



Jus Corpus Law Journal

Open Access Law Journal – Copyright © 2023 – ISSN 2582-7820
Editor-in-Chief – Prof. (Dr.) Rhishikesh Dave; Publisher – Ayush Pandey

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Bibliometric Mapping of Blockchain-Based Smart Contracts

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Received 25 April 2023; Accepted 13 May 2023; Published 17 May 2023

Blockchain technology has gained researchers' attention in the last few years because of its essential features like peer-to-peer, sharing, and openness. These features have allowed the research community to develop faster, more efficient solutions. This evolving technology is used to record transactions, contracts, and agreements in a peer-to-peer distributed ledger. A smart contract is nothing but a deal that blockchain manages. The provisions of the buyer's and seller's deal are explicitly written into lines of text. These smart contracts operate in a variety of ways, used in many industries like banking, energy, education, e-government, and many more. As this concept has rapidly evolved in recent years, there is a need to do a detailed study of smart contracts' existing implementation in various domains, their benefits, and related issues. By understanding this need, researchers have conducted bibliometric research on blockchain in the context of smart contracts. For this study, researchers used the Scopus database for bibliometric analysis. The analysis is performed on the articles published in Scopus, indexed resources, and secondary documents (not indexed by Scopus but extracted from the reference list of Scopus). The analysis findings are helpful to the researcher in finding the scope for conducting further research in this domain and offering a substantial basis for their work on smart contracts.

Keywords: *sedition, law, legislation, ipc, constituent assembly.*

INTRODUCTION

In recent years, the world has witnessed many technological innovations that have had a high impact on several industries. Blockchain is one of them, which is the most disruptive technology and can continue for the next few years. Blockchain technology is also found to help develop smart cities¹ because of its decentralized and immutable distributed nature. In the blockchain, transactions are recorded digitally and linked together in the form of blocks. The consensus protocol is used for approving the transactions; these approved transactions are then added directly to the blockchain. Blockchain is also considered one of the most transparent modes of record-keeping.² These advantageous features of blockchain make it suitable for developing a smart contract.

Smart contracts can be simple or complex. These contracts are built as lines of code as per the agreement and stored on a blockchain. The code executes automatically when the conditions and terms in the contract are met. Innovative arrangements are beneficial in business collaborations, where all the participants in the agreement can be sure of the outcome without an intermediary's involvement.³ ⁴ Smart contracts are used for simple money transactions, registering ownership and property rights, agreements with suppliers and service providers, renewable energy, voting, land registrations, managing intelligent access, sustainability,

¹ Sonali Karale and Vishal Ranaware, 'Applications of Blockchain Technology in Smart City Development: A study' (2019) 8(11S) International Journal of Innovative Technology and Exploring Engineering

<<https://www.ijitee.org/wp-content/uploads/papers/v8i11S/K109309811S19.pdf>> accessed 24 April 2023

² Z Zheng et al., 'Blockchain challenges and opportunities: A survey' (2018) 1(4) International Journal Web Grid Service <<https://www.henrylab.net/wp-content/uploads/2017/10/blockchain.pdf>> accessed 24 April 2023

³ M Alharby et al., 'Blockchain-based Smart Contracts: A Systematic Mapping Study of Academic Research' (2018) International Conference on Cloud Computing, Big Data and Blockchain

<https://www.researchgate.net/publication/334426155_Blockchain-based_Smart_Contracts_A_Systematic_Mapping_Study_of_Academic_Research_2018> accessed 24 April 2023

⁴ Daniel Macrinici et al., 'Smart contract applications within blockchain technology: A systematic mapping study' (2018) 35(8) Telematics, and Informatics

<https://www.researchgate.net/publication/328128951_Smart_Contract_Applications_within_Blockchain_Technology_A_Systematic_Mapping_Study> accessed 24 April 2023

scalability, etc.^{5 6} To understand innovative contract development's current research scope,^{7 8} the researcher needs to identify the top funding agencies, countries, subject areas, and leading researchers in this domain. To address these questions, researchers have conducted a bibliometric analysis of relevant papers related to smart contracts. The researchers chose the Scopus database for further research.

Scopus is Elsevier's abstract and citation database, launched in 2004.⁹ It is one of the prevalent databases used by researchers to get excellent-quality research articles across all disciplines. Scopus is the largest peer-reviewed literature database, including conference proceedings, journals, books, etc.¹⁰ Scopus-indexed essays, conference papers, review papers, and secondary documents on smart contracts from 2016 to March 2021 were used to perform the bibliometric study and are presented in this paper. The collected papers are analyzed against six research questions, and findings are noted. These findings are helpful to both fresh and experienced researchers when they initiate research on smart contracts.

Our research paper is organized so that the method used for data collection and interpretation is covered in Section II. The findings of the analysis are presented in Section III. Section IV concludes with a summary of the results.

BIBLIOMETRIC DATA COLLECTION AND METHODOLOGY

After receiving the relevant papers based on our search, the researchers performed a detailed analysis by considering the questions that were raised in the earlier section.

⁵ Sonali Karale and Vishal Ranaware (n 1)

⁶ Esther Salmerón-Manzano and Francisco Manzano-Agugliaro, 'The Role of Smart Contracts in Sustainability: Worldwide Research Trends' (2019) 11 Sustainability <<https://www.mdpi.com/2071-1050/11/11/3049>> accessed 26 April 2023

⁷ Tatiana Cutts, 'Smart Contracts and Consumers' (2019) 122(2) West Virginia Law Review <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3354272> accessed 26 April 2023

⁸ Prince Arora et al., 'Designing Optimized Scalable Framework for Block chain Based Applications' International Journal of Emerging Technologies and Innovative Research <<https://www.jetir.org/view?paper=JETIRDQ06017>> accessed 26 April 2023

⁹ Jeroen Baas, 'Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies' (2020) Quantitative Science Studies <http://dx.doi.org/10.1162/qss_a_00019> accessed 26 April 2023

¹⁰ A V Kulkarni et al., 'Comparisons of Citations in Web of Science, Scopus, and Google Scholar for Articles Published in General Medical Journals' (2009) <<https://doi.org/10.1001/jama.2009.1307>> accessed 26 April 2023

In recent years, many papers have been published on smart contracts and documents like conference papers, articles, secondary documents, etc. related to smart contracts. The study indicates that researchers are now exploring the blockchain’s application in the development and use of smart contracts

Year	No. of Documents Published
2021	32
2020	171
2019	124
2018	71
2017	14
2016	7

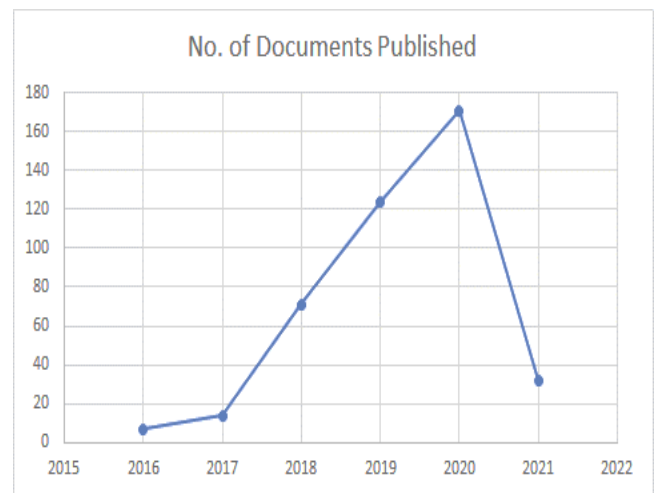


Fig. 1: Illustration of the total number of publications year-

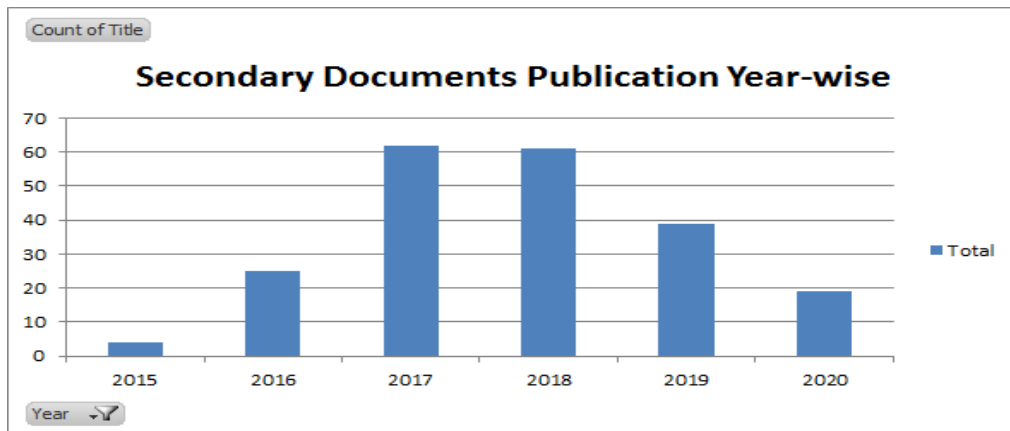


Fig. 1.1: Illustration of the total number of Secondary documents publications year-wise

ANALYSIS AND INTERPRETATION OF RESEARCH PUBLICATIONS

Articles are analyzed from 2016 to March 2021, indexed in Scopus, and extracted from the Scopus document reference list. Fig. 1 shows the upward graph, which indicates the increasing interest in and significance of blockchain technology in innovative smart contract development or management. The yearly volume of blockchain publications is shown in the above graphs, which helps predict future research interests and scope. The first seven papers were published in 2016, and by 2020, 171 research articles had been published. There was a total of 124 and 71 articles released in 2019 and 2018, respectively. If you see a discrepancy, it means that further testing was done in 2020.

Document Type	No. of Documents
Conference Paper	254
Article	136
Review	15
Book Chapter	11

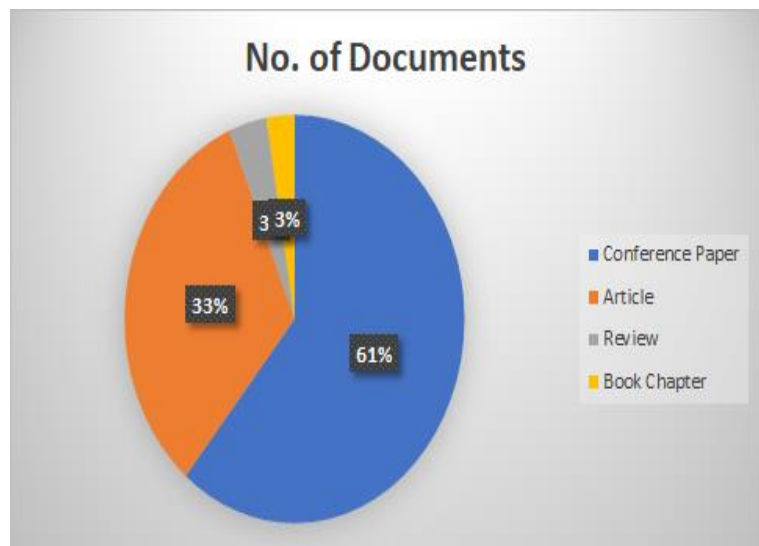


Fig. 2: Number of publications based on the type of document

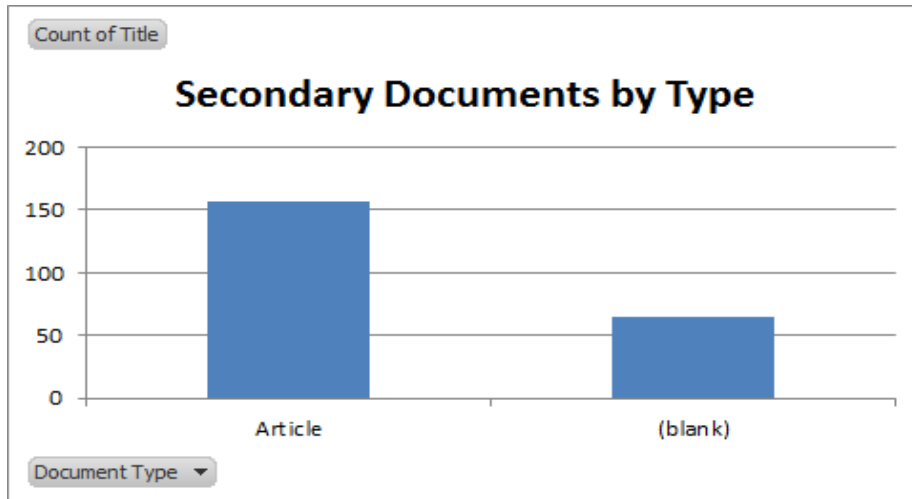


Fig. 2.1: Number of secondary documents publications based on the type of document

The above chart shows the document type-wise publications. The types are conference papers, articles, reviews, conference reviews, book chapters, etc. Out of 419 document results, 254 are conference papers, and 136 are articles that will help the researcher decide the mode of publication. Out of 222 secondary documents, 154 are articles. The researchers can say that there is massive scope for publication in conferences, followed by commentaries.

Computer science is the subject area primarily investigated in a smart contract, with a 37.7% contribution.

Documents by subject area

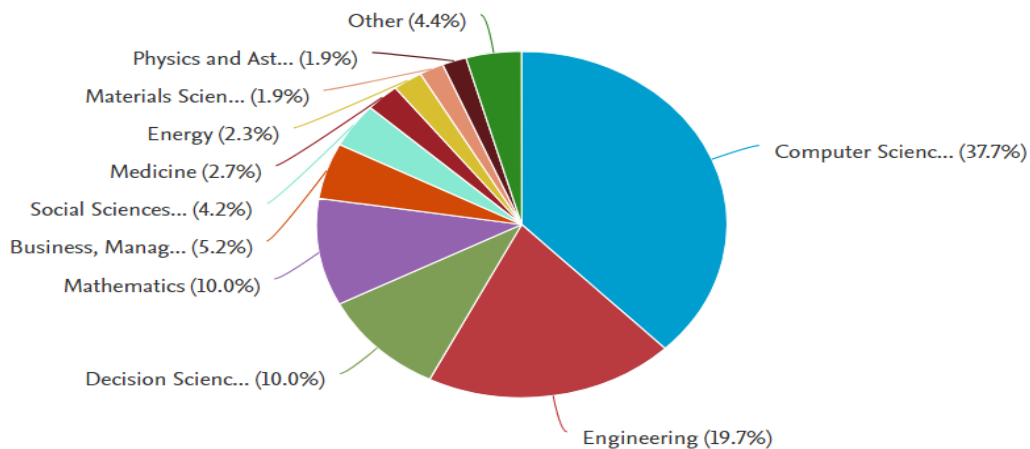


Fig. 3: Number of publications based on the subject area

Based on the total number of blockchain papers published in each subject area, the chart above ranks the various subject areas. As shown in Fig. 3, Computer Science has the largest number of blockchain papers (354, or 37.7%), followed by Engineering (185, or 19.7%), and Decision Science (94, or 10.0%). It is essential to notice that the imaginative contract scope is not limited to computer science or engineering; it also covers mathematics, decision sciences, social sciences, energy, business, management, accounting, and medicine fields.

The below table indicates the list of the most cited papers on blockchain in a smart contract.

Sr. No.	Title of the Article	Year of Publication	Total No. of Citations (till 10.03.2021)
1	Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts. ¹¹	2016	794
2	Understanding modern banking ledgers through blockchain technologies: Future of transaction processing and smart contracts on the internet of money. ¹²	2016	192
3	Healthcare Blockchain System Using Smart Contracts for Secure Automated Remote Patient Monitoring.	2018	160

¹¹ Ahmed Kosba et al., 'Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts' (2016) IEEE Symposium on Security and Privacy <<https://ieeexplore.ieee.org/document/7546538>> accessed 22 April 2023

¹² Gareth Peters and Efstathios Panayi, 'Understanding Modern Banking Ledgers Through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money' in Handbook of Blockchain, Digital Finance, and Inclusion' (2018) 1 <http://dx.doi.org/10.1007/978-3-319-42448-4_13> accessed 22 April 2023

4	Blockchain contract: Securing a blockchain applied to smart contracts. ¹³	2016	125
5	Blockchain and smart contracts for insurance: Is the technology mature enough?	2018	120
6	Blockchain Disruption and Smart Contracts	2019	103
7	Blockchain-Enabled Smart Contracts: Architecture, Applications, and Future Trends. ¹⁴	2019	102
8	Smart contract applications within blockchain technology: A systematic mapping study. ¹⁵	2018	87
9	Improving data transparency in clinical trials using blockchain smart contracts. ¹⁶	2016	75

¹³ Hiroki Watanabe 'Blockchain contract: Securing a blockchain applied to smart contracts' (2016) IEEE International Conference on Consumer Electronics <<https://ieeexplore.ieee.org/document/7430693>> accessed 22 April 2023

¹⁴ Shuai Wang et al., 'Blockchain-Enabled Smart Contracts: Architecture, Applications, and Future Trends' (2019) 49(11) IEEE Transactions on Systems, Man, and Cybernetics: Systems <<https://ieeexplore.ieee.org/document/8643084>> accessed 22 April 2023

¹⁵ Daniel Macrinici et al., 'Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study' (2018) 35 Telematics and Informatics <<https://doi.org/10.1016/j.tele.2018.10.004>> accessed 22 April 2023

¹⁶ Timothy Nugent et al., 'Improving data transparency in clinical trials using blockchain smart contracts' (2016) <<https://doi.org/10.12688/f1000research.9756.1>> accessed 22 April 2023

10	Disrupting governance with blockchains and smart contracts. ¹⁷	2017	69
11	Evaluation of logic-based smart contracts for blockchain systems. ¹⁸	2016	69
12	A decentralized sharing app running a smart contract on the Ethereum blockchain. ¹⁹	2016	66
13	Supply chain re-engineering using blockchain technology: A case of smart contract-based tracking process. ²⁰	2019	58

Table 1: Tabular representation of Blockchain-based papers with publication and citation count during 2016-2021

Out of the 419 resulting papers, the researchers chose the top 13 cited articles. The most preferred paper is “Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts”, which is a good source of information for the researcher and has been cited 794 times.²¹ Hawk is a decentralized smart contract framework introduced in this paper that

¹⁷ Shermin Voshmgir, ‘Disrupting Governance with Blockchains and Smart Contracts’ (2017) 26 Strategic Change <<https://doi.org/10.1002/jsc.2150>> accessed 22 April 2023

¹⁸ Florian Idelberger et al., ‘Evaluation of Logic-Based Smart Contracts for Blockchain Systems’ <https://www.researchgate.net/publication/303679677_Evaluation_of_Logic-Based_Smart_Contracts_for_Blockchain_Systems> accessed 22 April 2023

¹⁹ Andreas Bogner et al., ‘A Decentralised Sharing App running a Smart Contract on the Ethereum Blockchain’ 21st International Conference on Computer-Supported Cooperative Work and Social Computing <https://www.researchgate.net/publication/310396688_A_Decentralised_Sharing_App_running_a_Smart_Contract_on_the_Ethereum_Blockchain> accessed 22 April 2023

²⁰ Shuchih Ernest Chang et al., ‘Supply Chain Re-engineering Using Blockchain Technology: A Case of Smart Contract Based Tracking Process’ (2019) 144 Technological Forecasting and Social Change <<https://ideas.repec.org/a/eee/tefoso/v144y2019icp1-11.html>> accessed 22 April 2023

²¹ Ahmed Kosba (n 11)

preserves transactional privacy while not storing financial transactions on the blockchain. The majority of citations come from conference papers, accompanied by journals.

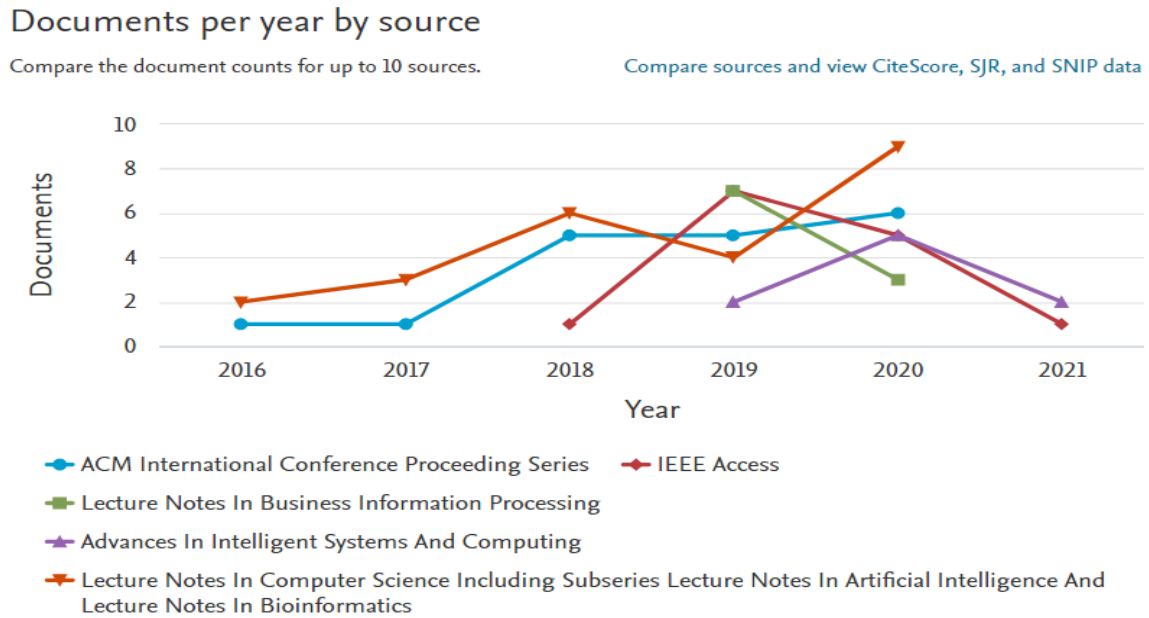


Fig. 4: Documents published per year by source

Fig. 4 shows the year-wise publication by source. It includes IEEE Access, the ACM International Conference Proceeding Series, Communications in Computer and Information Science, and lecture notes. It can help the researcher choose the source for the publication. IEEE and ACM International Conference Proceeding Series are the most preferred sources other than lecture notes.

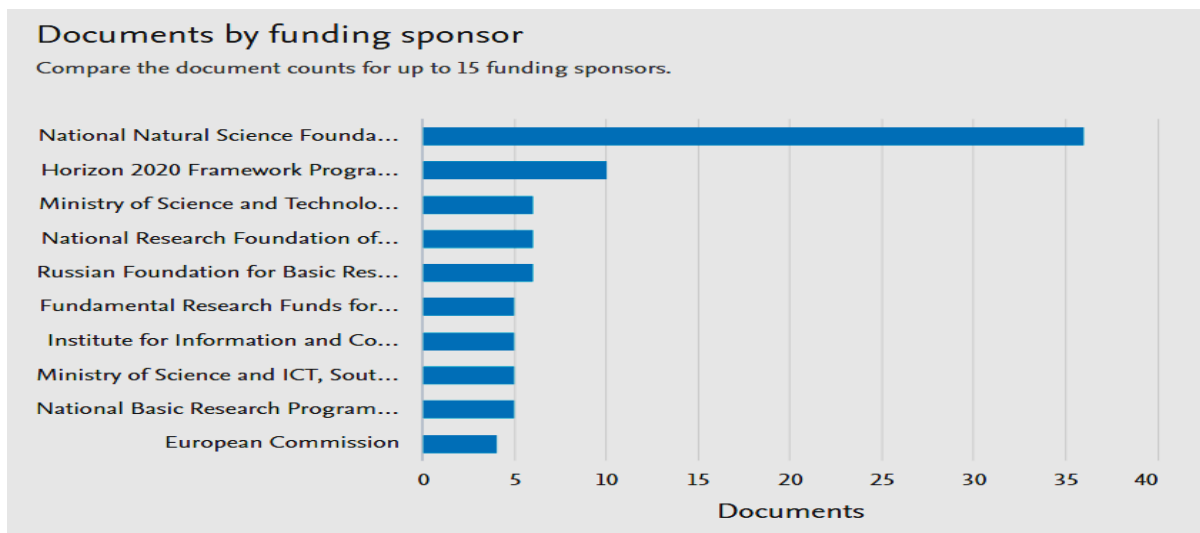


Fig. 5: Total number of documents funded by various sponsors

The above chart shows the number of documents that various funding sponsors fund. The National Natural Science Foundation of China sponsors 36 papers out of 419, followed by the Horizon 2020 Framework Programme with 10. This analysis helps the researcher find the sponsor for their research and contact them for funding.

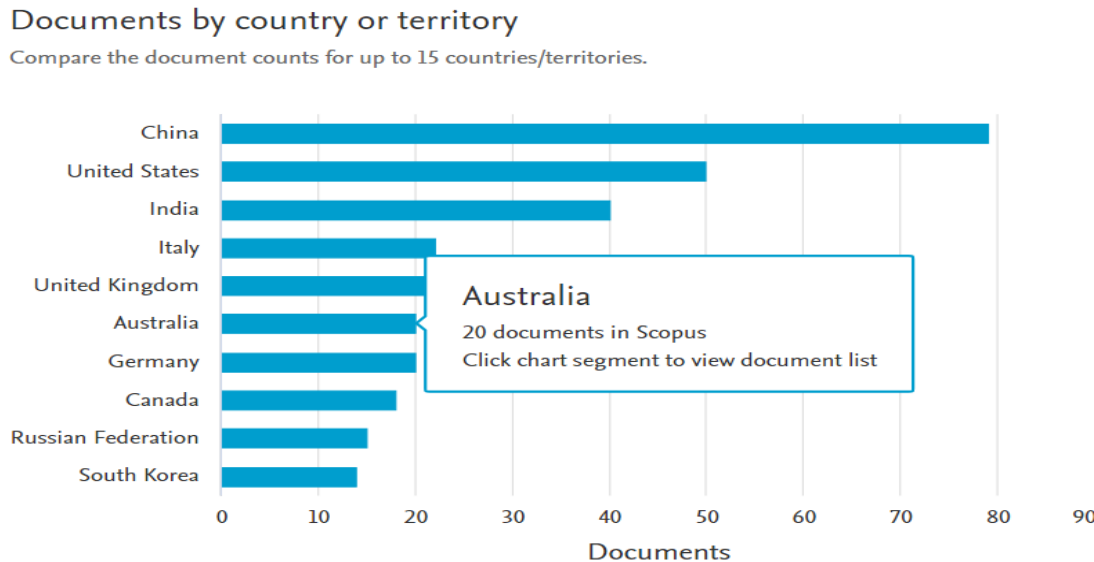


Fig. 6: Number of documents country-wise (source: www.scopus.com, accessed on 10.03.2021)

Almost all countries are actively participating in conducting research on blockchain technology. From the above analysis, the researchers can say that China is one of the top countries in publishing blockchain research in the smart contract industry, which is now becoming smarter since almost every sector is now moving towards the adaptation of blockchain technology.²² Out of 419, China has published 79 papers, followed by the United States with 50 articles. India is in 3rd place with 40 items. The above analytical data would help the researcher determine the scope of publication in the respective countries.

²² Ajay Shriram Kushwaha et al., 'Smarter Implementation of Blockchain for Smart Contracts' (2018) 12(10) International Journal of Computer Engineering and Applications
https://www.researchgate.net/publication/331974133_SMARTER_IMPLEMENTATION_OF_BLOCKCHAIN_FOR_SMART_CONTRACTS accessed 22 April 2023

CONCLUSION AND SCOPE FOR FURTHER RESEARCH

This research offered a thorough review of the Scopus bibliometric analysis focused on the smart contract database. According to our quest, 419 papers and 222 secondary papers published from 2016 to March 2021 have been found. The bibliometric research shows a broad range of further investigations in this area. The researchers are forecasting that many publications from the last couple of years will be presented, demonstrating the increasing developments that will continue. Smart contracts are not found in computer science or the engineering sector. Blockchain modeling, cryptography, and smart contract security are the most widely alluded to in peer-reviewed analyses on blockchain since they have been focused on authoritative publications. Our review will allow researchers in blockchain technology to concentrate on the right path when contemplating smart contract deployment and creative solutions.