

Article

A Bibliometric Analysis of Blockchain Technology Research Using VOSviewer

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Abstract: Blockchain technology remains popular for several reasons. The main one is that it has facilitated the rise of digital currencies over the past several years and many other uses of non-crypto currency. There is a belief that the technology itself could far exceed cryptocurrencies by its impact. Thus, researchers are still discovering the real potential of blockchain. This study aims to conduct a comprehensive blockchain analysis with a bibliometric study. The data was retrieved from the Scopus database and was analyzed using the VOSviewer software, developed at Leiden University's Centre for Science and Technology Studies (CWTS), Leiden University, the Netherlands. The study is based on the analysis of 1842 documents published in the 2007–2021 period using Scopus. From the visualization, three main groups of six clusters are generated. The red area includes topics related to blockchain technology, supply chain management, and sustainable development. The green cluster stands for such keywords as blockchains, smart contracts, electronic money, and Bitcoin and Ethereum. The blue cluster area focuses on issues related to artificial intelligence, big data, health care, and COVID-19. The analysis helps to improve the quality of the review by directing researchers to the most significant documents and mapping areas of publications.

Keywords: blockchain technology; bibliometric; Scopus; VOSviewer



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1. Introduction

The Fourth Industrial Revolution (Industry 4.0) refers to a great variety of industries. It brings the development of digital technologies. The article studies blockchain as one of them. Blockchain technology applications are already implemented in a great variety of areas. They are finance, accounting sphere, manufacturing data collection, automotive, information and security, digital purchasing, business, supervision, transaction recording, supply chain, data storage, proper management, integration of the system, and digital directory [1,2]. Beyond its more usual financial applications, we consider blockchain technology's potential to have come to the foreground in many other sectors. According to Gad et al. [3], a proper classification is provided for the current blockchain-enabled applications. They single out financial applications, business and industrial applications that include supply chain and logistics and energy sector, education, health care management, governance that covers digital identification, public sector, and voting, security and privacy, Internet of Things (IoT), Big Data management, cloud and edge computing, and other miscellaneous applications. Rawat et al. [4] propose an in-depth analysis acquiring the following application classification: finance including cryptocurrency, global payments (global currency), and insurance claims and processing; blockchain government; Internet of Things (IoT) consisting of energy cyber-physical system, vehicular cyber-physical system, blockchain in aviation systems, supply chain systems/sensors, smart homes, and Internet of Battle-Field Things (IoBT); cybersecurity; smart property and public value embodying hard money lending, cars and phones, smart appliances, asset management, cloud storage and

provenance, intellectual property, food safety, blockchain notary, blockchain health-care, fundraising and transparency, and wireless networks and virtualization; real estate involving smart contracts; identity management encompassing academic records, blockchain music, birth, marriage, and death certificates, passports, personal identity and privacy, and voting; reputation system and other applications and use cases. The mentioned types of classifications reflect the widespread cases of blockchain technology use. Blockchain is transforming the functioning of a wide range of industries. Furthermore, a significant amount of case uses of the technology makes it possible not only to classify industries that adopt blockchain but also some subareas where the technology has found its application.

Blockchain is defined to be a distributed ledger technology by way of a distributed transactional database and includes cryptography security and consensus mechanisms [5]. Therefore, blockchain provides the secure and unalterable preservation of transactional information. The characteristics of blockchain as a disruptive technology include distinctness, intangibility, and backtracking [6,7]. Such mechanisms as a tamper-resistant and time-stamped database for creating and managing data have an impact on different sectors. They increase efficiency and automate processes, reduce costs, or spur new organizational and business models [8]. There is a range of key characteristics appropriate to the blockchain. They are distributed ledger, digital, cryptographically sealed, updated near real-time, chronological, timestamped, irreversible, and auditable [9]. Blockchain technologies can increase efficiency and provide cost-effective solutions across markets. Fostering operational efficiency through unchangeable and distributed record-keeping validated by community consensus, improvement of information symmetry through transparent record-keeping, and use of a blockchain voting system, or a blockchain accounting and production system, or a blockchain shareholders registry by decentralised corporations are some of the ways in which technologies can bring enhancements [10].

This article aims to provide a bibliometric analysis of the literature related to blockchain technology research. The analysis can reveal the topic areas that are the subject of most publications and research opportunities for blockchain.

Consequently, a substantial contribution to the study has been identified. Firstly, the paper focuses on the various use cases of blockchain with applications across diverse sectors. The results of this study can provide an overview of a bibliometric analysis of the literature on blockchain technology. Secondly, the research reveals the subject areas of most publications and shows the evolution of publications related to blockchain technology. What is more, the paper uncovers further research opportunities in blockchain. Therefore, the article fulfils the objectives as follows. First of all, the paper aims to examine the trends and efficiency of publications about blockchain technology using bibliometric analysis. This analysis is an approach that allows sorting articles by document and source type, year of publication, subject area, and most active source titles and displaying relationships among them. Furthermore, the paper addresses the analysis of the clusters on the basis of the analysis of the keywords of the examined publications and words appearing in titles and abstracts.

2. Related and Background Work

Since it appeared that blockchain technology has had the potential to facilitate unique levels of innovation, researchers have been interested in the impacts, functionality, benefits, and challenges organizations face while implementing technology. Adams et al. [11] emphasized the necessity of an appropriate regulation to follow technological evolution. It turns out that there is a permanent requirement for use cases, practical demonstrations, norms, and lexical coherence. Taskinsoy [12] stated that blockchain technology has been revolutionising the way of conducting business and lifestyle. They provided the historic period, the banking crisis, as a reason for its widespread adoption. Huckle et al. [13] declared that the peer-to-peer consensus model of blockchain, its design feature, allowed us to prevent conflicts. However, there have still been open research challenges that need to be resolved to reinforce the benefits of blockchain. For instance, the authors indicated the

development of a secure IoT-focused blockchain consensus protocol with some embedded features as a possibility to benefit the entire IoT ecosystem [14].

To achieve these targets, we asked the following research questions: Q1: What is the allocation scheme of blockchain publications over recent years? Q2: What are the key blockchain subjects based on the number of publications? Q3: Which are the main international contributing countries in blockchain research? Q4: What are the research trends in blockchain?

Interest in blockchain has recently escalated, especially due to the increasing popularity of cryptocurrencies and the prompt digitization engendered by the pandemic. The number of citations that a publication receives determines its impact [15]. Therefore, to gain an understanding of the intellectual dynamics of the field, we analyze the most influential publications in a research field. The most cited articles from the collection are revealed in Table 1. The results displayed that the article of Yli-Huumo et al. [5] on the state of blockchain technology, challenges, and future directions regarding it from the technical perspective reached 869 citations.

Table 1. Most cited articles on blockchain technology.

Document Title	Authors	Journal Title	Total Citations
Where is current research on Blockchain technology? A systematic review [5]	Yli-Huumo J., Ko D., Choi S., Park S., Smolander K.	PLoS ONE	879
Blockchain technology in the energy sector: A systematic review of challenges and opportunities [16]	Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., McCallum P., Peacock A.	Renewable and Sustainable Energy Reviews	727
On blockchain and its integration with IoT: Challenges and opportunities [6]	Reyna A., Martín C., Chen J., Soler E., Díaz M.	Future Generation Computer Systems	705
A systematic literature review of blockchain-based applications: Current status, classification and open issues [7]	Casino F., Dasaklis T.K., Patsakis C.	Telematics and Informatics	568
Blockchain distributed ledger technologies for biomedical and health care applications [17]	Kuo T.-T., Kim H.-E., Ohno-Machado L.	Journal of the American Medical Informatics Association	461
Digital technology and COVID-19 [18]	Ting D.S.W., Carin L., Dzau V., Wong T.Y.	Nature Medicine	517
A Review on the Use of Blockchain for the Internet of Things [19]	Fernández-Caramés T.M., Fraga-Lamas P.	IEEE Access	448
A Survey on IoT Security: Application Areas, Security Threats, and Solution Architectures [20]	Hassija V., Chamola V., Saxena V., Jain D., Goyal P., Sikdar B.	IEEE Access	408
A survey on the security of blockchain systems [21]	Li X., Jiang P., Chen T., Luo X., Wen Q.	Future Generation Computer Systems	419
BlockChain: A Distributed Solution to Automotive Security and Privacy [22]	Dorri A., Steger M., Kanhere S.S., Jurdak R.	IEEE Communications Magazine	405

Based on the most cited articles, it is estimated, that the research of Yli-Huumo et al. [5] mainly focused on the Bitcoin system and other blockchain applications, such as smart contracts and licensing. Furthermore, Andoni et al. [16] examined the fundamental principles of blockchain technologies in the energy sector, including benefits and limitations for energy applications as well as reviewed energy applications and adopting cases such as P2P energy trading. Kuo et al. [17] focused on the advantages of blockchain for healthcare applications, the latest biomedical applications compared to traditional distributed databases, and possible constraints and proposed resolutions, while implementing blockchain technologies in biomedical care domains. Through the application of blockchain, hospitals could ensure timely delivery of medications to patients with accurate tracking [18]. The rest of the most

cited articles refer to the current stages and use, challenges, open issues and opportunities of blockchain technology [6,19,20], as well as its security [21,22].

3. Materials and Methods

Bibliometric analysis is a widespread and accurate method for examining and analyzing large volumes of scientific data. This technique is intended to comprehend interconnectedness among journal citations and sum up the up-to-date situation in terms of a current or rising research topic [15].

In the research, the data used in a bibliometric analysis is retrieved from Scopus. Visualization of similarities (VOS) viewer that aims to provide easy formation and visualization of bibliometric maps is gaining popularity in bibliometric research. This method allows us to efficiently collect literature and establish the interrelationships between chosen publications within the options.

As of the end of April 2022, 1842 publications have been retrieved by the database Scopus with the use of the following keywords search (TITLE-ABS-KEY (blockchain) AND TITLE-ABS-KEY (blockchain AND technology) AND TITLE-ABS-KEY (blockchain AND technology AND application)) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2007)) AND (LIMIT-TO (LANGUAGE, "English")).

The received results have been downloaded in CSV format to be processed using VOSviewer to visualize and analyze the trends in the bibliometric form. VOSviewer makes the creation of country maps possible based on a network (co-citation), builds a keyword map based on shared networks, and creates maps with many items [8,23]. Data mining, mapping, and grouping of articles retrieved from the database can be done using the VOSviewer software [24].

4. Results

There have been efforts to take advantage of the main features of blockchain for different applications and use cases. Some of the articles indicate the following opportunities. The infrastructure design of blockchain as well as peculiar features of smart contracts and storage mechanisms are issues of concern among companies that aim to implement blockchain. Although the capacities of smart contracts, as the way of their realization, facilitate extensive process automation and joint information systems that allow the redesign of sharing business models, companies must have a transparent awareness of probable difficulties that can arise when adopting blockchain technology [25].

The tourism industry potentially benefits from blockchain technology implementation with interactive applications [26]. Disintermediation, as of the main features of blockchain technology, provides consumers with more autonomy in travel planning that is usually accompanied by operational efficiency, reduction in costs, and impersonal transactions.

The accuracy of the information and the expense of distinctness are preferable features while implementing blockchain technology. Furthermore, the introduction of a trustworthy, transparent, and protected system can provide a reduction in the risk of fraud and enhancement of the efficiency of the supply chain process as a result of blockchain embedding into the supply chain. Subsidy as an instrument stimulates the adoption of blockchain technology in the supply chain system substantially under conditions of medium-term product cost and low cost of the expense of distinctness [27]. The adoption of blockchain technology is effective in alleviating supply chain risks caused by climate change, crop diseases, supply and demand uncertainties, and the long payback period [28].

It is estimated that blockchain applies to big data, and big data affect digital marketing constructively and substantially. Therefore, blockchain has an affirmative and significant effect on digital marketing where the direct effect of blockchain on digital marketing prevails over the indirect effect through big data [29].

The application of blockchain in the control of metrological support, measurement of a circuit of production, voting process of shareholders, marine logistics and freight, and control of rail shipment allows oil and gas companies to decrease operational risks and transaction costs, and improve, for instance, the level of fulfilment and automatization of the processes of quality monitoring [28].

In the construction sector, blockchain technology has tremendous potential through the blockchain smart contracts application and blockchain technology along with BIM technology incorporation [30].

There is a common trend to apply and use blockchain technology for making smart systems secure and trustworthy. However, three important concerns regarding cryptocurrencies, namely energy consumption, international disharmony, and the risk of a speculative bubble, have postponed the international adoption of cryptocurrency as a gold standard due to regulatory differences in the current political and economic landscape of the countries around the world [31].

This research was conducted with an application of bibliometric analysis. In this study, the data was collected from the Scopus database by searching for the phrases ‘blockchain, blockchain technology, and blockchain technology application’ in three aspects: article title, abstract, and keywords. The search results determined a total of 1842 documents in the Scopus database during the 2016 to 2021 research period.

The number of publications by year is represented in Table 2. The period 2016–2021 saw an upward trend in publishing the materials. The table shows that from the years 2017 to 2019, the number of publications has doubled. The significant increase in the number of publications has been due to the great interest of overall organizations to implement blockchain technology. An increasing tendency has continued although the annual growth rate has got entrenched at the rate of nearly 35%. In 2021, the number reached 724. The year 2022 will likely see a further increase in research trends referred to as the blockchain.

Table 2. Number of publications by year.

Year	Number of Publications	Annual Growth Rate (%)
2016	10	0
2017	35	240
2018	130	285
2019	393	202
2020	526	36
2021	724	37
Total	1842	-

The study examines different types of documents, which includes blockchain-related research. Table 3 represents publications with the keywords blockchain and blockchain technology by document type. Displayed statistics indicate that 57% of documents have been focused on one category and published as articles. Such categories as conference papers constitute 30% of documents. The other document type includes editorials, book chapters, notes, books, data papers, and letters.

Table 3. Publications by document type.

Document Type	Number of Publications	Percentage of Total Publications (%)
Article	1041	57
Conference paper	560	30
Review	221	12
Other	24	1
Total	1842	100

Figure 1 provides summary statistics for the five main sources of publications on the blockchain. The list of these five sources was formed according to the number of documents on the blockchain published in the source. IEEE Access has stood out among other sources with a dramatic increase up to the year 2020. There has been a tendency to increase in the number of publications in Sustainability Switzerland and Applied Sciences Switzerland whereas their quantity has declined in such sources as Sensors Switzerland and Journal of Physics Conference Series.

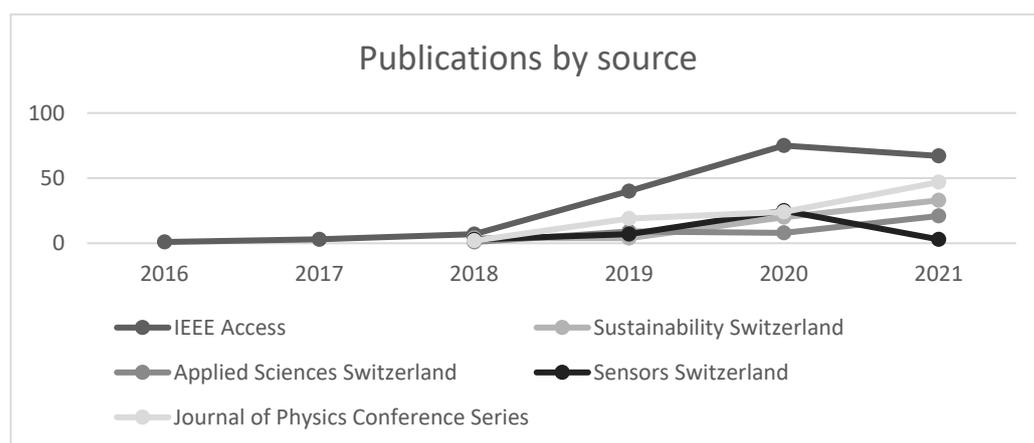


Figure 1. The number of publications by source.

Citations by sources in Figure 2 due to the analysis are divided into four clusters: IEEE Access and Sensors Switzerland belong to a red cluster, Sustainability Switzerland represents a blue cluster, Applied Sciences Switzerland enters a green cluster, and Journal of Physics Conference Series stands for a yellow cluster. The constraints applied in this analysis are 8 as the minimum number of documents of a source and 130 as the minimum number of citations of a source. They are applied to achieve a more accurate visualization of the sources that include the biggest number of publications and are the most cited. IEEE Access embodies the greatest number of documents that correspond to the biggest node with indicators of links (7) and total link strength (217). After it follow Sensors Switzerland (6/73), Applied Sciences Switzerland (6/47), Sustainability Switzerland (5/47), and the Journal of Physics Conference Series (3/6). In terms of the top five publication sources and their links to each other, IEEE Access and Applied Sciences Switzerland have relationships between all mentioned sources, Sustainability Switzerland, and Sensors Switzerland—except Journal of Physics Conference Series, while Journal of Physics Conference Series is only connected to IEEE Access and Applied Sciences Switzerland.

If we analyse publication sources in terms of citation, the analysis reveals three new sources in Table 4 that were not mentioned among sources with a high number of documents related to blockchain. However, both selected groups of sources, ones that contain documents on blockchain in a high number and ones that include most cited publications are considerably connected.

Two kinds of analysis approaches are applied. The first one, co-occurrence mapping, refers to the relationship among the keywords, and the second one, co-authorship mapping, refers to the interrelatedness of authors and contributing countries. A scientific software, VOSviewer, creates data mining, mapping, and grouping of articles retrieved from the database. The use of VOSviewer software provides a graphical analysis of bibliometric data and visualization of research results. All keywords that assisted with the full counting method have been considered as an element of the analysis while conducting co-occurrence mapping. To obtain a more accurate result, the study set some constraints in the analysis. The number of keywords to be used can be adjusted by removing less relevant keywords. A minimum of seven occurrences of a keyword was applied as a limiting factor. A VOSviewer thesaurus file can be used to indicate that different names refer to the same researcher,

to merge terms, synonyms, and abbreviated terms with full terms, to correct spelling differences as well ignore terms [32]. A thesaurus file has also been used to perform data cleaning in the study. Therefore, 278 out of 8569 keywords fulfill several criteria.

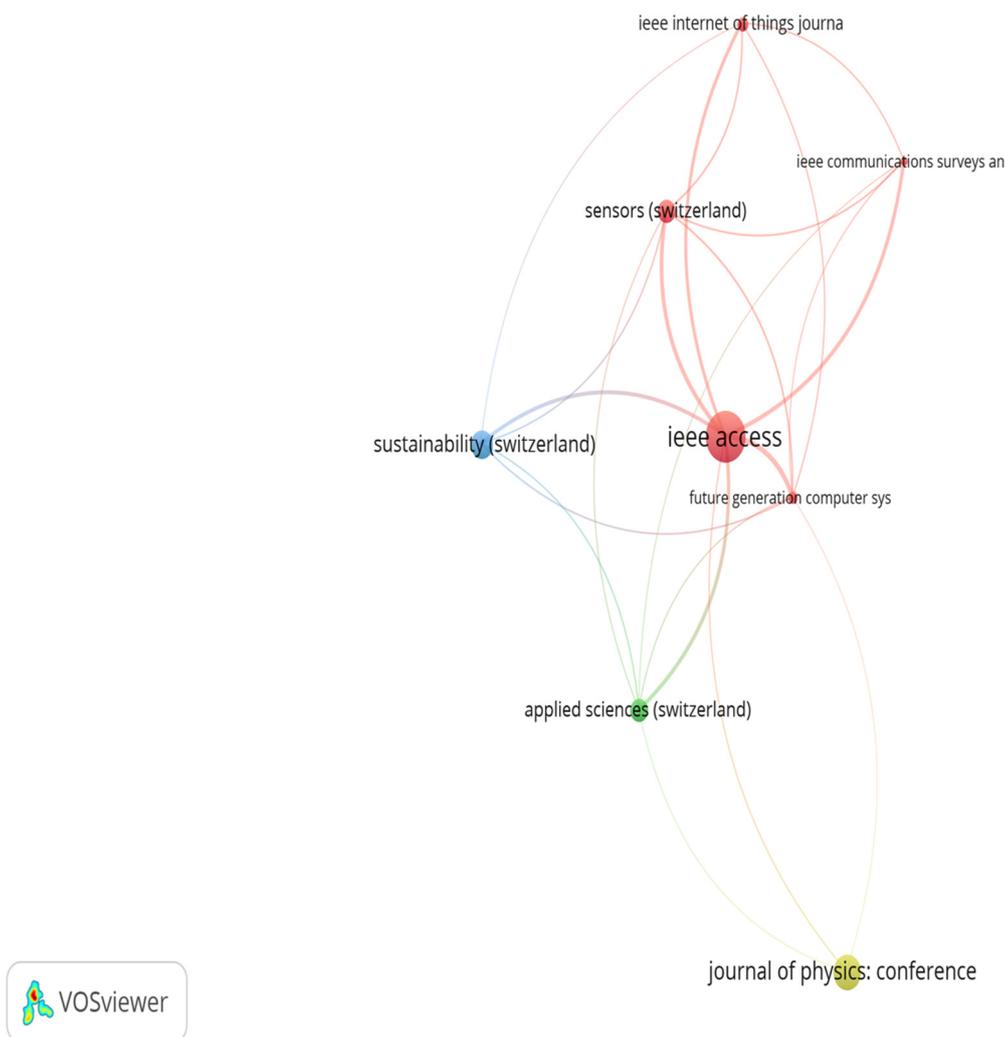


Figure 2. The citation of publications by source.

Table 4. Citation of publications by source.

Name of Source	Number of Citations
IEEE Access	7194
Future Generation Computer Systems	1591
Sensors (Switzerland)	1558
IEEE Communications Surveys and Tutorials	999
IEEE Internet of Things Journal	938

The clustering technique has been used to highlight three clusters out of seven. Figure 3 stands for the network visualization that emerged in the scientific papers. The cloud map shows the number of occurrences of the word in the article and the relationship of the keywords. In the network, each term is presented by a circle while the size of the circle is commensurate with the number of publications in which the term is found. Each colour represents a group of terms merged into clusters, and the length of curved lines specifies the approximate connection of the repetition of the term while the thickness of ones shows

the strength of pairs of topic areas or keywords. The clusters represent the relationship between one topic and another.

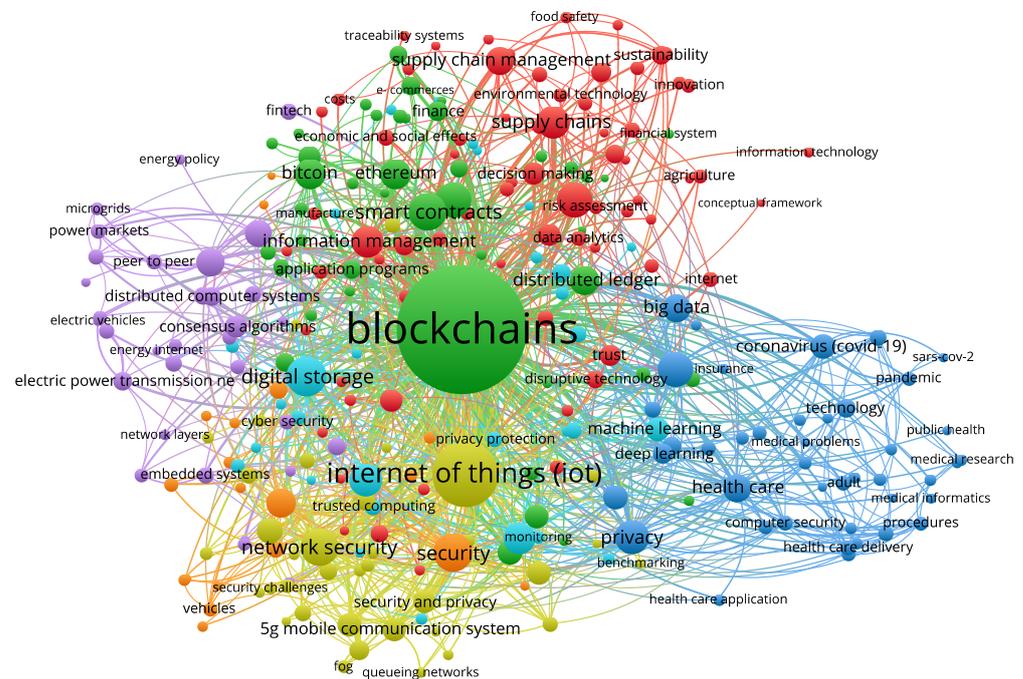


Figure 3. Network visualization.

Three clusters out of six, red, green, and blue ones, are more extensive than the rest.

The red area consists of topics related to blockchain technology, supply chain management, and sustainable development. The main element in chain management is data exchange for carrying out which of the latest developments in blockchains can be used; for instance, smart sensors can be helpful for the companies to gather information regarding the supply chain, and blockchain technology can be used for disruptive transformation for efficient and secure supply chains and network [4,33]. It is highlighted that areas such as smart contracts and information visibility can be achieved by the blockchain technology [34]. The authors of the article [35] insist on the importance of the awareness of the benefits that blockchain technology provides for efficiently managing supply chain operations and improving performance.

The green cluster stands for blockchains, smart contracts, electronic money, and Bitcoin and Ethereum. Bitcoin is known as an alternative to fiat currency. Blockchain technology was initially developed to provide the possibility of cross-border payments. Over the period after the introduction of Ethereum, blockchain technology became a computational network, including decentralized applications, smart contracts, and many more, with cryptocurrency and the token system as a basic unit for each platform [7]. Smart contracts run operations, such as some computations, providing access, storing information, and even reverting the financial transactions [7]. Ethereum runs smart contracts built over them while the Bitcoin blockchain does not support smart contracts [4]. Future trends in terms of Bitcoin include reviewing the possibility of deanonymization of bitcoin forward to prevent illegal acts, such as robbery and ransomware, and utilizing machine learning and deep learning techniques to estimate the price of bitcoin and classify the possible threats on the bitcoin network [33].

The blue cluster area focuses on artificial intelligence, big data, healthcare, and COVID-19. Healthcare is one of the most essential sectors, which blockchain affected significantly. Both artificial intelligence and blockchain jointly can provide a great number of implications in solving real-time contexts, while big data analytics adapting blockchain can focus on the quality of data [33,36]. The use of blockchain technology can allow any

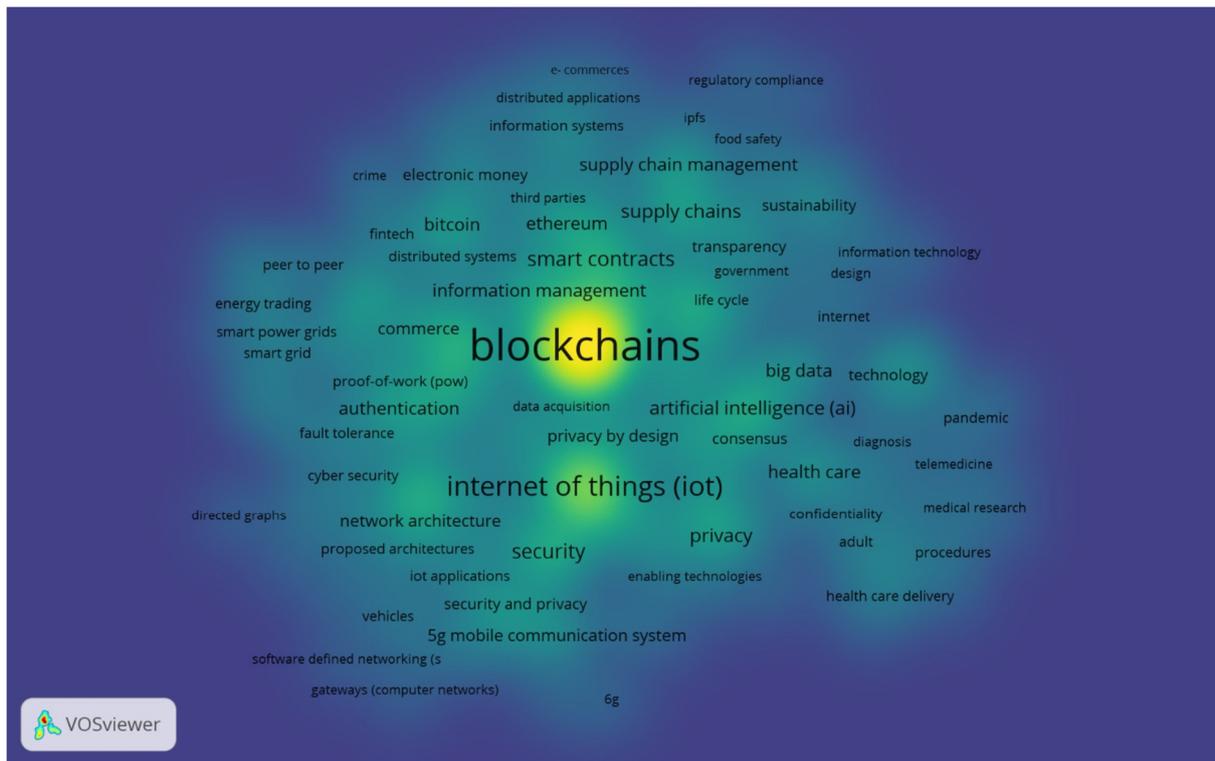


Figure 5. Density visualization.

Figure 4 shows trends related to the keyword over the researched period. The colors of the keyword nodes indicate the period of research.

The depth of research related to the topic area can be seen in Figure 5. The more concentrated the colors, the more researchers are conducting research related to the topic area. Blockchains, the Internet of things (IoT), smart contracts, supply chains, digital storage, and such characteristics as privacy, overall security, and network security are widely discussed topics.

Figure 6 represents the bibliographic coupling where countries are used as a unit of analysis. The study also set some limitations in the analysis. For instance, a minimum number of five documents of a country has been set as a limiting factor. The analysis singles out 62 countries and divides them into 8 clusters.

Table 6 presents the top 10 countries that contribute 60% of the total documents. As of 2021, China has the most published articles, followed by the USA, the United Kingdom, India, and Australia.

Table 6. Top ten countries with the highest number of publications.

Countries	Documents	Citations
Australia	102	3575
Canada	61	2434
China	467	7375
Germany	73	1523
India	167	3297
Italy	89	2923
Saudi Arabia	68	1358
South Korea	98	2975
United Kingdom	220	6960
United States	235	8709

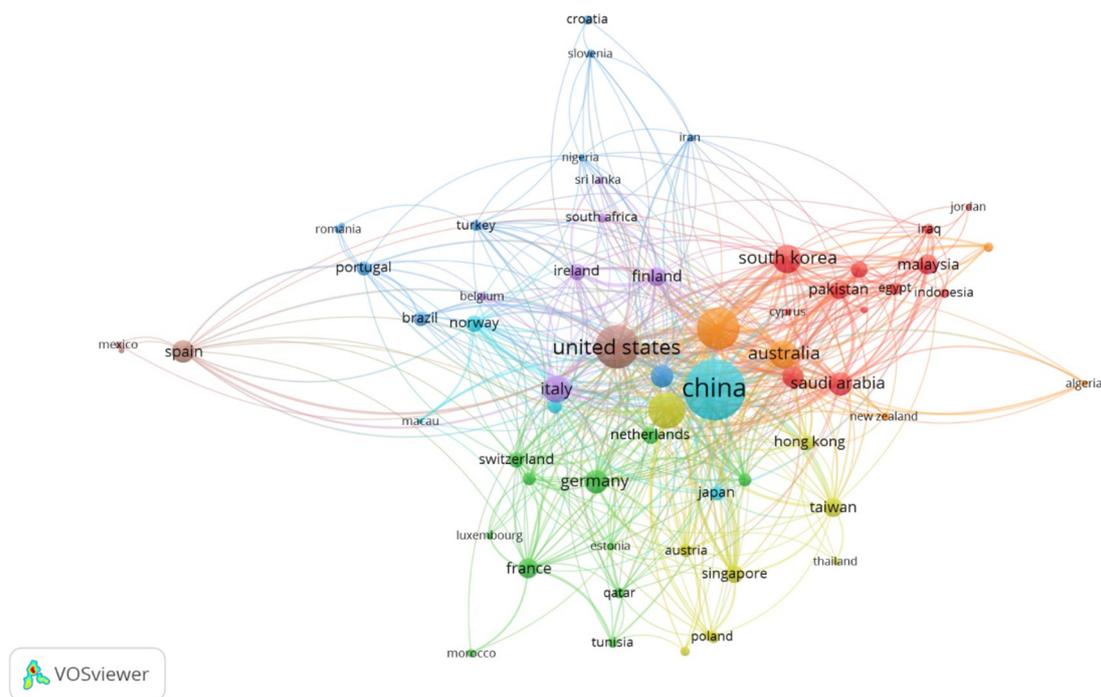


Figure 6. Countries analysis.

5. Discussion

According to Deloitte's 2021 Global Blockchain Survey, an impressive 97% of financial services industry (FSI) Pioneers see blockchain and digital assets as a way to gain a competitive advantage [37]. Other industries, such as FSI, are still in the process of estimating the potential implications of digital currencies. Nowadays, blockchain is already an integral and essential tool for creating new, advanced solutions. Previously, blockchain has been recognized as the base of cryptocurrency. However, leaders are embracing it as a robust solution that enables advancements in 3D printing, artificial intelligence, and digital security, to name a few.

It is indicated that the blockchain research has evolved from the decentralized transaction and smart contract, and future research will focus on the role of blockchain in financial risk management, organizational structure, and the digital transformation of society [38]. A Gartner Trend Insight Report [39] describes the period from 2022 through 2026 to be characterized by targeted large initiatives and many successful business models, while the next phase will see global, large-scale value-add. Gartner forecasts that by 2030, blockchain technologies will deliver USD 3 trillion of value worldwide, through a combination of cost reduction and revenue gains [39].

Therefore, blockchain technology is still examined from the viewpoint of opportunities and challenges. Blockchain technologies draw attention as they represent new ways to exchange value, represent digital assets, and embody trust mechanisms; however, it is still difficult to develop a phased plan of approach to observe different options to ensure successful enterprise production results. Although the development of blockchain is rapid, before blockchain is fully ready for widespread use, business challenges and technology gaps will remain to form the areas for future research. Bhadoria et al. [40] discussed the highly flexible environment to implement the blockchain technology in which powerful smart contracts can be created using Hyperledger Fabric and Ethereum providing the generic platform for many kinds of applications, such as e-governance, agriculture, and real estate. The authors claim that by studying their research, one can create their own methodology for blockchain without hopping onto preexisting knowledge on it. Swarnkar et al. [41] highlighted the importance of optimizing the performance of the blockchain system with proper implementation of security and privacy.

In recent years, a great deal of attention has been focused on the impact of blockchain on supply chains. The features of blockchain technology have a positive and substantial impact on the efficiency of supply chains [42].

Based on an investigation on whether, and to what extent, blockchain-based applications might affect firms' organizations, innovations, and strategies by 2030, Levis et al. [43] allocated two main features, the digitization of assets and the change in business models, to describe four main development scenarios of how the technology will facilitate financing, reduce costs, increase transparency and, in general, influence firms' business models. Most enterprise blockchain experiments are an attempt to improve today's business process. Hosseinpouli Mamaghani et al. [44] provided a framework to evaluate the blockchain technology implementation readiness that can help to prevent financial and non-financial losses before implementing the technology. There are several managerial insights in terms of traceability vs. sustainability in supply chains: (1) firms should consider investing in blockchain regardless of whether or not it is directly or indirectly related to distrust; (2) when the distrust is stochastic, firms can become either risk-takers when the probability of distrust is low, or risk-averse when the probability of distrust is medium or high. When firms face a high risk of distrust, blockchain is not sufficient to mitigate its negative consequences; (3) the preference for blockchain technology does not depend on the presence of a leader-follower structure in the supply chain relationships [45].

Paul et al. [46] investigated the impact of the announcement of the COVID-19 pandemic on the market value and trading volume of supply chain finance (SCF) firms. The authors found out that blockchain-enabled SCF firms are protected from valuation loss and volatility in trading due to higher research and development (R&D) and capital expenditures by firms.

Focus on further reducing the malicious data reporting in the intelligent IoT and further reducing the evaluation costs is one more point that requires further investigation. Li et al. [47] examined a BTS system that consists of a malicious deterrence scheme, strict penalty mechanism, and MA-DRL scheme, to deter the malicious data reporting in the intelligent IoT. To provide IoT security AI technologies have been widely embedded in crowdsourcing applications. The existing trust evaluation mechanisms raise doubts as they are not able to exclude co-cheating and neglect the conflicts with the privacy disclosure of participants. These issues are studied as well. For instance, Ren et al. [48] proposed a data collection scheme, Reinforcement Learning (PICRL), to maximize the utility and verify the effectiveness of the proposed PICRL through the extensive simulation experiments in their research.

6. Conclusions

The extraordinary speed at which infrastructure develops and the constant demand for flexibility are driving many industries to adapt to the new era of digital assets. Their participation in the age of digital assets becomes unavoidable, stimulating them to find their way in it.

This study uses a bibliometric analysis of "blockchain" literature. On the basis of the Scopus database, this research also examined scientific literature on the issue of blockchain from 2016 to 2021. Nevertheless, the research limitation of this study is that the data has been generated from Scopus. Therefore, the future study should utilize various data sources, such as the Web of Science or SpringerLink. Based on 1842 documents, the study overviews several aspects, such as changes in the number of publications over the research period, types of documents published, sources of publications, and referenced research using VOSviewer.

Figures 2–6 are mapping derivations based on the title, keywords, and abstract as well as a year of publication. It appears that blockchain is linked with various fields. However, it can be seen from the search for keyword blockchain, blockchain technology, and blockchain application and visualization mapping using VOSviewer that there are keywords that do

not have a network with other keywords and can be identified as potential topic areas related to the research in the future.

In this study, both the results of statistical analysis and co-cited articles, authors, and keywords have formed the basis for the formulation of the answers to the following research questions:

Q1: What is the allocation scheme of blockchain publications over recent years?

The number of published blockchain articles significantly dramatically since 2016. In 2018, the number of articles increased almost three times more compared to the previous one, and the number of publications is likely to continuously grow.

Q2: What are the key blockchain subjects based on the number of publications?

Blockchain-related research is more substantial in the field of Computer Science compared with other categories. Other major fields include Engineering, Materials Science, Physics and Astronomy, Social Sciences, Business, Management and Accounting, Mathematics, Environmental Science, Decision Sciences, and Energy.

Q3: Which are the main international contributing countries in blockchain research?

A total of 62 countries participated in the blockchain study during the research period. China is indicated to be the most influential country in the field of blockchain. It plays the leading role among all countries, with publications of 467 (29.56%), followed by the United States, the UK, India, Australia, and South Korea.

Q4: What are the research trends in blockchain?

The study priorities in blockchain-related research change by the observation period. Firstly, bitcoin was a major blockchain research field. It is followed by cryptocurrency and digital currency. Later blockchain and smart contracts were widely discussed in blockchain-related research. After that, distributed ledger and blockchain technology were under research. Hereafter, research will focus on the opportunities and challenges, the efficiency of blockchain, and possible solutions to the occurred issues.

This article employed bibliometrics analysis using VOSviewer to identify the main topic areas. As a result, three primary groupings from six clusters have been singled out.

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Conflicts of Interest: The authors declare no conflict of interest.

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