Bibliometric Analysis of the Blockchain Scientific Evolution: 2014–2020

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ABSTRACT As one of the disruptive technologies in the fourth industrial revolution, Blockchain has irrevocably changed how people live and work. Many scholars have studied the Blockchain, and the number of related publications has increased over time. Bibliometrics is an excellent method to study the development trend of a specific field. However, few scholars have used bibliometrics to research Blockchain; the inheritance and evolution among its different research themes have not yet been fully understood. This study emphasizes the scientific evolution and research focus of Blockchain through bibliometric analysis. We analyzed 2993 publications from 2014 to 2020 using co-word analysis and cluster analysis with bibliometric tools such as the SciMAT. The most productive author, country, institutions and leading research areas were identified, outlining the Blockchain field’s fundamental developments. The results show the changes in keywords regarding Blockchain summarize the research hotspots in different periods. The study discusses the evolution process of various themes in each period, providing a meaningful reference for scholars to identify research hotspots and future research directions in the Blockchain field.

INDEX TERMS Bibliometric analysis, blockchain, co-word analysis, scientific evolution, SciMAT.

I. INTRODUCTION
Blockchain is a distributed ledger, and its storage is characterized by transparency, decentralization, anonymity, and immutability. Its essential feature, decentralization, is widely used in the Internet of things (IoT) [1], [2]. The Blockchain’s transparency and traceability are of particular interest to the supply chain [3]–[5]. Its anonymity can be used to protect information such as location privacy [6], transactions [7], and health records [8]. Besides, consensus mechanisms, such as Proof of Work (PoW), Proof of Stake (PoS), and Delegated Proof of Stake (DPoS), have also received increasing attention as tools for ensuring data integrity [9], [10].

Making use of the Blockchain in all industries can provide an absolute advantage. Therefore, in recent years, various aspects of society have shown interest in Blockchain technology and actively explored the innovative model of “Blockchain+.” Scholars have begun addressing multiple industries that make use of the Blockchain. For example, Joo et al. [11] comprehensively reviewed the contribution of Blockchain technology in the financial field. Mubarakali [12] proposed a Blockchain-based healthcare system to supervise healthcare services in the Cloud. Additionally, IoT [13]–[15], healthcare [16]–[18], and education [19]–[21] have also been integrated with the Blockchain.

In this paper, a bibliometric analysis was adopted. Bibliometrics, a method to quantify the research object, is often employed to determine the literature’s law. Unlike traditional narrative commentary that relies on researchers’ experience and knowledge, the bibliometric analysis takes science as a knowledge generation system [22]. It indirectly reflects the correlation between different types of content, gradually demonstrating its advantages. Moreover, bibliometrics provides author keyword analysis to provide better current or future research trends, reflecting the recent trends in a particular field [23], [24]. Many scholars use bibliometrics to study the development status, hot issues, or future research directions of a topic, such as the field of neuroscience [25] and recommendation systems [26]. Even more exciting topics, for example, multiple risks [27] and emerging interest in water research and collaboration [28], are analyzed through bibliometrics. This article uses bibliometrics software for modeling to explore the Blockchain field’s development status and future research trends.

Although bibliometrics is widely used by researchers [29]–[31], academic research on the Blockchain has addressed only a limited number of topics. Darabseh and Martins [32] used VOSviewer to perform content analysis
on the literature in the Blockchain field and employed statistical data to evaluate its maturity in the construction literature. Klarin [33] employed VOSviewer to analyze the cryptocurrency-related literature and clustered four main streams. Mussigmann et al. [34] used Gephi to conduct citation network analysis and co-citation analysis of Blockchain-related literature to assess Logistics and Supply Chain Management (LSCM). Joao [35] employed R to analyze Blockchain technology’s recent progress, limitations, and future trends. Anjum et al. [36] used VOSviewer to draw an expanded diagram of scientific and academic research on Blockchain-related healthcare studies to identify research trends. Wang and Su [37] analyzed Blockchain’s development status in the energy field using the bibliometric method. Miuau and Yang [38] reviewed the Blockchain literature from 2008 to March 2017 from space and time dimensions. Gupta and Dhawan [39] conducted a quantitative and qualitative analysis of Blockchain publications from 2010 to 2018 and identified the most productive countries/regions, authors, and journals, among other aspects.

Most scholars used bibliometrics to investigate the Blockchain’s use in a specific field, and few studies have used it to address the overall trend of Blockchain development. The changes in keywords, the transformation of research hotspots in different periods, and the inheritance of various topics in the Blockchain field have not yet been investigated. However, with bibliometrics’ help, we can summarize the current research status of Blockchain, the changing law of hot topics, and predict future trends through co-word analysis and visual analysis of documents published by other researchers in Blockchain field.

Therefore, the main contributions of this study are:

1) We summarize the research hotspots in different periods in the Blockchain field and discuss the internal connections between hotspots in each period.

2) We examine the development context of various topics in the Blockchain field across periods and summarized five groups of evolution paths.

3) We discuss the future development trends in Blockchain and possible research directions.

The remainder of this paper is organized as follows. Section 2 describes the research design and the data retrieval and processing steps. Section 3 presents the results of the descriptive analysis. Section 4 discusses the results of clustering. Finally, Section 5 summarizes the study’s contributions and identifies future research hotspots.

II. METHODOLOGY
A. BIBLIOMETRIC ANALYSIS

The origin of bibliometrics can be traced back to the 19th century. As a part of scientometrics, bibliometric analysis uses mathematical and statistical tools to analyze scientific activities in a certain research field [40]. Bibliometric analysis is a tool for quantitatively researching scientific publications used to assess leading trends, discover research hotspots, and describe the relationship between countries/regions, institutions, research fields, and author collaboration [41]. The use of bibliometric analysis has been increasing rapidly. Researchers have conducted bibliometric research in a wide range of fields, including microplastics [42], finance [43], medicine [44], supply chain management [45], operations research and management science [46], business [47], and physics [48].

Scholars such as [49]–[51] divided bibliometric research into two categories: descriptive and evaluative research [52]. The former analyzes the author, journal, geography, period, and discipline, while the latter examines citations and references. Zupic and Cater [53] summarized the five main bibliometric methods: citation, co-citation, bibliographical coupling, co-author, and co-word analysis. Co-word analysis examines the relationship between research topics in a specific field by studying the co-occurrence of topic words in literature [54]. Co-word analysis is the most important and commonly used method in bibliometric analysis. Compared with other methods that only use bibliographic metadata, the co-word analysis addresses a concept [55] to study its scientific evolution.

Scientific mapping is closely related to co-word analysis. It illustrates a scientific field’s structure and dynamics [53]. Most existing software, such as VOSviewer, Gephi, Bibexcel, CiteSpace II, Science of Science (Sci²) Tool, and SciMAT, can perform scientific mapping analysis. SciMAT is a powerful scientific mapping software based on co-citation and co-word analysis, combining the many advantages of standard science mapping software [56]. It provides three essential functions: a preprocessing module, bibliometric methods, and a wizard for configuration analysis [57]. Additionally, science mapping can be used to express the cognitive structure of a research field [55], a form of spatial representation that reflects how disciplines, fields, professions, documents, or authors are related to each other. Its spatial characteristics help understand conceptual relationships and developments [58]. In this study, we employ SciMAT for scientific mapping; Fig. 1 provides an example of such mapping.

Fig. 1a provides an example of keyword evolution. The number in the circle represents the number of keywords in this period. The inward arrow indicates the number of newly emerging keywords in the same period. The outward arrow represents the number of disappearing keywords in the period, and the horizontal arrow indicates the number of keywords covered in the adjacent period. The number in brackets reflects keyword consistency.

In SciMAT, strategic diagram and thematic network are two methods used to achieve theme visualization. A strategic diagram (Fig. 1b) is a graph with two dimensions: density and centrality [40]. Centrality measures the internal connection between themes. High centrality indicates that a theme has a robust internal connection with other themes and plays an essential role in developing the research field. Density measures the external relationships between themes. High density indicates that a theme is highly developed [55], [59]. Thus, a strategic diagram divides essential themes into four
classes: motor themes (well-developed and critical); highly developed and isolated themes (well-developed but less crucial); emerging or declining themes (both weakly developed and marginal); and basic and transversal themes (critical for the discipline but not developed). The thematic network is shown in Fig. 1c, which indicates that several themes are interrelated. The circle size is proportional to the number of documents corresponding to each theme. The thicknesses of the lines between the circles are proportional to the specified index.

Fig. 1d represents the thematic evolution. The circles represent clustering themes. The size of the circles is proportional to the number of documents related to the themes. The solid line between the circles in the adjacent period represents the inheritance relationship, and the dotted line indicates the theme differentiation. The thickness of the line is directly proportional to the relevance between the themes measured by the specified index. Theme C represents a dead theme, and Theme D indicates a newly emerging theme.

SciMAT can visualize the interrelationships between themes, as well as the evolution of keywords and themes. Thus, this research uses SciMAT to build a thematic analysis of Blockchain’s significant themes using co-word analysis. It examines the evolution of the theme of the Blockchain using various indexes. It draws the overlay graph, strategic diagram, and the thematic evolution map through SciMAT to explore the changes in concept subdomains related to Blockchain in different periods and analyzes Blockchain’s scientific evolution.

B. DATA

1) DATA SOURCES

The bibliometric databases used for analysis are Scopus, CSA Illumina, Google Scholar, and Web of Science (WoS). The success of bibliometric analysis primarily depends on sufficient documentation in the research field, usually obtained through the citation index provided by WoS. Moreover, the most significant advantage of WoS compared with the databases mentioned above is that it contains social science literature [60]. As a comprehensive search engine, WoS includes detailed information on each document and provides complete search results, helping with research and analysis of a specific field.

We screened the information several times to obtain the original data more accurately (Fig. 2).

The first search on WoS followed five steps.

1. We selected the database for documentary analysis (Web of Science Core Collection).
2. We set up a basic search ("BLOCKCHAIN" or "BLOCK CHAINS" or "BLOCK CHAIN" or "BLOCKCHAIN" or "BLOCKCHAINS" or "CHAIN OF BLOCKS" [TOPIC]. All keywords were enclosed in quotation marks to ensure that they were not split during the retrieval process, except for "BLOCKCHAIN" and "BLOCKCHAINS").
3. We cut the search time to 2020 without setting the start time.
4. We chose the relevant citation indexes ("SCI-EXPANDED" and "SSCI" and "A&HCI").
5. We limited the file type to "ARTICLE" and the language to "ENGLISH."

A total of 3589 publications were retrieved. To optimize the search results, we manually screened the literature identified by WoS according to Table 1.

After the second search, we obtained 2993 publications used to analyze the Blockchain’s scientific evolution.

C. DATA PROCESSING

After obtaining the initial data, we processed 2993 documents in SciMAT in the following way.

As the quality of science mapping results depends on the data quality, data preprocessing is one of the most critical steps [59]. The data preprocessing methods used in this research were keyword merging and de-duplication. We used word merging to unify singular and plural words and combined words with the same concept. For example, “CRYPTOCURRENCY” and “CRYPTOCURRENCIES” were merged into “CRYPTOCURRENCY” and
“BLOCK-CHAIN” and “BLOCKCHAIN” were merged into “BLOCKCHAIN.” Finally, we removed keywords with high frequency and broad meaning and meaningless keywords, such as “SYSTEM” and “0.”

D. RESEARCH PERIOD DIVISION
Blockchain research is relatively new. The first Blockchain-related article on WoS was published in 2014 (Fig. 3). Although Nakamoto [61] proposed the concept of Bitcoin in 2008, it did not receive too much attention from the academic community in the early years. It was not until 2014 that the concept of Blockchain began to appear frequently. Therefore, we use 2014 as the starting point for time division.

Until 2017, only a few studies were published, but the number of publications has increased since then, and a sharp rise has been observed in the past two years. To study the scientific evolution of the Blockchain themes more accurately, to avoid the monotony of data, and to ensure comparability across periods, the entire period (2014-2020) was divided into four consecutive phases: 2014-2016, 2017-2018, 2019, and 2020. As shown in Fig. 3, 10 studies were published in the first period, 342 in the second, 867 in the third, and 1774 in the fourth. This increasing trend can also be observed in the number of publications in each period, which went up approximately 34.2, 2.53, and 2.05 times from the first to the second period, the second to the third, and the third to the fourth period, respectively.

E. PARAMETER CONFIGURATION
Parameter settings affect the final result of SciMAT. The parameters selected in this research are reported in Table 2.

III. RESULTS
Analysis of the most productive authors, countries, institutions and leading research areas contribute to scholars’ understanding of Blockchain development.

A. MOST PRODUCTIVE AUTHORS
Table 3 shows the top 10 authors in terms of productivity. The number of publications between them is minimal. There are three authors whose publication volume is more than 30—they are Choo Kim-Kwang Raymond, Guizani Mohsen, and Yu Fei Richard; six authors with a work of 20–30 articles, and only one author’s work is below 20.

An analysis of the most productive authors shows that they published a similar number of documents. The result is inconclusive because of the short period of analysis. However, in terms of the number of publications, the most productive author is Choo Kim-Kwang Raymond. He mainly studies privacy and security [62]–[65], and the topics account for one-third of his published literature. The second most productive author is Guizani Mohsen, who primarily studies specific issues by constructing models [66]–[69]. Similarly, each author has a research direction, and researchers can read according to their research topic.

B. MOST PRODUCTIVE COUNTRIES AND INSTITUTIONS
In line with Table 4, Fig. 4 locates the top 10 countries in terms of productivity and shows the geographic distribution.
of 2993 publications researching Blockchain. Table 4 lists the top 10 countries in terms of publication volume. China is the most productive country, with 1314 articles published, twice the USA's publications. The difference in the number of documents published by the first and tenth countries is very vast, as China’s productivity is 13 times that of Germany’s. Chinese scholars have conducted the most extensive research effort on the Blockchain globally.

A total of 2648 institutions contributed to 2993 publications. We discussed the 10 institutions with the highest volume of publications (as shown in Table 5). It is worth noting that 6 universities, 1 research institute, and 3 university systems are involved. And it is not difficult to find that the top ten institutions are from China (6), the USA (3), and Saudi Arabia (1), of which China accounts for 60%. According to Table 5, the Beijing University of Posts and Telecommunications contributed the most with the highest number of publications (96), frequency of citations (1614), and h-index (21). Besides, there are the University of Electronic Science Technology of China and the University of Texas System with higher citation frequency and h-index. Other prolific institutions included the Chinese Academy of Sciences (73) and Xidian University (60).

An analysis of the number of papers by country shows that countries in Europe and Asia have more research on Blockchain. Combined with the analysis of the top ten influential institutions, China is a well-deserved leader, contributing about 43% of the research literature.

### TABLE 3. Most productive authors.

| Authors            | TP* |
|--------------------|-----|
| Choo Kim-Kwang Raymond | 33  |
| Guizani Mohsen     | 32  |
| Yu Fei Richard     | 31  |
| Du Xiaojiang       | 29  |
| Salah Khaled       | 26  |
| Kumar Neeraj       | 26  |
| Zhang Yan          | 22  |
| Park Jong Hyuk     | 21  |
| Zhu Liehnaung       | 20  |
| Niyato, Dusit       | 19  |

*TP*—Total Publications

### TABLE 4. Number of publications by top 10 countries.

| Country       | TP* |
|---------------|-----|
| China         | 1314|
| USA           | 599 |
| South Korea   | 264 |
| England       | 262 |
| Australia     | 198 |
| India         | 194 |
| Canada        | 162 |
| Italy         | 120 |
| Saudi Arabia  | 102 |
| Germany       | 101 |

*TP*—Total Publications

### TABLE 5. The top 10 influential institutions.

| Institution                                      | Country | TP* | TC* | %TP* | H-index |
|-------------------------------------------------|---------|-----|-----|------|---------|
| Beijing University of Posts and Telecommunications| China   | 96  | 1614| 3.21 | 21      |
| Chinese Academy of Sciences                      | China   | 73  | 760 | 2.44 | 13      |
| Xi'an University                                 | China   | 60  | 678 | 2.01 | 14      |
| University of Electronic Science Technology of China| China   | 59  | 1109| 1.97 | 14      |
| University of Texas System                       | USA     | 52  | 912 | 1.74 | 14      |
| Beijing Institute of Technology                  | China   | 49  | 621 | 1.64 | 15      |
| King Saud University                             | Saudi Arabia | 48 | 566 | 1.61 | 14      |
| University of California System                  | USA     | 42  | 362 | 1.40 | 10      |
| Pennsylvania Commonwealth System of Higher Education Peshe | USA   | 40  | 670 | 1.34 | 12      |
| Tsinghua University                              | China   | 39  | 427 | 1.30 | 8       |

*TP*—Total Publications; *TC*—Total Citations; %TP*—(TC/TOTAL Citations / All Citations) *100%

### C. MAIN RESEARCH AREAS

Fig. 5 presents the top 10 research areas addressed by global scholars in the field of Blockchain. Five of the main areas are related to computer science. The top three — computer science, information systems (28%), engineering electrical & electronic (25%), and telecommunications (22%) — accounted for more than 20% of the total research areas. The proportions of other research fields were all below 10%.

An analysis of the leading research fields shows that computer science is still the most popular research direction, and researchers are more interested in computer science, information systems [70]–[74], engineering electrical & electronic [75]–[77], and telecommunications [78]–[80].

### IV. DISCUSSION

Based on the 2993 documents collected by the WoS database, this study summarizes the Blockchain research through bibliometrics. Firstly, we used Gephi for keyword clustering to discuss the research content of each community. After configuring all necessary parameters (Table 2), overlapping maps, thematic diagrams, and the thematic evolution map were developed to conduct a longitudinal analysis of the Blockchain.

### A. BIBLIOMETRIC AND CONTENT ANALYSIS

In this paper, keywords with a frequency greater than 13 are selected for visual analysis and clustering, close keywords in the visual network are analyzed and summarized, and research characteristics in Blockchain are further analyzed. Judging from the community division results of the subject-related network, the current Blockchain field has formed five research directions (or subject communities) of
different scales, namely: data security and privacy protection, new algorithms, Blockchain’s characteristics and applications, new technology research and researches on Cloud technology, as shown in Fig 6 and Table 6.

**B. CLUSTER 1 (RED): DATA SECURITY AND PRIVACY PROTECTION**

Blockchain’s current privacy protection technology is at an early stage of development, and there are still many risks of privacy leakage. With the development of big data, a large amount of data is gradually stored in the Cloud, prone to privacy leakage [81]. Blockchain is considered a technology that may provide a powerful solution to network security and a high level of privacy protection [82]. Such as encryption and signature algorithm [83], k-anonymity [84] and transparency [85] of Blockchain can effectively protect privacy. Data security and privacy protection are challenges to be accepted in the explosive growth of data and rapid technology development.

**C. CLUSTER 2 (PINK): NEW ALGORITHMS**

In this community, Blockchain frameworks based on some new algorithms (federated learning, machine learning and deep learning) are applied to address privacy and security issues. Federated learning (where data is kept on the owner’s device and updates to the model are summarized through security protocols) is the latest technology to support secure multi-party machine learning [86], has recently been introduced as an efficient solution for achieving privacy protection [87]. Federated learning can solve the problem of “data silos”, featuring privacy protection and efficient processing, while Blockchain provides incentives that are robust against poison attacks in a completely decentralized manner [88]. These three algorithms tend to build a concrete application model. With the gradual prominence of data security and privacy issues, it will be more meaningful to study the utility size of specific models to solve the problem.

**D. CLUSTER 3 (YELLOW): BLOCKCHAIN’S CHARACTERISTICS AND APPLICATIONS**

This is a huge community. The public understood bitcoin and Blockchain, but it was not universally accepted, from 2013 to 2015. Subsequently, the wealth creation effect of Bitcoin, as well as the transaction overflow caused by the congestion of the Bitcoin network, led to the explosion of other virtual currencies and various Blockchain
applications and the emergence of numerous Blockchain assets with a hundredfold, thousand-fold or even a ten-thousand-fold multiplication, which triggered a global craze. From 2016 to 2018, Blockchain entered the mainstream stage. The research on Blockchain itself has increased during this period. At present, Blockchain has entered the industrial landing stage, which has inspired a large number of applications based on Blockchain technology, such as smart grid [89], smart city [90] and healthcare [91].

E. CLUSTER 4 (BLUE): NEW TECHNOLOGY RESEARCH
This community reflects a series of newer and gradually mature technologies and the integration of Blockchain. Blockchain is a newly emerging distributed ledger technology with a wide range of applications in various fields (especially supply chain management) [92]. It, as a new generation of secure information technology, is driving innovation in business and industry. Industry 4.0 (which is the era of using information technology to promote industrial reform) has seen much Blockchain-related research [93]. Blockchain and Cloud computing integration can complement each other’s advantages, have infinite potential with artificial intelligence, and continuously improve solutions with the Internet of things (IoT). Blockchain integration of new technologies will get a broader application space to solve the traditional industry’s pain points.

F. CLUSTER 5 (GREEN): RESEARCH ON CLOUD TECHNOLOGY
The theme of this community is closely related to cloud technology. It is worth noting that many computing methods are mentioned. The application of Blockchain combined with a variety of computing methods is also one of the manifestations of its application landing. The combination of Blockchain and the IoT is powerful and could lead to major changes in multiple industries [94]. The IoT has high requirements for data processing capacity, and cloud computing, fog computing and edge computing can play a good role. Cloud computing is a new generation of centralized computing, while fog computing is a new generation of distributed computing. Edge computing relies on a single node that does not constitute a network and runs its nodes in an island, which needs to realize peer traffic transmitted through the Cloud. In the future, a solution that combines the application of Blockchain and multiple technologies will completely replace a single technology and become an important engine for technological innovation and development.

G. OVERLAY GRAPH
As themes evolve, many keywords are reborn or die each period and are covered in consecutive periods. An overlay map is drawn to show the changes in keywords in each period.
Table 6. Clusters of keywords.

| Cluster 1 (red) | Data security and privacy protection | Keywords |
|----------------|--------------------------------------|----------|
| Cluster 2 (pink) | New algorithms | Security and privacy, distributed databases, industrial Internet of things, federated learning, deep learning, permissioned Blockchain, data models |
| Cluster 3 (yellow) | Blockchain's characteristics and applications | Consensus, consensus algorithm, peer-to-peer computing, Hyperledger fabric, innovation, decentralization, proof of work, smart city, cryptography, consensus mechanism, network security, microgrid, crowdsourcing, Blockchain, healthcare, game theory, cybersecurity, IPFS, smart grid, smart contract, incentive mechanism, bitcoin, fairness, Ethereum, energy trading, data mining, distributed ledger, fintech, transparency, sustainability, consensus protocol, distributed systems, technology |
| Cluster 4 (blue) | New technology research | Big data, supply chain management, artificial intelligence, supply chain, traceability, industry 4, reputation, trust, Blockchain technology, logistics, Cloud |
| Cluster 5 (green) | Research on Cloud technology | Resource management, protocols, fog computing, computer architecture, Internet of vehicles, cryptography, computational modeling, task analysis, Internet of things, scalability, servers, reliability, pricing, monitoring, cloud computing, games, edge computing, data integrity, performance evaluation, trust management, collaboration, optimization, cloud storage, quality of service, mobile edge computing |

FIGURE 7. Overlay graph.

Fig. 7 shows the changes in the number of keywords in the Blockchain field in different periods. In the first period, 40 keywords are observed; 26 keywords disappear at the end of the period, and the remaining 14 keywords enter the next period. In the second period, 975 newly emerging keywords are observed. Together with those from the previous period, they amount to 989 keywords. At the end of the period, 638 keywords disappear. The remaining 351 keywords enter the next period. In the third period, 1964 newly emerging keywords are observed. With the remaining keywords in the second period, 2315 keywords are observed in this period. However, 1409 keywords disappear at the end of the period, and the remaining 906 keywords enter the next period. There are 3797 newly emerging keywords in the fourth period. In addition to the remaining keywords from the third period, 4703 keywords are observed in this stage. Furthermore, the keywords' consistency between the four periods is 0.01, 0.12, and 0.15.

The analysis of keyword evolution shows that the number of keywords in the Blockchain field has significantly increased during the entire sample period. The number of newly emerging keywords and the total number of keywords in each period continue to grow, indicating that researchers have tried many different research directions in each period. However, according to the coefficient between each period, only a few keywords were retained, and the evolution of keywords in the Blockchain field has not yet stabilized.

H. THEMATIC STRUCTURE

We draw a strategic diagram of the four periods to analyze the Blockchain’s most critical themes for each literature period. The analysis of strategic diagrams can explore the research
hotspots in different periods and their changes. The motor theme of each period is the hot topic of research in that period.

In the strategic diagram, the node size is related to the h-index associated with each research topic. The h-index names authors’ research quality based on the number of articles published in scientific journals and the number of citations received [56]. In the thematic network, we use the Jaccard index to represent the similarity between the themes: the thicker the line between the two themes, the stronger the correlation. Table 7 shows the number of core documents, h-index, and sum citations for each topic in different periods.

1) FIRST PERIOD (2014-2016)
As shown in Fig. 8a, five major research themes of this period related to Blockchain are presented: HEALTHCARE, BLOCK-CHAIN-TRACEABLE-GRAPH, COSTS, TREE, and BITCOIN. HEALTHCARE and TREE are motor themes in this period, with one core document showing strong centrality and high density. COSTS is a highly developed and isolated theme, with only one core document. BLOCK-CHAIN-TRACEABLE-GRAPH is an emerging or declining theme, and its total citation frequency is only one. BITCOIN is a basic and transversal theme related to Blockchain, with three core documents. The literature behind the topic TREE studies the healthcare data gateway, from which we can infer that HEALTHCARE is undoubtedly the research hotspot in this period. Scholars have studied human body channels and e-health [95] and healthcare data [96].

It is worth noting that although BITCOIN is not yet perfect and ideal, it is much higher than other topics, reflecting that people have done more research on it in the later period. According to Nakamoto [61], the “most beautiful part” of cryptocurrencies like Bitcoin is their “mining,” a term he proposes. In 2015, academic research on Bitcoin had reached a peak. Some scholars began to turn their research direction from bitcoin to Blockchain. For example, Kiviat [97] conducted research based on regulating Blockchain transactions to improve the legal community’s understanding of Blockchain technology.

Additionally, based on Blockchain’s decentralized characteristics, scholars used it in IoT [98], medical [96], and other fields in this period to solve security and privacy issues. Fig. 10a shows BITCOIN’s thematic network, exploring the research directions. Among the 11 related topics, Blockchain has the largest circle, which means that the number of documents related to it is the largest. The significance of bitcoin to Blockchain is proved from the reverse side.

Hence, in the first subperiod, HEALTHCARE and BITCOIN are the focus of attention.

2) SECOND PERIOD (2017–2018)
Fig. 8b shows nine entirely new significant themes of this period related to Blockchain: INTERNET, INTEGRATION, SECURE, SUSTAINABILITY, CRYPTOCURRENCY, BIG-DATA, QUALITY, CONSORTIUM-BLOCKCHAIN, and CONSENSUS. INTERNET, INTEGRATION, and SECURE became research hotspots in this period, with 92, 11, and 19 core documents, respectively. QUALITY and BIG-DATA are newly emerging themes, with three core and six core documents. CONSORTIUM-BLOCKCHAIN and CONSENSUS are highly developed and isolated themes, implying that it has developed but still has low importance in this period. SUSTAINABILITY and CRYPTOCURRENCY are basic and transversal themes, suggesting significant themes but have not yet been fully developed.

In line with the first period, the motor themes of the second period underwent tremendous changes. The last five themes disappeared, and newly emerging themes were observed. Research hotspots, in this period, were become INTEGRATION, INTERNET, and SECURE. INTERNET has the highest number of core documents (92), h-index (38) and total citation frequency (9391). There is no doubt that it is a research hotspot in this period, and it also has an important impact on future research in Blockchain. Then SECURE and INTEGRATION also received great attention, and the three indicators were in the top five.

With the development of cryptocurrency, more and more platforms have launched their cryptocurrency. BITCOIN, which showed significant importance in the last period, has also been replaced by CRYPTOCURRENCY in this period. Researchers are no longer limited to bitcoin. In 2018, the Bitcoin circle faced a bear market challenge, and the price of Ethereum fell from $480 to less than $200. Within a month and a half, Ethereum’s fall began attracting scholars’ attention [99]–[101]. Moreover, breakthroughs were made in the Blockchain’s core technology during this period, and research on secure [102] and privacy-preserving [103] further deepened and developed.

In terms of sum citation frequency, BIG-DATA ranked third, indicating that later scholars paid more attention to this theme. Big data reached its propaganda climax in 2012 and 2013. After 2014, the conceptual system gradually took shape, and its cognition became more rational. With the maturity of theoretical concepts, the research of BIG-DATA in the field of Blockchain appeared in front of the public in the form of new themes. As shown in Fig. 10b, there were few pieces of research on big-data-related themes in this period, such as cyber-physical system [104], Blockchain technology [105], and access control [66]. It is proved from the side that the research on big data in Blockchain is still developing and improving, and it still needs further precipitation.

Consequently, during this period, it is clear that INTERNET, SECURE and INTEGRATION are the research focus of researchers in the Blockchain field. Also, BIG-DATA, as a potential research hotspot, has attracted the attention of later researchers.

3) THIRD PERIOD (2019)
Fig. 9a shows eight major research themes of this period related to Blockchain: BLOCKCHAIN, SUPPLY-CHAIN, CLOUD, DESIGN, SUPPLY-CHAIN-MANAGEMENT,
PEER-TO-PEER-NETWORK, AUTHENTICATION, and PRIVACY-PRESERVING. Among them, BLOCKCHAIN, SUPPLY-CHAIN, and CLOUD are three motor themes. DESIGN is a highly developed and isolated theme. PEER-TO-PEER-NETWORK and PRIVACY-PRESERVING are two newly emerging or declining themes. AUTHENTICATION is a basic and transversal theme. SUPPLY-CHAIN-MANAGEMENT lies between four themes, with four core documents.

Compared with the sluggishness of 2018, the third period was marked by ups and downs. BLOCKCHAIN became a research hotspot, and SUPPLY-CHAIN and CLOUD were also the research focus of this period. Their three major indicators (core documents, h-index, and sum citations) are all in the top three, which is a hot issue for researchers in the third period.

SUPPLY-CHAIN and CLOUD became hot issues during this period, possibly because of the capabilities given to them by the development of The Times. For one thing, the supply chain can realize the control of information flow, logistics and capital flow. As it matures, it also faces problems such as data visualization and product traceability. Every transaction information on the Blockchain (transaction parties, transaction content, etc.) can be recorded on a block. It is stored on the distributed ledger of each node on the chain, ensuring the integrity, reliability, and transparency of the information. The features of Blockchain bring many advantages to the supply chain field, which is bound to excite the research enthusiasm of scholars.

For another, with the development of various features in the Cloud, the cloud era has gradually entered the field of vision. CLOUD has become one of the research hotspots in this period. As shown in Fig. 10c, extensive research on themes, such as edge computing [109], mobile edge computing [110], and industrial IoT (IIoT) [111], all show strong similarities with CLOUD.

In 2019, Facebook launched Libra, which attracted global governments’ attention and pushed the Blockchain concept to a new level. Many scholars began addressing Blockchain, exploring its role in various industries [106]–[108]. With the advent of the cloud age, the importance of Cloud was gradually recognized, and CLOUD formed in-depth and wholly developed motor themes in this period. As shown in Fig. 10c, themes such as edge computing [109], mobile edge computing [110], and industrial IoT (IIoT) [111], all show strong similarities with CLOUD.

AUTHENTICATION has also gained a certain degree of attention in the third period. At this point, the research themes related to it are still limited to a few topics, such as secure [112] and digital signature [113]. But its total citation frequency (1624) also hints to a certain extent that scholars will pay attention to it in the next period.

As a result, regardless of the concept of Blockchain itself, SUPPLY-CHAIN and CLOUD are the research focus of the third subperiod, and AUTHENTICATION can be considered a potential research hotspot.

4) FOURTH PERIOD (2020)

Fig. 9b shows the 19 major research themes of this period related to Blockchain: BLOCKCHAIN, TASK-ANALYSIS, AUTHENTICATION, ADOPTION, TRUST, BIG-DATA, CLOUD-COMPUTING, CONTRACTS, FRAMEWORK, CRYPTOCURRENCY, HEALTHCARE, SMART-GRID, INDUSTRIAL-INTERNET-OF-THINGS, INDUSTRIAL-INTERNET, GAMES, SCALABILITY,
FIGURE 9. a) The strategic diagram of 2019, b) The strategic diagram of 2020.

PROOF-OF-WORK-(POW), WIRELESS-COMMUNICATION, and DIRECTED-ACYCLIC-GRAPH.

The four motor themes of this period are BLOCKCHAIN, TASK-ANALYSIS, AUTHENTICATION, and ADOPTION. Six highly developed and isolated themes are observed: DIRECTED-ACYCLIC-GRAPH, GAMES, WIRELESS-COMMUNICATION, INDUSTRIAL-INTERNET, PROOF-OF-WORK-(POW), and SCALABILITY. TRUST, CONTRACTS, FRAMEWORK, CLOUD-COMPUTING, BIG-DATA, and CRYPTOCURRENCY are basic and transversal themes. HEALTHCARE, SMART-GRID, and INDUSTRIAL-INTERNET-OF-THINGS are newly emerging or declining themes.

In 2020, there were four research hotspots: ADOPTION, BLOCKCHAIN, TASK-ANALYSIS, and AUTHENTICATION. Compared with the previous period, only the Blockchain remains. ADOPTION and TASK-ANALYSIS (three indicators of which the advantages are not obvious) are themes focusing on the application of Blockchain technology and research methods. Facts have proved that AUTHENTICATION, a potential research hotspot discussed in the third period, developed into one of the focus issues in this period.

It is worth mentioning during this period that healthcare received close attention from people in this period, and HEALTHCARE [116]-[118] as a newly emerging or declining theme returned to researchers‘ vision. During this period, researchers’ research on healthcare was mainly data interoperability [119] and electronic medical records [120]. This change may be related to COVID-19. Due to the long-term impact of the epidemic, research on HEALTHCARE may grow further.

Therefore, in this period, BLOCKCHAIN and AUTHENTICATION are relatively important hot issues. BIG-DATA and TRUST, as potential hot topics, deserve the attention of scholars. Besides, during this period, we also need to pay attention to the development of HEALTHCARE, which is perhaps one of the themes strongly influenced by the current context.

I. THE THEMATIC EVOLUTION MAP

We used SciMAT to map the thematic evolution of the Blockchain concept (Fig. 11), used the Jaccard index to measure the interrelationships between different themes, and observed that the circle changes‘ size proportion to the h-index. Our study explored the theme’s evolution by analyzing the evolution map and predicting the future development trend.

As shown in Fig. 11, the themes that died out in the evolution process are TREE, BLOCKCHAIN-TRACEABLE-GRAPH and CONSENSUS; the new themes are CRYPTOCURRENCY, SUSTAINABILITY, CON Sortium-BLOCKCHAIN, INDUSTRIAL-INTERNET, SCALABILITY, HEALTHCARE, WIRELESS-COMMUNICATION, GAMES, PROOF-OF-WORK-(POW), and DIRECTED-ACYCLIC-GRAPH.

The theme of extinction centers on the first and second periods. Blockchain technology has just entered people’s
vision at this stage, and the research on it is not stable, and the number of researches is also small. Li et al. [121] used a heavy subgraph to study the traceability of Blockchain. This is a study on the characteristics of Blockchain, which was very popular among scholars in the early days when the concept of Blockchain was put forward. With the gradual maturity of technology, the research focus is gradually shifting to the traceability research of specific products [122], [123] and industries [124] based on Blockchain.

As for the theme TREE, Yue [96] referred to the multidimensional binary search tree proposed by Bentley [125], and used the Blockchain platform to ensure the sharing and security of medical and healthcare data. Topic CONSENSUS evolved from HEALTHCARE, and again focused on the privacy protection of healthcare data. Gradually, the issue of privacy protection is no longer confined to the medical field [126]–[128], and privacy-preserving has appeared in front of people as an independent research topic.

Many new themes were born in the fourth period, which is inseparable from the development of Blockchain technology in this period. 2020 has created excellent conditions for the development of Blockchain. First of all, 2019 is the first year of 5G applications, the starting point of the IoT. The active exploration of the central bank’s digital currency by the People’s Bank of China and the Federal Reserve will greatly promote the popularization of digital currency [129]. Next, Blockchain 3.0 technology (all the attributes obtained through the decentralization of Blockchain distrust (such as immutability, transparency and no intermediary) transplanted to other systems built on Blockchain technology) [130] can
**FIGURE 11.** The thematic evolution of 2014-2020 with H-index.
improve the Blockchain’s performance, improve the ease of use, operability, and scalability. Most of these technologies will enter the mature stage in 2020. Finally, China, Singapore, and the United States have promoted Blockchain technology and promoted its development. Broadening the research field of Blockchain will help promote its application, bring positive impact to enterprises [131], [132] and facilitate people’s life [133].

The demise, rebirth and integration of the theme reflect the change of researchers’ research on Blockchain from concrete to abstract to concrete. To explore the interrelationships between themes in different periods, we referred to the results of keyword clustering and the hot themes presented in the strategic diagrams, and divided all paths into five categories (see Table 8), namely, cryptocurrency, privacy preserving, Cloud technology, supply chain, and others.

1) CRYPTOCURRENCY
Several paths in this category are relatively simple and revolve around bitcoin, Blockchain and cryptocurrency. It is worth noting that nearly half of the paths involve a peer-to-peer network. P2P will come to a close in China in 2019, with the number plummeting by 70% to 343, and leading platforms have transformed. Academic research on it has gradually faded after the surge in 2019. We need to pay attention to that in paths 12 and 13, PEER-TO-PEER-NETWORK has evolved into SMART-GRID. Blockchain has some excellent features that make it a promising application in the smart grid paradigm [134]. Smart grid is the development trend of the next-generation grid, and the introduction of Blockchain technology can meet its development needs [135]. However, the smart grid development in the world is still in its infancy, which provides a very good research environment for most scholars.

In short, for the evolution path of this category, researchers can pay more attention to the application of Blockchain to the smart grid.

2) PRIVACY
Only four paths are summarized in this category, and the path structure is relatively simple. PRIVACY-PRESERVING evolved from the two directions of BITCOIN to SECURE and CONSORTIUM-BLOCKCHAIN, and it evolved into FRAMEWORK and CLOUD-COMPUTING in the fourth period. Since bitcoin transactions are public on the entire network, for a transfer transaction, the transaction amount and the addresses of both parties to the transaction can be viewed and monitored by anyone. Otherwise, the consortium Blockchain can conduct distributed user data storage and effectively solve a single point of failure and data tampering. It guarantees users’ privacy to a certain extent and has confidentiality and unforgeability [136]. This will stimulate people’s research on privacy protection. In the decade since

| TABLE 8. Evolutionary path classification. |
|------------------------------------------|
| Category               | Paths                                                                 |
| Cryptocurrency         | 1) Bitcoin → internet → Blockchain → cryptocurrency                 |
|                       | 2) Bitcoin → secure → Blockchain → cryptocurrency                    |
|                       | 3) Blockchain → secure → peer-to-peer-network → cryptocurrency       |
|                       | 4) Cryptocurrency → Blockchain → cryptocurrency                      |
|                       | 5) Cryptocurrency → peer-to-peer-network → framework                |
|                       | 6) Costs → integration → Blockchain → cryptocurrency                 |
|                       | 7) Costs → internet → Blockchain → cryptocurrency                    |
|                       | 8) Cryptocurrency → peer-to-peer-network → framework                |
|                       | 9) Bitcoin → secure → peer-to-peer-network → framework              |
|                       | 10) Bitcoin → secure → peer-to-peer-network → Blockchain            |
|                       | 11) Cryptocurrency → peer-to-peer-network → Blockchain              |
|                       | 12) Bitcoin → secure → peer-to-peer-network → smart-grid            |
|                       | 13) Cryptocurrency → peer-to-peer-network → smart-grid              |
| Privacy preserving    | 14) Bitcoin → secure → privacy-preserving → framework               |
|                       | 15) Consortium-Blockchain → privacy-preserving → framework          |
|                       | 16) Bitcoin → secure → privacy-preserving → cloud-computing          |
|                       | 17) Consortium-Blockchain → privacy-preserving → cloud-computing     |
| Cloud technology      | 18) Costs → internet → cloud → IoT                                  |
|                       | 19) Bitcoin → internet → cloud → IoT                                |
|                       | 20) Bitcoin → secure → cloud → IoT                                  |
|                       | 21) Cryptocurrency → cloud → IoT                                   |
|                       | 22) Consortium-Blockchain → cloud → IoT                            |
|                       | 23) Consortium-Blockchain → cloud → authentication                  |
|                       | 24) Costs → internet → cloud → authentication                       |
|                       | 25) Cryptocurrency → cloud → authentication                         |
|                       | 26) Bitcoin → secure → cloud → authentication                        |
|                       | 27) Bitcoin → internet → cloud → authentication                     |
|                       | 28) Costs → internet → cloud → big-data                             |
|                       | 29) Bitcoin → internet → cloud → big-data                           |
|                       | 30) Bitcoin → secure → cloud → big-data                             |
|                       | 31) Cryptocurrency → cloud → big-data                               |
|                       | 32) Consortium-Blockchain → cloud → big-data                        |
|                       | 33) Costs → internet → cloud → framework                            |
|                       | 34) Bitcoin → internet → cloud → framework                          |
|                       | 35) Bitcoin → secure → cloud → framework                            |
|                       | 36) Cryptocurrency → cloud → framework                              |
|                       | 37) Consortium-Blockchain → cloud → framework                       |
|                       | 38) Costs → internet → cloud → task-analysis                        |
|                       | 39) Bitcoin → internet → cloud → task-analysis                      |
|                       | 40) Bitcoin → secure → cloud → task-analysis                        |
|                       | 41) Cryptocurrency → cloud → task-analysis                          |
|                       | 42) Consortium-Blockchain → cloud → task-analysis                   |
|                       | 43) Costs → internet → cloud → Blockchain                          |
|                       | 44) Bitcoin → internet → cloud → Blockchain                         |
|                       | 45) Bitcoin → secure → cloud → Blockchain                           |
|                       | 46) Cryptocurrency → cloud → Blockchain                            |
|                       | 47) Consortium-Blockchain → cloud → Blockchain                      |
|                       | 48) Costs → integration → supply-chain → framework                  |
|                       | 49) Costs → internet → supply-chain → framework                     |
|                       | 50) Bitcoin → internet → supply-chain → framework                   |
|                       | 51) Sustainability → supply-chain → framework                       |
|                       | 52) Costs → integration → supply-chain → Blockchain                 |
|                       | 53) Costs → internet → supply-chain → Blockchain                    |
|                       | 54) Bitcoin → internet → supply-chain → Blockchain                  |
|                       | 55) Sustainability → supply-chain → Blockchain                      |
|                       | 56) Costs → integration → supply-chain → adoption                    |
|                       | 57) Costs → internet → supply-chain → adoption                       |
|                       | 58) Costs → quality → supply-chain-management → adoption             |
|                       | 59) Bitcoin → internet → supply-chain → adoption                     |
TABLE 8. (Continued.) Evolutionary path classification.

| Evolutionary path classification | 60) Sustainability → supply-chain → adoption |
|----------------------------------|--------------------------------------------|
|                                  | 61) Sustainability → supply-chain-management → adoption |
|                                  | 62) Costs → integration → supply-chain → trust |
|                                  | 63) Costs → internet → supply-chain → trust |
|                                  | 64) Costs → quality → supply-chain-management → trust |
|                                  | 65) Bitcoin → internet → supply-chain → trust |
|                                  | 66) Sustainability → supply-chain → trust |
|                                  | 67) Sustainability → supply-chain-management → trust |
|                                  | 68) Costs → integration → supply-chain → big-data |
|                                  | 69) Costs → internet → supply-chain → big-data |
|                                  | 70) Bitcoin → internet → supply-chain → big-data |
|                                  | 71) Sustainability → supply-chain → big-data |
| Others                           | 72) Costs → integration → Blockchain → Blockchain |
|                                  | 73) Costs → internet → Blockchain → Blockchain |
|                                  | 74) Bitcoin → internet → Blockchain + Blockchain |
|                                  | 75) Bitcoin → secure → Blockchain → Blockchain |
|                                  | 76) Cryptocurrency → Blockchain → Blockchain |
|                                  | 77) Cryptocurrency → Blockchain → contracts |
|                                  | 78) Costs → integration → Blockchain → contracts |
|                                  | 79) Costs → internet → Blockchain → contracts |
|                                  | 80) Bitcoin → internet + Blockchain + contracts |
|                                  | 81) Bitcoin → secure → Blockchain → contracts |
|                                  | 82) Costs → internet → design → big-data |
|                                  | 83) Costs → quality → design → big-data |
|                                  | 84) Bitcoin → internet → design → big-data |
|                                  | 85) Bitcoin → internet → Blockchain → authentication |
|                                  | 86) Bitcoin → secure → Blockchain → authentication |
|                                  | 87) Bitcoin → secure → authentic → authentication |
|                                  | 88) Cryptocurrency → Blockchain → authentication |
|                                  | 89) Cryptocurrency → authentication → authentication |
|                                  | 90) Costs → integration → Blockchain → authentication |
|                                  | 91) Costs → internet → Blockchain → authentication |
|                                  | 92) Cryptocurrency → authentication → trust |
|                                  | 93) Bitcoin → secure → authentication → trust |
|                                  | 94) Healthcare → consensus |

TABLE 9. Identifying research directions in Blockchain research.

| Category          | Research direction                                                                                                                                 |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Cryptocurrency    | It is recommended to pay attention to the application of Blockchain in the smart grid. Here are some examples:                                     |
|                   | • Design Blockchain-based access control [151]                                                                                                       |
|                   | • Research data security based on Blockchain [152]                                                                                                   |
|                   | • Energy transaction in Blockchain-based smart grid [153]                                                                                            |
| Privacy preserving| Consider starting with some new algorithms to research privacy issues in the Blockchain field. For example:                                       |
|                   | • Cloud computing security attacks [154]                                                                                                              |
|                   | • Protect privacy in Blockchain through federated learning [155]                                                                                     |
|                   | • Try to build a deep learning model using Blockchain [156]                                                                                        |
|                   | • Fusion of Blockchain and distributed learning [157]                                                                                               |
| Cloud technology  | It is recommended to pay attention to IoT and big data with appropriate attention to authentication. The following perspectives can be referred to: |
|                   | • Introduce the algorithm to IoT in combination with Blockchain [158]                                                                                 |
|                   | • Effective storage and management of data based on Blockchain [159]                                                                               |
|                   | • Blockchain-based applications of online and offline integration [160]                                                                           |
| Supply Chain      | Try looking at supply chain issues based on big data and using Blockchain technology’s characteristics to solve these problems. Examples of reference are as follows: |
|                   | • Focus on the key Blockchain-based applications of the supply chain in different fields [161]                                                       |
|                   | • Supply chain traceability based on Blockchain [162]                                                                                               |
|                   | • Analyze the performance of Blockchain in the supply chain [163]                                                                                  |
| Others            | Pay due attention to the design of smart contracts. Such as:                                                                                         |
|                   | • Design a system based on Blockchain and smart contract [164]                                                                                    |
|                   | • The problem with smart contracts [165]                                                                                                             |

the concept of cloud computing was first proposed, the technology has matured. It is distributed computing, network storage and other technologies that can be well aligned with Blockchain, providing new ideas to solve privacy issues.

If researchers want to research privacy issues in the Blockchain field by analyzing these paths, they can consider starting some new computing methods, such as cloud computing.

3) CLOUD

In this category, we have summarized 30 paths. According to the evolution results of different paths in the fourth period, it can be roughly divided into four categories: IIoT, authentication, big data, and research methods.

First of all, cloud computing or edge computing, which is closely related to the Cloud, can greatly improve the computing efficiency of IIoT systems [137]. As far as IIoT is concerned, there are still many unresolved issues, such as the privacy and security of data storage [138] and the efficiency of data sharing [139]. Second, 5 paths involve CLOUD’S evolution to AUTHENTICATION. Users should first conduct identity authentication for cloud data users and then obtain the required services from the Cloud [140]. And in 2020, the research on authentication has expanded to multiple aspects such as mutual authentication [89], authentication scheme [141] and fog computing [142]. The research on it has continued from the third period to the fourth period and has gradually matured. In addition, the two themes of CLOUD and BIG-DATA also show inheritance. Big data and the cloud era are coexisting, and related research emerges endlessly.

In general, there are still gaps in the research of the Industrial Internet of Things (IIoT), and authentication has received close attention for two consecutive periods. It is inferred that the possibility of continuing to become a research hotspot in the future is low, and some breakthroughs may need to be combined. Finally, big data is a contemporary development trend and can be used as a basic topic for scholars to study.

4) SUPPLY CHAIN

In this group, there are a total of 24 paths. According to the results of their evolution in the fourth period, they can be simply classified into 5 directions: framework, Blockchain, adoption, trust and big data. At present, supply chain management is the world’s top 500 enterprises to maintain a strong competition indispensable means. The concept of the supply chain is no longer the traditional sales chain. It has gone beyond the boundaries of enterprises, from an operational tool to a management method system, a kind of operation management thinking and mode.

What we need to pay more attention to is big data, which appeared in the second period. The previous chapter compared BIG-DATA’s thematic network of two periods (period 2 and period 4). We can see that the research on BIG-DATA is
becoming mature and developing. In the digital era, the role of big data is proliferating. All fields have shown extensive attention to it, and the supply chain field is no exception [143]. The process of integrating big data into the supply chain is to put the internal and external data, structured data and unstructured data of the enterprise into the framework of data analysis. Judging from the current research results, there are still research gaps, such as sustainable supply chain management [144], [145], the source of big data in the supply chain, and the impact of bad data on supply chain performance [146], waiting for future scholars to explore. Furthermore, multiple studies have shown that supply chains face challenges due to a lack of trust in data sharing [147]. Blockchain technology can alleviate the trust problems faced by supply chains in different fields.

In conclusion, researchers can try to study supply-chain issues based on big data (for example, focusing on trust) and try to solve them with the characteristics of Blockchain technology.

5) OTHERS
In this group, in addition to BIG-DATA, AUTHENTICATION, and TRUST mentioned earlier, we need to look at the path about CONTRACTS. The path presented in this article, it is all evolved from BLOCKCHAIN, and related topics include cryptography [148], data privacy [149], 5g mobile communication [150], and others. Most of these studies are based on the application of smart contracts, and there are not too many studies in each aspect, and it is worthwhile for scholars to further in-depth.

J. FUTURE RESEARCH DIRECTIONS
Based on the strategic diagram and the thematic evolution map, Table 9 proposes five future research directions for Blockchain, and we provide readers with some reference directions.

V. CONCLUSION
This research examined keywords evolution, changes in research hotspots in different periods, and inheritance and evolution among themes related to Blockchain from 2014 to 2020, based on publications in the WoS database. Although this study is not the first to analyze the Blockchain theme using bibliometric methods, it is the first to explore its scientific evolution. Hence, it offers a reference for researchers to discover research hotspots in the field quickly.

This analysis identified the top 10 most productive authors, countries, institutions, and central research areas. The results showed that the most effective author is Choo Kim-Kwang Raymond, the most productive country is China, the most influential institution is Beijing University of Posts. The main research field is computer science, information systems. A noteworthy finding related to these studies is that China has a low amount of research conducted per researcher, which needs to be increased despite being the most productive country.

Based on the classification of keywords by Gephi, it is found that the current research mainly focuses on the application of Blockchain, the combination of cloud technology, new algorithms and some other new technologies with Blockchain, as well as the research on data security and privacy.

According to the proposed overlay graph, although the number of keywords has shown an upward trend as a whole, keywords inheritance between two adjacent periods is not high. Several newly emerging and dying keywords are observed in each period. Blockchain research had shown rapid growth, the research team has expanded rapidly, and the research themes have become more abundant. However, its evolution has not yet stabilized.

The proposed strategic diagram shows that the Blockchain field is expanding as a whole, and the research direction is continuously enriched. The update iteration speed of most themes is still very rapid, consistent with the disappearance of keywords in different periods. Themes, such as PEER-TO-PEER-NETWORK, appear only in one period. The joint analysis of the thematic networks indicates that themes such as SECURE and those closely related to it predict future research directions to a certain extent.

Regarding the conceptual evolution of the field, we divide all the evolutionary paths into five groups (cryptocurrency, privacy preserving, Cloud technology, supply chain, and others) and discuss each group separately to predict future research directions. Firstly, Blockchain application development will shift from a single technology to the comprehensive application of multiple technologies. Scholars can pay attention to the integration of cloud computing, fog computing and other computing methods with Blockchain. Secondly, the application of Blockchain and smart contracts can be studied to solve the pain points of traditional industries, such as smart grid, IoT and IIoT. Finally, the topic of authentication can be appropriately concerned.

Researchers have increasingly realized that Blockchain research is related to its characteristics and is inseparable from its background. Blockchain can exert various advantages in different fields. In the future, as the Blockchain technology system becomes clearer, the degree of cross-domain integration and innovation will further increase. Moreover, more precise infrastructure changes production relations, an increasing number of economic and social affairs and intermediary agencies will be replaced by program codes and algorithms. A programmable society may become a reality. These phenomena are expected to attract researchers’ attention to the Blockchain field.

The study has some limitations. First, they are the limited number of documents found on the Web of Science and covered a relatively short reference period. Next, this research is mainly based on SciMAT. The keyword classification steps in SciMAT were discussed by several of our authors. There may still be individual improper classification, but it does not affect our final research results.
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