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A Decade in Blockchain: A Bibliometric Reflection on the Growth and Interdisciplinary Reach of a Disruptive Technology

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ABSTRACT

This study seeks to deliver a comprehensive bibliometric analysis of blockchain research undertaken from 2013 to 2023. It seeks to map the field's evolution, highlight emerging trends, and identify key contributors and thematic areas. Understanding these aspects is crucial for guiding future research and policymaking in the rapidly growing domain of blockchain technology. The study utilises a systematic bibliometric analysis approach and the Scopus database was used

for collecting data. The analysis includes keyword trends, citation patterns, author productivity, and network analysis. The results reveal significant expansion and diversification in blockchain research, with 13,369 publications and 52,009 contributing authors. Key metrics include a total citation count of 266,483 and an average of 19.93 citations per paper, underscoring the field's scholarly impact. The study identifies core research themes such as smart contracts, security, IoT integration, and emerging topics like AI and sustainability. The findings highlight the interdisciplinary nature of blockchain research and its global distribution, with notable contributions from China and the United States. The study's reliance on selected databases and predefined keywords may exclude relevant grey literature and industry reports. Future research should integrate these sources for a more complete view. This study provides a panoramic view of blockchain research, offering valuable insights into its development, current state, and future directions. Identifying key trends, influential contributors, and emerging themes contributes to the academic discourse and supports strategic planning for researchers, practitioners, and policymakers engaged in blockchain technology.

Keywords: Blockchain; Bibliometric Analysis; Publication Trends; Research Evolution; Co-occurrence Networks; Thematic Mapping.

INTRODUCTION

The landscape of publications has increased significantly since Bitcoin's inception in 2008, extending beyond cryptocurrencies to a variety of industries (Javaid et al., 2021; Laroiya et al., 2020; Rakhra et al., 2021). This expansion reflects growing interest in blockchain's decentralised, secure, and transparent systems (Abd Wahab et al., 2023; Bhutta et al., 2021; Tapscott Don & Tapscott Alex, 2016). Blockchain research has diversified to encompass various sectors, including government, supply chains, health, finance, economics, and energy (Abou Jaoude & George Saade, 2019; Alam et al., 2021; Baiod et al., 2021). Efforts also focus on addressing scalability, interoperability, and sustainability challenges (Tripathi et al., 2023), with interdisciplinary collaboration and regulatory frameworks becoming increasingly important (Düdder et al., 2021; Rodríguez Bolívar et al., 2021). For this reason understanding blockchain publications is vital for guiding policy and industry practices. Recent

research emphasises the rising use of blockchain across industries. Jorika and Medishetty (2023) note its appeal because it has certain features like immutability, enhanced security, and transparency. Tseng et al. (2023) discovered that corporate assets and research and development (R&D) drive blockchain adoption, with larger US firms leading the way. Blockchain enhances innovation and performance, particularly in the US, surpassing Chinese counterparts. These findings contribute significantly to the literature on blockchain's impact.

Despite the considerable and swift expansion of literature concerning blockchain, a notable gap persists in comprehensive studies explicitly devoted to discerning the trends, patterns, and research deficiencies within this contemporary domain. This paper seeks to produce a thorough bibliometric analysis of the blockchain literature, methodically delineating the scholarly terrain, elucidating the field's evolution, pinpointing research frontiers, and uncovering knowledge clusters and networks. The importance of this investigation extends beyond simply documenting the historical progression of blockchain research; it also lies in elucidating the principal influences and research horizons, thereby facilitating forthcoming scholarly pursuits and industry shifts toward sustainability:

Specifically, this study endeavours to answer the following research questions:

1. What is the current landscape of blockchain research over the past decade, as reflected in the existing literature?
2. Who are the most productive contributors, including authors, institutions, and countries, driving the advancement of blockchain research?
3. Which source titles serve as the primary platforms for disseminating high-impact blockchain research?
4. What core research themes define the evolution and growth of blockchain technology, and how do these themes suggest directions for future research in the field?

The comprehensive scope of this study offers an opportunity to gain a thorough understanding of the extent of blockchain research.

Employing bibliometric and network analysis methodologies, it constructs a nuanced comprehension of the scholarly landscape, principal themes, and clusters within this domain. The insights derived from this analysis are crucial for developing more efficient and sustainable practices, ensuring alignment with the current needs of Industry 4.0. This study endeavours to delineate the complex terrain of blockchain and it does this through a systematic examination. Here, the aim is to provide a cohesive overview of the field's historical and contemporary status while laying the groundwork for advances in the field.

LITERATURE REVIEW

Blockchain Technology

Blockchain technology has become considerably popular in recent years since the invention of Bitcoin, a digital currency, in 2008 (Baviskar et al., 2021) and continues to receive a lot of interest from various researchers and practitioners to this day. Blockchain functions as a decentralised ledger, securely recording all transactions conducted over a peer-to-peer network in a transparent and verifiable manner. The primary benefit of blockchain, compared to current technologies, lies in its ability to facilitate secure transactions over the Internet between two parties without any interference from intermediaries. Eliminating the involvement of a third party can lower processing costs while enhancing the security and efficiency of transactions. Due to the considerable number of benefits that blockchain can bring to every industry, its significance level has been compared to the role of the Internet in the early 1990s (Folkerts & Koehorst, 1997).

Although blockchain technology holds much promise, it faces significant challenges in scalability, security, privacy, and usability. Scalability issues result in slow transaction processing and higher costs (Patel, 2024). Meanwhile, security risks, such as network attacks and privacy concerns from data transparency, require strong encryption and control measures (Krishnaraj Rao et al., 2022; Nair et al., 2022). Additionally, the complexity of the technology discourages user adoption. Despite these issues, ongoing research aims to improve blockchain's security and efficiency.

With these issues in mind, blockchain is revolutionising various industries, ranging from finance (Kayikci et al., 2022; Dorling, 2021), Internet of Things (IoT) (Madichie & Yamoah, 2017; Sarpong, 2014), healthcare (Costa et al., 2012; Boffey & Connolly, 2017), reputation systems (Guido et al., 2020; Hayati & Nugraha, 2018), and supply chain management (Madumidha et al., 2019; Wang et al., 2019). It is worth noting here that global expenditure on blockchain solutions amounted to US$6.6 billion in 2021, with forecasts indicating a steady increase in spending over the following years. By 2024, expenditures are expected to soar to nearly US$19 billion (Statista, 2023).

Previous Studies on Bibliometric Analysis and Blockchain

Analysing the collective findings of past studies on blockchain bibliometric analysis reveals various objectives, each contributing to our understanding of the academic discourse on blockchain technology. Examining these studies together allows us to identify overarching trends, common gaps, and areas ripe for further investigation. Firdaus et al. (2019) and Bukhari (2020) utilised the Scopus database to analyse keyword trends, citation patterns, and author productivity, covering periods from 2013 to 2018 and 2008 to 2019, respectively. These studies provided foundational insights into early blockchain research and author productivity trends. Kuzior and Sira (2022) extended the temporal scope to 2021, offering a more up-to-date analysis using Scopus data. They included keyword, topic, network, and country analyses, thus providing a broader overview of the research landscape. Another study conducted by Pratibha and Kaur (2024) involved a bibliometric analysis of blockchain technology research from 2016-2023 using the Scopus database, highlighting key developments and emerging areas of interest. However, the study overlooks the emerging niche areas that could offer valuable insights for future research. Other studies, such as those by Zeng et al. (2018) and López-Sorribes et al. (2023), utilised different databases and focused on specific aspects like leading researchers, institutions, and trending topics. Zeng et al. (2018) used EI and CNKI databases for their analysis from 2011 to 2017, which now appears outdated, given the rapid evolution in blockchain technology. López-Sorribes et al. (2023) analysed a substantial ACM, IEEE, Springer, and Elsevier dataset covering the period 2016 to 2022. Judijanto and Gamaliel (2024) used databases like PubMed, IEEE Xplore, ACM Digital Library, Scopus, and Web of Science from 2016 to 2024.

Guo et al. (2021) and Khurana and Sharma (2024) employed the Web of Science (WoS) database for their analyses. Guo et al. (2021) examined publications from 2013 to 2020 and identified key research areas but called for deeper insights into specific topics such as security and blockchain standards. Khurana and Sharma (2024) covered data from 2014 to 2020. These studies highlight the limitations of relying solely on WoS and the need to integrate data from multiple sources for a more comprehensive bibliometric analysis. The studies by Dabbagh et al. (2019) and Günek and Yurttakal (2022) further illustrate the constraints of single-database reliance. Both used WoS data but acknowledged excluding significant articles from other prominent databases, emphasising the necessity for a more inclusive approach in future bibliometric research.

In light of these observations, this study aims to fill these gaps by conducting a bibliometric analysis using the Scopus database, leveraging its extensive and diverse coverage to provide a more up-to-date and comprehensive view of blockchain research. By extending the analysis to the most recent publications and integrating diverse aspects such as keyword trends, citation patterns, author productivity, network analysis, and geographic distribution, this research will offer a nuanced understanding of blockchain research's current state and evolution. This approach will not only update and expand upon the findings of previous studies but also address the identified gaps, particularly in capturing the latest advances and providing a holistic view of the blockchain research landscape.

METHODS

This section highlights the systematic approach to ensure a comprehensive bibliometric analysis of the selected literature. The chosen methodology was meticulously designed to capture relevant research on blockchain technology, leveraging a structured search strategy to encompass the breadth and depth of academic and industry publications.

Search Strategy

In the presented study, the methodological underpinnings for conducting a bibliometric analysis were drawn from a rigorously

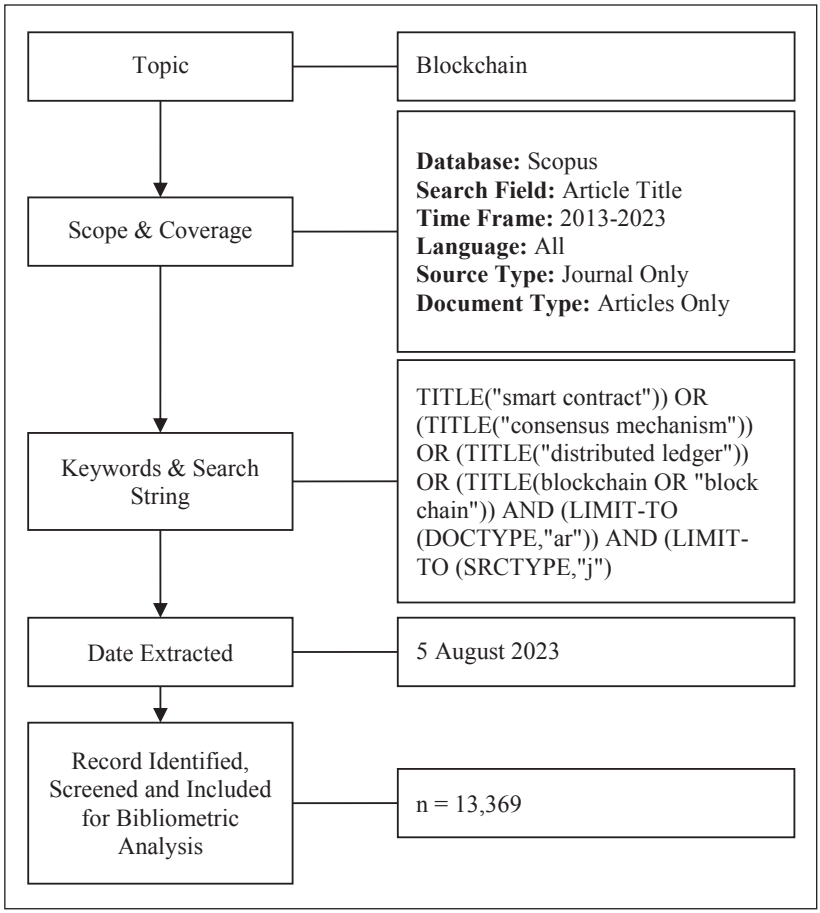
structured literature search strategy, as depicted in the provided flow diagram in Figure 1. This strategy commenced with identifying the research topic focused on blockchain. The research strategy began by pinpointing blockchain as the subject of interest, leading to Scopus being selected for the literature search. Introduced by Elsevier in 2004, Scopus stands out as a premier search and discovery platform, boasting a comprehensive database of peer-reviewed abstracts and citations (Punj et al., 2023; Baas et al., 2020; Schotten et al., 2017). Initially comprising 27 million records dating from 1966 to 2004, it has grown to incorporate over 76 million records from 1788 to 2019, establishing itself as one of the most extensive bibliographic and citation databases currently available. It ensures access to a vast repository of high-quality scholarly articles for the research (Baas et al., 2020).

The temporal scope of the search covers the years 2013 to 2023. After the introduction of Bitcoin in 2008 (Nakamoto, 2008) as the world's first decentralised cryptocurrency, the subsequent years saw the technology underlying Bitcoin—blockchain—gain recognition for its potential beyond digital currencies. By 2013, the broader implications and applications of blockchain technology began to be explored and documented more extensively in academic and industry research (Dabbagh et al., 2019), making it a pivotal year for starting a comprehensive analysis to capture the technology's emerging trends, developments, and its expanding impact across various sectors.

The search fields were confined to the article title to ensure that the retrieved documents were centrally concerned with blockchain as a primary subject. The search was further refined by limiting the document type to journal articles only, excluding conference papers, reviews, and other types of publications, which aligns with the study's focus on high-quality and impactful research. The terms employed in the search string were carefully chosen to encompass the core aspects of blockchain technology: "smart contract," "consensus mechanism," "distributed ledger," and "blockchain OR block chain." The strategic use of Boolean operators was essential in this process—the "OR" operator broadened the search to include various terminologies associated with blockchain. In contrast, the "AND" operator functioned to refine the results to articles most pertinent to the intersection of these key concepts.

Figure 1

Flow Diagram of the Search Strategy. Source: Punj et al. (2023), Moher et al. (2009)



Data Cleaning, Harmonisation, and Tools

Before proceeding with the bibliometric analysis, it is crucial to clean and harmonise the dataset to ensure the output's accuracy and reliability. Key issues addressed during this phase included standardising author names to consolidate variations and merge multiple Scopus profiles for the same authors. Additionally, standardising institution names was necessary to resolve inconsistencies. To achieve this, we utilised biblioMagika (Ahmi, 2024), which effectively standardised author

names, affiliations, and countries. Furthermore, OpenRefine (Ahmi, 2023) ensured that the data was uniformly processed, enhancing the overall dataset quality. OpenRefine also facilitated the standardisation of author and index keywords, ensuring that the results produced later would be precise and accurate. In addition to aiding data cleaning and harmonisation, biblioMagika played a pivotal role in generating various metrics used in this paper. For science mapping purposes, we utilised Biblioshiny by Aria and Cuccurullo (2017), which made possible comprehensive and insightful visualisations of the bibliometric data.

RESULTS

This section is dedicated to results. A thorough and comprehensive analysis of the blockchain research landscape has been conducted, addressing the research questions (RQs) outlined in the introductory section. This endeavour aims to provide a deep and insightful understanding of the field. By carefully aligning our investigative efforts with the previously identified research questions, we aspire to offer a nuanced and complex exploration of the blockchain research domain. It, in turn, is anticipated to yield substantial insights and contributions beneficial to academics, practitioners, and policymakers engaged in this study area.

Current Landscape

The current landscape of blockchain research from 2013 to 2023 reveals substantial growth and diversity, with 13,369 publications by 52,009 authors, reflecting the field's interdisciplinary and collaborative nature (see Table 1). Key metrics, including a total citation count of 266,483 and an average of 19.93 citations per paper, underscore the significant scholarly impact of blockchain studies. The robust h-index of 196 and g-index of 297 further attest to the high quality and influence of the research, indicating substantial foundational work that consistently garners academic attention. The cited papers, numbering 10,237, with an average of 26.03 citations each, highlight blockchain research's relevance and academic currency. Annual citation engagement at 24,225.73 and a citation per author metric of 5.12 suggest that scholarly recognition is broadly distributed. The h-core citation sums

of 119,976 and the h-index of 196 illustrate the enduring relevance of the research outputs. At the same time, the g-index of 297 emphasises the profound impact of the most cited works within the corpus. These statistics collectively present a detailed picture of blockchain research's established and growing presence in scientific inquiry.

Table 1

Main Information. Source: Generated by the Authors Using biblioMagika® (Ahmi, 2024)

Main Information	Data
Publication Years	2013 - 2023
Total Publications	13369
Citable Year	11
Number of Contributing Authors	52009
Number of Cited Papers	10237
Total Citations	266,483
Citation per Paper	19.93
Citation per Cited Paper	26.03
Citation per Year	24225.73
Citation per Author	5.12
Author per Paper	3.89
Citation sums within h-Core	119,976
h-index	196
g-index	297
m-index	17.82

Most Productive Authors

In addressing RQ2, our detailed bibliometric analysis of prolific authors in the blockchain domain illuminates these researchers' substantial influence on advancing blockchain technology. Table 2 provides a detailed bibliometric analysis of the most productive authors in the field of blockchain research. The table not only lists the total number of publications (TP) for each author but also provides insights into the impact of these publications through the number of cited publications (NCP), total citations (TC), and average citations per publication (C/P). Furthermore, it includes the average citations per cited publication (C/CP) and the h-index, g-index, and m-index, which indicate the authors' influence and quality of research within

the academic community. The leading author in the total number of publications is Neeraj Kumar from Shri Ramswaroop Memorial University in India, with 76 publications, which have amassed 3,744 citations. It reflects a high level of productivity and suggests that Kumar's work has been influential in the field, as indicated by the high h-index of 33 and a g-index of 61. These indices demonstrate that many of Kumar's publications have been cited multiple times, signifying his prominence in blockchain research.

Following closely is Khaled Salah from Khalifa University of Science and Technology in the United Arab Emirates, with 74 publications and an even higher number of total citations at 5,069. Salah's average citations per publication stand at 68.50, which is higher than Kumar's, indicating that Salah's work has, on average, attracted more attention per article. His equal h-index to Kumar's suggests a comparable level of recognition among peers, while a higher g-index of 71 points to a collection of highly cited papers within his publication set. Sudeep Tanwar from Nirma University, also in India, has contributed 70 publications with 2,958 citations. He maintains an influential presence in the field, as evidenced by his h-index of 25 and g-index of 54. The C/P and C/CP for Tanwar indicate a robust citation rate, further confirming the impact of his research contributions.

The data also reveals geographical diversity among the top contributors, with authors from universities across the United States, China, the United Arab Emirates, and other global institutions, illustrating blockchain research's international interest and collaborative nature. An interesting observation from the table is the variance in the average citations per publication and cited publication across authors. This could be attributed to the authors' varying research focuses within the blockchain, the timeliness of their research topics, and their different collaborative networks. Moreover, the h-index across these authors ranges from 14 to 33, reflecting a solid acknowledgement by the academic community. The g-index, which extends the assessment to the most cited papers, further emphasises the depth of their scholarly impact. What is also noteworthy is considering the m-index, which provides an annualised measure of an author's cumulative impact. This index varies among the authors, potentially indicating the durations over which authors have been active and the rates at which they have achieved their citations.

Table 2

Most Productive Authors. Source: Generated by the Authors Using biblioMagika® (Ahmi, 2024)

Author's Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Kumar, Neeraj	Shri Ramswaroop Memorial University	India	76	70	3744	49.26	53.49	33	61	6.60
Salah, Khaled	Khalifa University of Science and Technology	United Arab Emirates	74	67	5069	68.50	75.66	33	71	5.50
Tanwar, Sudeep	Nirma University	India	70	63	2958	42.26	46.95	25	54	6.25
Choo, Kim-Kwang Raymond	University of Texas at San Antonio	United States	70	67	3627	51.81	54.13	28	60	4.67
Zhu, Liehuang	Beijing Institute of Technology	China	59	46	2779	47.10	60.41	20	52	3.33
Jayaraman, Raja	Khalifa University of Science and Technology	United Arab Emirates	54	48	1779	32.94	37.06	23	42	4.60
He, De-Biao	Wuhan University	China	54	44	1493	27.65	33.93	17	38	2.43
Guizani, Mohsen	Mohamed Bin Zayed University of Artificial Intelligence	United Arab Emirates	51	47	3515	68.92	74.79	25	51	3.57
Zheng, Zibin	Sun Yat-Sen University	China	38	33	4433	116.66	134.33	21	38	3.50
Park, Jong Hyuk	Seoul National University of Science and Technology	South Korea	38	37	2658	69.95	71.84	22	38	3.14
Javaid, Nadeem	COMSATS University Islamabad	Pakistan	38	36	983	25.87	27.31	15	31	3.00
Srivastava, Gautam	Brandon University	Canada	38	33	1693	44.55	51.30	19	38	3.80
Gupta, Rajesh	Nirma University	India	36	31	871	24.19	28.10	14	29	3.50
Yaqoob, Ibrar	Khalifa University of Science and Technology	United Arab Emirates	36	33	870	24.17	26.36	16	29	4.00

(continued)

Author's Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Das, Ashok Kumar	International Institute of Information Technology	India	36	31	1159	32.19	37.39	16	34	4.00
Yu, F. Richard	Carleton University	Canada	36	35	2666	74.06	76.17	25	36	4.17
Zhang, Yan	Simula Metropolitan Center for Digital Engineering	Norway	35	35	4742	135.49	135.49	23	35	3.83
Niyato, Dusit	Nanyang Technological University	Singapore	33	29	2928	88.73	100.97	20	33	3.33
Du, Xiaojiang	Stevens Institute of Technology	United States	32	32	2579	80.59	80.59	23	32	3.29
Treiblmaier, Horst	Modul University Vienna	Austria	29	27	1215	41.90	45.00	14	29	2.33
Wang, Fei-Yue	Institute of Automation Chinese Academy of Sciences	China	29	27	2311	79.69	85.59	15	29	1.88

Note: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

Most Productive Institutions

As encapsulated in Table 3, our bibliometric analysis identifies the most prolific institutions in blockchain research and underscores their integral roles in driving the field's frontiers. The Beijing University of Post and Telecommunications in China has 269 publications, indicating a significant contribution to the blockchain field. These publications have received 8,755 citations, reflecting the profound influence of the institution's research. It is further substantiated by an h-index of 44, suggesting that at least 44 of these publications have been cited at least 44 times, a testament to the sustained impact of their scholarly work. The g-index of 93 indicates that the top-cited papers from this institution have garnered considerable attention, thus affirming the high quality of research produced. King Saud University in Saudi Arabia, with 170 publications and 5,189 citations, also demonstrates a strong presence in blockchain research. The relatively high average citations per publication (30.52) and per cited publication (35.30) indicate the significant impact and recognition the university's research has attained in the academic community.

Table 3

Most Productive Institutions. Source: Generated by the Authors Using biblioMagika® (Ahmi, 2024)

Institution	Country	TP	TC	NCP	C/P	C/CP	h	g	m
Beijing University of Post and Telecommunications	China	269	8755	208	32.55	42.09	44	93	6.29
King Saud University	Saudi Arabia	170	5189	147	30.52	35.30	38	72	6.33
National Institute of Technology	China	136	2453	113	18.04	21.71	25	49	5.00
Beijing Institute of Technology	China	126	5087	101	40.37	50.37	32	71	5.33
Hong Kong Polytechnic University	Hong Kong	123	4873	99	39.62	49.22	32	69	6.40
Shanghai Jiao Tong University	China	120	3760	101	31.33	37.23	31	61	3.10
Chinese Academy of Sciences	China	116	3934	94	33.91	41.85	24	62	2.67
Nanjing University of Post and TeleCommunications	China	106	1579	83	14.90	19.02	21	39	2.63
Beijing University of Technology	China	103	1626	73	15.79	22.27	18	40	3.00
SRM Institute of Science and Technology	India	101	392	58	3.88	6.76	11	19	2.20
North China Electric Power University	China	99	2449	82	24.74	29.87	26	49	3.71
Nanyang Technological University	Singapore	97	4472	82	46.10	54.54	32	66	4.57
Indian Institute of Technology	India	96	2006	71	20.90	28.25	22	44	3.67
Beijing Jiaotong University	China	92	1747	60	18.99	29.12	18	41	3.00
Beihang University	China	90	1407	68	15.63	20.69	19	37	2.71
Guangzhou University	China	87	1862	70	21.40	26.60	20	43	3.33
Southeast University	China	86	911	56	10.59	16.27	16	30	2.67
Shenzhen University	China	84	1947	69	23.18	28.22	24	44	4.00
Sun Yat-Sen University	China	84	5359	69	63.80	77.67	28	73	4.00
Nanjing University of Information Science and Technology	China	83	1956	69	23.57	28.35	24	44	4.00

Note: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

Several other institutions in China, such as the National Institute of Technology, Beijing Institute of Technology, and the Hong Kong Polytechnic University, have notable metrics. For instance, the Beijing Institute of Technology has a high average of 40.37 citations per publication, surpassing even that of the leading institution, which suggests their publications have a high individual impact. Singapore's Nanyang Technological University has fewer total publications (97) than the leading Chinese institutions, yet it boasts a high average citation rate (46.10 per publication) and a substantial h-index of 32. It indicates that while the volume of publications is smaller, the impact and quality of the university's research are significant.

The Indian institutions listed - SRM Institute of Science and Technology and Indian Institute of Technology - display a commendable presence in the field. However, their average citations per publication are on the lower end compared to the leading Chinese institutions. It may reflect differing research focuses, collaboration patterns, or the maturity of their blockchain research programs. A disparity is evident among the institutions when reviewing the average citations per publication and cited publication. For instance, SRM Institute of Science and Technology has an average of 3.88 citations per publication, while Sun Yat-Sen University has an impressive 63.80 citations per publication. Such variations could be influenced by the nature and novelty of the research, the institution's global academic network, and the accessibility and dissemination of its scholarly outputs.

Institutions' diversity and global spread reflect a vibrant ecosystem of international collaboration and knowledge exchange. These institutions function as epicentres where multidisciplinary teams converge to explore blockchain's potential across various applications, from fintech and smart contracts to IoT and beyond. Their collective scholarly output, adorned with high citation metrics, underscores the quality and influence of the research conducted under their auspices, marking them as key players in shaping the blockchain research agenda. Table 7 reflects the diverse landscape of institutional contributions to blockchain research. The leading institutions, particularly those in China, exhibit a combination of high productivity and impactful research. The metrics demonstrate the quantity and quality of the research output, as reflected in the citation rates and indices, painting a picture of influential research hubs in the blockchain arena.

Most Productive Countries

Table 4 and the corresponding Figure 2 present a compelling view of the global distribution of blockchain research output as measured by various bibliometric indicators. The table ranks countries by their scholarly contributions to the blockchain field. China emerges as the most prolific contributor to blockchain research, with a substantial 5,215 publications garnering 102,881 citations. This high level of productivity is matched by a notable h-index of 140, the highest in the dataset, indicating that a significant portion of these publications are frequently cited, a hallmark of influential research. The g-index of 320 further highlights the depth of highly cited papers, suggesting that the top echelon of Chinese publications in blockchain research is extensively recognised in the field. India's contribution stands at 1,921 publications with a total citation count of 27,031, which, while smaller in volume than China, nonetheless represents a significant body of work with a respectable h-index of 79 and a g-index of 164.

Table 4

Top Countries with a Minimum of 100 Publications. Source: Generated by the Authors Using biblioMagika® (Ahmi, 2024)

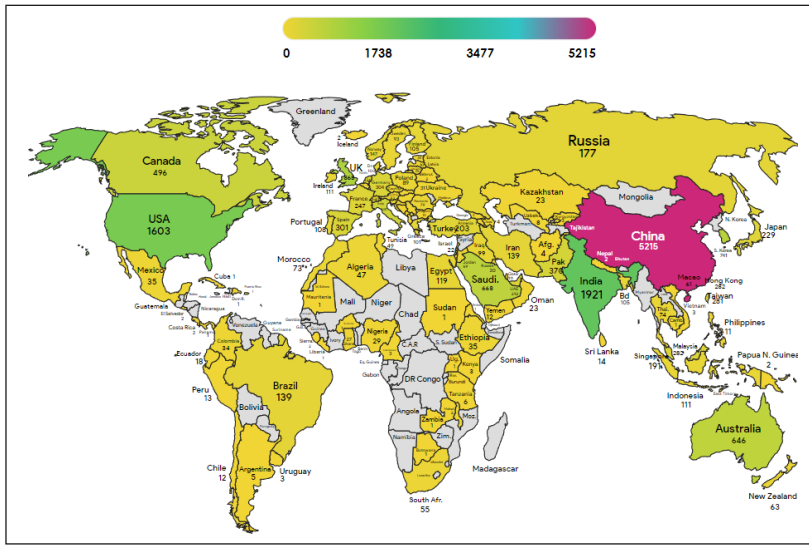
Country	TP	TC	NCP	C/P	C/CP	h	g	m
China	5215	102881	3898	19.73	26.39	140	320	15.56
India	1921	27031	1349	14.07	20.04	79	164	11.29
United States	1603	53602	1366	33.44	39.24	117	231	13.00
United Kingdom	868	28062	746	32.33	37.62	89	167	8.90
South Korea	741	17878	629	24.13	28.42	65	133	6.50
Saudi Arabia	668	10776	523	16.13	20.60	48	103	8.00
Australia	646	19168	555	29.67	34.54	72	138	10.29
Canada	496	16297	425	32.86	38.35	68	127	9.71
Italy	440	9572	363	21.75	26.37	46	97	6.57
Pakistan	370	9191	319	24.84	28.81	46	95	7.67
Germany	304	7505	258	24.69	29.09	40	86	5.00
Spain	301	5337	237	17.73	22.52	33	73	5.50
United Arab Emirates	292	10409	247	35.65	42.14	50	102	8.33
Malaysia	282	4424	220	15.69	20.11	34	66	5.67
Hong Kong	282	9328	230	33.08	40.56	50	96	8.33
Taiwan	281	7324	239	26.06	30.64	42	85	6.00
France	247	6793	203	27.50	33.46	38	82	5.43
Japan	229	6070	186	26.51	32.63	41	77	3.73
Turkey	203	3123	158	15.38	19.77	30	55	5.00
Singapore	191	7754	164	40.60	47.28	41	88	6.83
Russian Federation	177	2851	136	16.11	20.96	27	53	4.50
Norway	147	6996	130	47.59	53.82	38	83	12.67
Iran	139	1998	110	14.37	18.16	25	44	5.00
Brazil	139	2719	112	19.56	24.28	22	52	3.14
Switzerland	132	3141	95	23.80	33.06	27	56	3.86
Netherlands	126	3576	112	28.38	31.93	31	59	4.43
Egypt	119	1158	88	9.73	13.16	17	34	2.83
Qatar	111	3666	101	33.03	36.30	31	60	7.75
Ireland	111	3237	93	29.16	34.81	30	56	4.29
Indonesia	111	600	76	5.41	7.89	14	24	2.80
Portugal	108	1837	88	17.01	20.88	20	42	4.00
Finland	105	4124	87	39.28	47.40	25	64	3.13
Bangladesh	105	1309	85	12.47	15.40	19	36	3.80
Greece	101	2304	82	22.81	28.10	23	48	3.83
Denmark	100	3434	88	34.34	39.02	31	58	4.43

Note: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

These figures illustrate India's substantial role in blockchain research, with a considerable number of publications that have made an impact in the field. The United States, with 1,603 publications and 53,602 citations, has an average citation rate significantly higher than China's and India's, at 33.44 citations per publication. Indicated here is that, on average, each blockchain-related publication from the United States is cited more frequently, suggesting the research's high quality or relevance. The h-index of 117 and g-index of 231 underscore the influential nature of the US in this area. Other notable entries include the United Kingdom, South Korea, and Saudi Arabia, each with numerous publications and citations. The United Kingdom, in particular, has a high average citation rate comparable to that of the United States, underscoring the impact of its research contributions.

Figure 2

Country Production. Source: Generated by the Authors Using iipmaps.com



The metrics presented in Table 8 and Figure 3 reveal blockchain research's quantity, quality, and influence across different nations. Countries with higher h and g indices are seen as leaders in the field, having produced a body of work widely recognised and cited by the academic community. The m-index across these countries varies, reflecting differences in the impact rate over time.

Publications by Source Titles

To thoroughly address RQ4, this section delves deeper into the contributions of key source titles in shaping the blockchain research landscape. This analysis identifies the leading journals that make a pool of literature content (Katuk et al., 2020) and explores the thematic evolution within these publications, their engagement with academic and industry collaborations, and their broad impact on policy and technological advancement. The analysis presented in Table 5 underscores the pivotal role of certain journals in nurturing and disseminating ground-breaking blockchain research. It provides a detailed bibliometric analysis focused on the most active source titles in blockchain research, applying Bradford's Law (Bradford, 1934) to identify the core journals within the field. The table highlights the most influential journals in disseminating blockchain knowledge, as evidenced by their publication output and citation impact. At the pinnacle of this list is IEEE Access, with 832 publications and a remarkable 30,365 total citations. It reflects a high volume of blockchain-related research published in IEEE Access and a significant influence on the academic community, as seen by the high average citations per publication (C/P) of 36.50. The h-index of 91 and the g-index of 144 for IEEE Access demonstrate a strong and sustained impact on blockchain research.

The IEEE Internet of Things Journal also stands out with 441 publications and a high citation impact, evident through 15,092 total citations and an average of 34.22 citations per publication. The journal's higher C/P ratio compared to IEEE Access, coupled with substantial h and g indices, underscores the high relevance and quality of the research published in this journal, particularly in the context of blockchain's intersection with the Internet of Things. Sustainability (Switzerland) follows, with 243 publications cited 4,442 times. This journal's presence in the list emphasises the importance of blockchain in the discourse on sustainability, resonating through a strong C/P of 18.28. The h-index of 36 and g-index of 58 affirm the journal's significant role in the scholarly conversation on sustainable practices enabled by blockchain technology. Other journals such as Sensors, Applied Sciences (Switzerland), and Electronics (Switzerland) also contribute notably to blockchain literature, although they have lower citation metrics than the leading IEEE journals. This situation could reflect a more specialised or emerging focus within blockchain research. The inclusion of various IEEE Transactions journals indicates the importance of blockchain research in specialised areas

such as industrial informatics, vehicular technology, and intelligent transportation systems. These journals have relatively high citation metrics, demonstrating the importance of blockchain technology applications in these specific domains.

Table 5

Most Active Source Titles Based on the Core Zone as per Bradford's Law. Source: Generated by the Authors Using biblioMagika® (Ahmi, 2023)

Source Title	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
IEEE Access	832	3610	723	30365	36.50	42.00	91	144	13.00
IEEE Internet of Things Journal	441	2245	337	15092	34.22	44.78	62	113	8.86
Sustainability (Switzerland)	243	927	210	4442	18.28	21.15	36	58	6.00
Sensors	210	954	165	1532	7.30	9.28	19	29	3.17
Applied Sciences (Switzerland)	202	869	154	2615	12.95	16.98	23	45	3.83
Electronics (Switzerland)	200	840	151	2271	11.36	15.04	27	42	4.50
Security and Communication Networks	199	916	150	1716	8.62	11.44	16	36	1.60
Wireless Communications and Mobile Computing	159	657	122	1015	6.38	8.32	17	26	2.83
IEEE Transactions on Industrial Informatics	155	755	141	8881	57.30	62.99	50	92	8.33
Future Generation Computer Systems	135	600	119	9817	72.72	82.50	45	98	7.50
IEEE Network	114	585	107	4221	37.03	39.45	34	62	5.67
Peer-to-Peer Networking and Applications	111	446	84	1809	16.30	21.54	19	40	2.38
Computers, Materials and Continua	99	502	63	674	6.81	10.70	15	23	3.00
International Journal of Advanced Computer Science and Applications	97	412	65	558	5.75	8.58	15	21	2.50

(continued)

Source Title	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
Sensors (Switzerland)	93	419	93	4442	47.76	47.76	35	64	5.83
IEEE Transactions on Vehicular Technology	91	462	80	3253	35.75	40.66	29	56	4.83
IEEE Transactions on Network and Service Management	76	327	61	427	5.62	7.00	9	18	2.25
Cluster Computing	76	292	59	1099	14.46	18.63	15	31	3.00
IEEE Transactions on Engineering Management	75	294	70	1805	24.07	25.79	23	40	5.75
IEEE Transactions on Intelligent Transportation Systems	74	368	63	1531	20.69	24.30	22	38	3.67
Future Internet	74	266	61	1465	19.80	24.02	18	37	2.25
Transactions on Emerging Telecommunications Technologies	74	290	61	1048	14.16	17.18	21	30	4.20
Journal of Supercomputing	74	241	49	781	10.55	15.94	13	26	1.86
Computers and Industrial Engineering	72	276	60	2287	31.76	38.12	25	47	5.00
Computer Networks	71	299	56	1058	14.90	18.89	17	31	2.83
Computer Communications	68	280	53	1013	14.90	19.11	17	31	4.25
Energies	68	303	61	1153	16.96	18.90	19	32	2.71
Multimedia Tools and Applications	67	258	42	538	8.03	12.81	12	22	1.71
Mobile Information Systems	67	184	36	282	4.21	7.83	7	15	1.17
Mathematics	63	286	41	239	3.79	5.83	7	13	1.40
IEEE Transactions on Network Science and Engineering	63	312	56	1257	19.95	22.45	19	34	4.75
Computers and Electrical Engineering	63	283	49	1584	25.14	32.33	20	39	3.33

Note: TP=total number of publications; NCA= Number of contributing authors, NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

Applying Bradford's Law makes it possible to discern the most central and prolific journals within a discipline. The 'core' journals identified in Table 9 publish the most significant work on blockchain, per the law's zoning principle. The journals listed have published a high research volume and attracted numerous citations, indicating their centrality to the field. Table 9 reveals that the most active source titles, as per Bradford's Law, are key disseminators of blockchain knowledge, shaping the research landscape. The high citation rates and index scores associated with these journals underscore the quality and impact of their published research. This table provides an invaluable reference for scholars seeking to publish in or track the development of the blockchain field, highlighting where the most influential and cited work is being disseminated.

Research Themes

The conceptual structure of literature within a given academic domain offers a comprehensive overview of the key themes, methodological approaches, and theoretical foundations that have shaped scholarly discourse. It serves as an analytical scaffold for understanding the evolution of ideas, the interplay of concepts, and the emergent trends within a body of research. The conceptual structure can be elucidated through various bibliometric analyses that reveal patterns and relationships between keywords, topics, and themes as discussed by authors in their scholarly works. In the context of the study at hand, the conceptual structure will be explored and presented through several bibliometric methods using Biblioshiny, which is a graphical user interface for the R-package Bibliometrix:

1) Co-occurrence Networks of Author Keywords - This analysis will graphically represent how often pairs of keywords appear together within the set of articles in the database. The resulting network enables researchers to visualise the strength of associations between topics, indicating the core focus areas and potential interdisciplinary linkages within the field.

2) Thematic Map of Author Keywords - A thematic map visually represents keyword clusters by plotting the keywords based on centrality and density. High centrality indicates keywords that are pivotal to the structure of the research domain, while

high density reflects the development of thematic areas within the literature. This map is instrumental in identifying both mature and emerging research themes.

Together, these bibliometric methods will elucidate the conceptual structure of blockchain literature, providing a foundational understanding that will precede the detailed examination of specific bibliometric results. This multi-faceted approach enhances the comprehensiveness of the literature analysis. It provides a robust platform for synthesising and interpreting the vast array of scholarly outputs contributing to the academic dialogue on blockchain technology.

Co-occurrence Networks

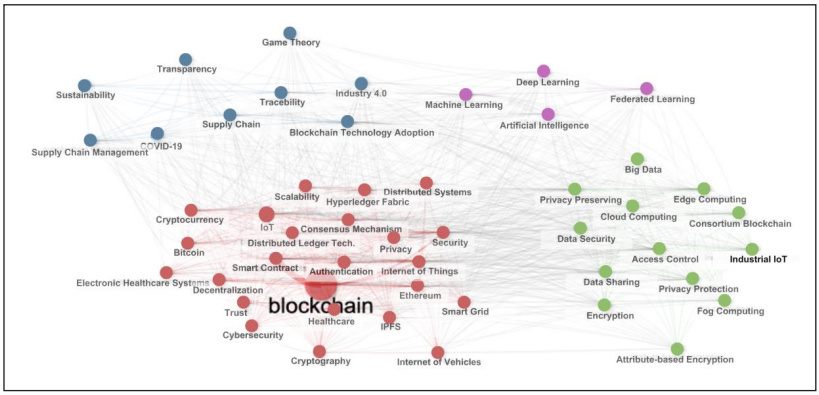
Figure 3 provides a visual representation of the co-occurrence network of author keywords in the domain of blockchain research. This network, which maps the interrelations between frequently used keywords, indicates the thematic concentration and diversity within the field. The nodes represent keywords, while the edges illustrate the co-occurrence of these keywords in the literature, highlighting the interconnectedness of concepts. In the centre of this network, the node for 'blockchain' is the most prominent, indicating its centrality and prevalence in the research corpus. The size of the node and its positioning underscore 'blockchain' as the pivotal concept around which the discourse in the field orbits. Other prominent nodes such as 'smart contracts', 'internet of things', and 'security' are closely associated with 'blockchain', suggesting that these are common topics of exploration in the literature.

The figure reveals that these keywords are not only central but also bridge between various clusters within the network. For instance, 'blockchain' has the highest betweenness centrality, confirming its role as a key connector between different research themes. 'Smart contracts' and 'Internet of Things' also hold significant betweenness centrality scores, reflecting their function as integrative topics linking disparate blockchain research areas. The closeness centrality measures show how close a keyword is to all other keywords in the network. Many primary blockchain-related keywords share the same closeness centrality score in this case. This uniformity suggests a cohesive body

of literature where key themes are interconnected and contribute to a unified field of study. This metric confirms the keyword's influence in the literature, as it likely appears in numerous important publications that are frequently cited.

Figure 3

Co-occurrence Networks Visualisation of the Authors' Keywords. Source: Generated by the Authors Using Biblioshiny (Aria & Cuccurullo, 2017)



The clusters identified in the network are indicative of thematic concentrations. Keywords within the same cluster are more frequently cited, while keywords in different clusters may represent distinct but related research areas. For example, the cluster containing 'blockchain', 'security', and 'privacy' points towards a significant focus on blockchain implementation's technological and ethical dimensions. In contrast, another cluster featuring 'supply chain', 'traceability', and 'sustainability' denotes a concentration on the application of blockchain in supply chain management and its potential for promoting sustainable practices. This co-occurrence network enables researchers to discern the most salient topics within blockchain research, providing a basis for further exploration of how these themes have developed over time, their current state, and potential future directions. It offers a snapshot of the field's intellectual landscape, informing seasoned scholars and new entrants about the key areas of emphasis and the dynamic interplay between various research strands.

Thematic Map

Figure 4 illustrates a thematic map based on co-occurrence networks of author keywords within the literature on blockchain technology. Thematic maps categorise keywords into clusters according to two key dimensions: centrality and density. Centrality measures the extent of interaction between a theme and other themes, signifying its importance to the overall research field. Density reflects the internal strength and cohesion within a theme. These measures help identify themes that are central to the field, as well as those that are more specialised or emerging.

The most prominent cluster on the map is the "blockchain" cluster, found in the upper-right quadrant, indicating its status as a Motor Theme. This cluster contains keywords like 'smart contracts,' 'consensus mechanism,' 'distributed ledger technology,' and 'ethereum,' all of which are highly relevant and mature areas of research within the blockchain field. The high density of this cluster indicates a well-developed body of work with strong internal coherence. Its high centrality, coupled with the dominance of terms like 'blockchain,' suggests that research in these areas is not only well-established but also pivotal in driving the overall discourse on blockchain technology. This high prominence is likely due to the increasing global adoption of blockchain across various sectors such as finance, supply chain management, and healthcare, which necessitates deeper investigations into its core technologies and applications.

The lower-right quadrant, representing Basic Themes, incorporates clusters like 'internet of things (IoT),' 'security,' and 'privacy.' These themes exhibit high centrality and subsequently indicates their foundational importance to blockchain research. However, their lower density suggests that while they are recognised as essential components of the field, research within these themes may still be evolving. The strong link between blockchain and IoT, for instance, reflects ongoing efforts to integrate blockchain technology into IoT ecosystems for enhanced security, traceability, and automation. Similarly, the focus on security and privacy indicates the continuous need to address vulnerabilities associated with decentralised systems. The lower density in these areas could be due to the interdisciplinary nature of research, which combines concepts from computer science, information systems, and cryptography, making it more complex and less cohesive.

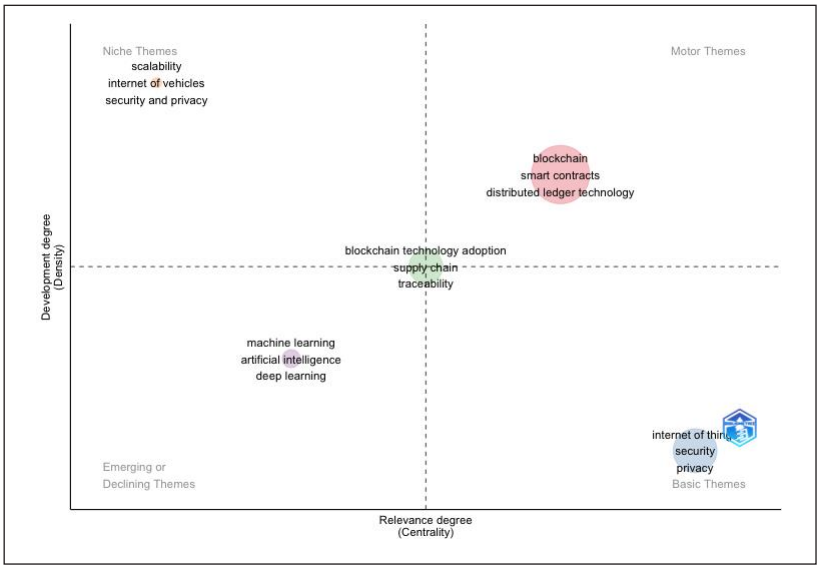
The Niche Themes cluster, located in the upper-left quadrant, includes specialised topics such as 'internet of vehicles' and 'scalability.' These themes are characterised by high density but low centrality, suggesting that while research in these areas is highly specialised and internally cohesive, it is not as connected to the broader blockchain research community. The presence of topics like 'scalability' in this quadrant is significant because it addresses one of the key technical challenges in blockchain adoption—ensuring that the technology can handle a large number of transactions and users without compromising performance. The low centrality of these themes could indicate that research in scalability, despite being advanced, is still isolated from mainstream blockchain discussions.

The lower-left quadrant typically includes Emerging or Declining Themes characterised by low density and low centrality. In the current analysis, there are no prominent themes in this quadrant, suggesting that most of the identified research areas have attained a certain level of maturity and integration within the field. This absence could imply the stabilisation of research topics within the blockchain domain, indicating a shift towards refining and enhancing existing technologies rather than exploring entirely new directions.

This thematic map reveals a well-structured research landscape with clear differentiation between core and peripheral topics. The concentration of Motor Themes around fundamental blockchain technologies and applications reflects the field's maturity, while the presence of Basic Themes like IoT and security signifies ongoing efforts to address integration and security concerns. The Niche Themes highlight specialised research challenges such as scalability and specific applications of blockchain in vehicular networks.

Figure 4

Thematic Map Based on Co-occurrence Networks Visualisation of the Author's Keywords. Source: Generated by the Authors using Biblioshiny (Aria & Cuccurullo, 2017)



DISCUSSION

This study undertook a bibliometric analysis to thoroughly examine blockchain research's development, present status, and potential future directions. Utilising a substantial collection of 13,369 papers, the study mapped out the intellectual terrain of the field, pinpointing primary themes, notable contributors, and prevailing patterns. This section seeks to delve deeper into the findings, interpreting their implications for the field and articulating their relevance for future research directions in blockchain. The chronological examination unveiled a steady rise in blockchain research, notably surging in 2022. Suggested here is a growing interest in and focus on blockchain within academic, industrial, or research communities. This implies two things: firstly, the potential applications, benefits, and challenges associated with blockchain in various industries, and secondly, a desire to explore and understand its various aspects more deeply. Furthermore, the growth in blockchain research suggests an increasing

understanding of its potential, spurring innovation, regulatory considerations, economic opportunities, and global collaboration in various industries, confirming the field's essential significance in modern discourse.

A thorough geographical analysis has revealed China's domination of blockchain research, followed by India. Positioned as a significant player in the global economic landscape, China's strategic emphasis on emerging technologies and innovation underscores its ambition to lead in technology development and digital transformation, particularly within Industry 4.0, where blockchain is reshaping industries worldwide. This dominance in blockchain research not only showcases China's technological prowess but also has implications for the country's potential geopolitical influence and economic competitiveness on a global scale. China's commitment to fostering a digital economy and leveraging technology for growth is evident, with blockchain positioned as a cornerstone of its Industry 4.0 strategy, facilitating advanced manufacturing and supply chain practices.

Various factors, including government support and talent accessibility, contribute to China's leadership in blockchain research, reinforcing its aspirations for technological dominance and influence. The enthusiasm in this domain has been further strengthened by China's national strategic plan, Made in China 2025, which emphasises the importance of innovation and the implementation of technologies like blockchain (Kuo & Shyu, 2021). Statistics show China's active engagement in blockchain patent applications in 2017, with a total number of 225, highlighting its commitment to advances in technology (Kuo & Shyu, 2021). The government's recognition of blockchain's strategic importance, as evidenced by initiatives such as the China Blockchain Technology and Application Development White Paper, further fuels research momentum in the field (Kuo & Shyu, 2021). Additionally, China's large population serves as a rich source of research talent, amplifying the depth and breadth of its research output. Collectively, these factors illustrate why China stands out as a leader in blockchain research.

The reason why China is leading blockchain research is its strategic emphasis on emerging technologies and innovation, particularly within the context of Industry 4.0, combined with strong government support, talent accessibility, and initiatives such as the Made in China 2025 plan, which reinforces its commitment to technological

dominance and influence. The notable lack of participation from other developing nations underscores a pressing global imperative to foster and bolster blockchain research in these areas. Addressing this substantial knowledge deficit has the potential to reveal unique viewpoints from diverse industrial contexts, thereby injecting novel perspectives and diverse expertise into the global conversation on blockchain. Incorporating these frequently marginalised voices promises to enhance and expand our comprehension, facilitating a more thorough and inclusive approach to one of the paramount challenges of our era.

Implications for Practice

The bibliometric analysis presented through Tables 3 to 10 and the corresponding figures offers rich insights with several practical implications for various stakeholders in the blockchain domain. For practitioners in the technology sector, the findings emphasise the centrality of blockchain technology as an innovation driver and its integrative potential with IoT, evidenced by the prolific research outputs and high citation rates in these areas. The focus on smart contracts and their rising prominence in recent literature signifies a growing need for robust legal and technical expertise to develop, deploy, and manage smart contract frameworks across industries.

Business leaders and managers can glean the importance of blockchain in transforming business operations, as highlighted by the research on blockchain adoption, supply chain management, and sustainability. These topics suggest a need for businesses to consider blockchain as a strategic technology that can offer competitive advantages through enhanced transparency, traceability, and efficiency. Moreover, the emphasis on privacy and security within the blockchain literature underscores the imperative for businesses to prioritise these aspects in their blockchain implementations to build trust with stakeholders and comply with regulatory standards.

For policymakers, the widespread international contribution to blockchain research indicates the global importance of the technology and the need for cross-border regulatory frameworks and standards. The engagement of countries across economic spectrums in blockchain research also suggests the potential for international collaborations to harness blockchain's benefits for economic development and innovation.

Recommendations for Future Research

The bibliometric analysis highlights several promising avenues for future research in the rapidly evolving domain of blockchain technology, reflecting emerging trends and ongoing challenges. Firstly, future research should delve deeper into the integration of blockchain with advanced technologies such as artificial intelligence (AI), machine learning (ML), and edge computing. These synergistic technologies have the potential to create transformative applications, particularly in optimising decentralised systems, automating smart contracts, and enhancing data security and privacy. Investigating these intersections could yield new insights into the capabilities of blockchain in handling complex, real-time data interactions and computational processes.

Additionally, understanding the economic implications of blockchain adoption remains a critical research priority. Future studies should focus on developing comprehensive economic models that quantify blockchain's impact on various business models, market structures, and global trade dynamics. This includes analysing blockchain's potential to drive cost efficiencies, streamline supply chain operations, and foster new economic ecosystems. Moreover, addressing blockchain's scalability challenges and energy consumption is crucial, as these factors directly influence the technology's broader adoption and sustainability. Research in these areas should explore innovative consensus mechanisms, such as proof-of-stake (PoS) and sharding, to enhance performance and reduce environmental impact.

Given the increasing convergence of blockchain with Internet of Things (IoT) devices, there is a pressing need for research on security vulnerabilities and privacy issues within these interconnected systems. Developing robust frameworks for secure data transmission, identity management, and compliance with global regulatory standards will be essential to ensuring the safe integration of blockchain in IoT environments. This research can pave the way for secure, scalable, and privacy-preserving solutions that address both current and future challenges.

Another promising area for exploration is the role of blockchain in advancing sustainability practices. Future studies should investigate blockchain's potential to support environmental sustainability by

enhancing supply chain transparency, reducing carbon footprints, and promoting adherence to sustainable development goals (SDGs). Research could also explore blockchain's utility in creating transparent and verifiable mechanisms for tracking and reporting on sustainability metrics, thereby contributing to responsible environmental management.

Finally, advancing interdisciplinary research collaborations and international partnerships will be essential to leverage blockchain's potential for global impact. Collaborative research can bridge gaps between technical development and policy implementation, facilitating the establishment of standardised frameworks and best practices for blockchain adoption. Encouraging cross-sectoral dialogue and international cooperation will also help address region-specific challenges, promote shared learning, and accelerate the deployment of blockchain solutions in diverse contexts. By pursuing these research directions, scholars can enhance the understanding of blockchain's transformative potential and contribute to its responsible and sustainable integration into future technological and societal landscapes.

CONCLUSION

In conclusion, the bibliometric analysis of blockchain research from 2013 to 2023 offers a detailed view of the field's development, current state, and future directions. The data from Tables 3 through 10 and the visual insights produced in the corresponding figures highlight a maturing field characterised by increased scholarly output, interdisciplinary expansion, and significant academic and practical impact. The growing number of publications and citations reflects blockchain's importance and the sustained interest of the scholarly community. The collaborative nature of the research underscores the complexity and multi-faceted approach needed to advance blockchain technology. Blockchain research spans various disciplines, including computer science, engineering, business, and social sciences, showcasing its potential to transform diverse sectors. This interdisciplinary integration demonstrates blockchain's versatility in revolutionising traditional systems, for instance, financial transactions, supply chain management, and data security. The analysis also reveals global contributions to blockchain research, with

significant input from various countries, indicating this technology's universal relevance and applicability.

The focus on foundational topics such as smart contracts, security, and IoT integration continues to draw significant scholarly attention, emphasising their importance as core areas of blockchain research. Emerging trends like blockchain applications in edge computing, artificial intelligence, and sustainability signal the field's dynamic nature and its responsiveness to new challenges and opportunities. High citation rates of seminal papers underscore the foundational research's quality and impact, shaping the field's trajectory and retaining its relevance. As blockchain technology evolves and integrates into society, future research is expected to explore new applications, address emerging challenges, and refine the theoretical underpinnings of the technology. The integration of blockchain with emerging technologies and its potential role in tackling global issues like climate change and economic inequality will likely become significant areas of scholarly interest. Continuous monitoring and analysis of the field are essential to capture its rapid evolution and ensure that research efforts align with technological advancements and societal needs. This study reflects prior scholarly efforts and guides future explorations of the expansive nature of blockchain research.

Limitations and Future Directions

While this bibliometric analysis provides comprehensive insights into blockchain research from 2013 to 2023, several limitations must be acknowledged. The reliance on selected databases and predefined keywords might have excluded relevant grey literature, patents, and industry reports. Future research could integrate these sources so that a more holistic or complete view of blockchain's impact across sectors is generated. The rapid evolution of blockchain technology, often outpacing academic publication cycles, suggests that future studies should consider real-time monitoring techniques and non-traditional metrics like social media analytics to capture emerging trends promptly. Additionally, while the study focuses on quantitative metrics such as publication counts and citation rates, qualitative assessments like content analysis of influential papers could offer deeper insights into theoretical contributions and practical implications. Incorporating qualitative methods would enrich our understanding of the thematic richness and interdisciplinary collaborations within blockchain

literature. This bibliometric analysis is a foundational step toward a nuanced understanding of blockchain research, opening avenues for future work that remains at the forefront of technological innovation and societal progress.

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