indicate that blockchain technology has expanded from cryptocurrency, payment transaction system, clearing and settlement to the whole field of business, management and its relevant fields, and possess the potential to further develop to the broader application.
- In answer to the second research question, this bibliometric analysis recognises the top 10 sources, authors, organizations and countries/regions with the coupling strengths. The results indicate that the research team of blockchain technology in the field of B&M is constantly expanding. At present, both developing and developed countries, East and West have made great contributions to blockchain research.
- In response to the third research question, this bibliometric analysis recognises the three hotspots: finance and risk management, organizational structure and digital transformation, and machine learning and artificial intelligence. The three phases that blockchain research goes through are also identified: From the initial active in financial service, expanded to the economic and management field, and now affecting the ecosystem.

This paper also has some limitations. In terms of methods, we only retrieved and collected literatures from one database, which would ignore the department characteristics of the publications. In terms of content, the failure to analyze the dynamic co-citation will result in a lack of attention to the dynamic evolution of blockchain research.

Future research can be carried out from both theoretical and methodological aspects. From a theoretical perspective, the digitalization process of organizations and society triggered by blockchain has resulted in changes in management practice, B&M disciplines and researches that naturally faced with the cognitive challenges of ''whether the logic of the existing core theory of B&M is still applicable in the new context?''. From the perspective of methods, when organizations adopt blockchain technology, the original centralized data

storage becomes distributed storage, resulting in challenges on data processing methods.

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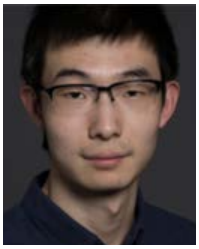

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