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ASSESSING THE IMPACT OF PUBLIC BLOCKCHAIN RESEARCH: A BIBLIOMETRIC APPROACH

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ABSTRACT

Public blockchains are open, decentralised networks that use consensus mechanisms like Proof of Work (PoW) or Proof of Stake (PoS) to validate transactions, ensuring transparency and security. This bibliometric analysis, utilising Scopus as the primary data source for its extensive journal coverage, examines the evolution of the public blockchain research scenario. The study follows a PRISMA flow diagram to identify, screen meticulously, and include relevant papers for the analysis. It focuses on trends in public blockchain studies, significant contributions, cooperative networks, research outcomes, and literature gap identification. This study utilises advanced bibliometric tools Biblioshiny and CiteSpace, providing a multifaceted view of the field's development and impact. The analysis yields significant insights into various aspects: the annual scientific production in the field, identifying the most influential authors, and discerning the most relevant sources. Furthermore, it highlights the most globally cited documents, pinpoints the most productive country in this research area, and delves into the trending topics. As a result, our findings pinpoint the dynamic nature of the field and reveal significant changes in research focus, notable contributors, and the evolution of the global collaboration pattern. Not only did the study point out the diversity and depth of public blockchain studies, but it also further identified both mature and evolving research areas. It also identified research gaps and practical consequences and proposed directions for future study and application.
Keywords: *Public Blockchains, Bibliometric Analysis, Biblioshiny, Vosviewer, Citespace*

1. INTRODUCTION

A public blockchain is an open and decentralised network accessible to everyone with no restrictions. Blockchain networks' decentration made them open and accessible to global consumers (1,2). They count on consensus mechanisms such as Proof of Work (POW) or Proof of Stake (POS) to authenticate transactions and add them to a transparent and immutable public ledger (3,4). The decentralisation and transparency enormously enhance protection, trust, and tamper-resistance, making all transactions publicly visible and protecting them from being controlled by a single entity (3). It is noted that public blockchains are being used in various applications, especially in public administration, i.e., electronic voting systems, public procurement, and land registration, are a few cases in point. Beyond doubt, using blockchain technology in the public sector increases trust in the Government system as it improves transparency (5).

Nevertheless, specific challenges like participants' identity and proof of ownership remain with public blockchains. Similarly, the legal issues associated with public blockchains include characters of cryptocurrencies, Tax structures, and the legalisation of intelligent contracts (5,6). However, with all reasonable consideration of technical and legal challenges, public blockchain helps implement the system successfully and enhances transparency and trust in the public sector. Bitcoin is just a public blockchain, an iconic example of a public blockchain. It introduced the popular concept of 'trust-less' digital currency (5,7). Essentially,

Bitcoin's blockchain acts as a virtual ledger for transactions, and miners (nodes) compete to solve intricate algorithms to confirm transactions and earn rewards in the form of new bitcoins (8,9). This popular mining process secures the network and ensures that only genuine transactions are added to the blockchain. With revolutionized finance, Bitcoin served as a model for succeeding blockchain projects. Ethereum blockchain, another prominent one, takes the concept to the next level through newly introduced smart contacts and self-executing contracts with predefined rules (10,11). These smart contracts systematize a varied range of processes and lead to the creation of decentralized applications (DApps) that run on the Ethereum blockchain (8,12).

This resourcefulness expands the potential use of public blockchain cases from supply chain management and decentralized finance (DeFi) to digital identity solutions and voting systems (6,13). However, public blockchains also face challenges, such as scalability concerns due to an increasing number of users and transactions, energy consumption in PoW-based systems, and regulatory considerations (14). While these challenges are persistent, public blockchains are constantly evolving to shape the future of technology and finance, as researchers and developers are actively working on solutions to address these issues (6).

A bibliometric study on public blockchains is an essential endeavour in the ever-evolving field of blockchain technology. Public blockchains, renowned for their decentralised and transparent nature, have garnered significant attention from researchers, practitioners, and policymakers alike. Keeping this in mind, we effectively incorporate this bibliometric analysis to embark on comprehensive exploration of the academic literature within the scope of public blockchain. To achieve this objective, we systematically scrutinize a vast body of scholarly publications and employ bibliometric methodologies. This endeavour, we hope, will provide valuable insights into the evolution and growth of this vibrant field while mapping out the vital trends, pivotal works, persuasive authors and new research themes in this area. This can also shed light on the important contributions that led us so far in the trajectory of understanding public blockchains and would guide future research in this transformative domain. Bibliometric analysis, a quantitative approach, uses statistical parameters to examine publication pattern, citation, authorship, content themes, impact and trends within a body of literature (15–18). Revealing influential contributors, key papers, and evolving research areas, this technique helps in charting the intellectual landscape of a research field (19–22). As our primary objective was the optimum accuracy and flawlessness in analysis and visualization, we relied on two well-known software tools, namely 'BiblioShiny' and 'CiteSpace'. These tools offer salient features and capabilities that complement each other and provide comprehensive information on the research overview in this domain. With the help of these particular tools, we carried out a multi-dimensional bibliometric analysis and uncovered a rich and detailed understanding of the current state of progression in the research of intersections in social media and health education.

BiblioShiny is an advanced user interface for the R package, while 'bibliometrix' is designed to achieve a more interactive and user-friendly experience in conducting analyses (23–25). This provides researchers with the opportunities to impulsively picture data, study trends, and perform detailed analyses with minimum programming knowledge. CiteSpace, a Java-based application mainly used for visualisation and trends analysis, acknowledges the patterns in the scientific literature (26,27). It focuses more on studying and mapping important points where research is progressing and is known for its capacity to expose growing trends, impactful publications, and dominant authors, often by joint citation analysis and clustering method (28,29).

The research objectives for this bibliometric analysis are:

- To analyse trends in public blockchain research over time.
- Identifying critical contributors to the field
- To map and analyse the collaboration networks within the field
- Assessing the impact of research in the public blockchain
- Identifying gaps in the existing literature

2. LITERATURE REVIEW

Belen-Saglam R., Altuncu E., Lu Y. & Li S. (2023) explore the possible strains among public

blockchain systems and the European Union's General Data Protection Regulation (GDPR) and similar data protection laws prevalent. They identify major issues such as challenges in freely exercising data subjects' rights, difficulties defining duties and responsibilities in blockchain data processing, and possible ambiguities in law application. The evaluation offers insights into solutions for improving GDPR amenability within the purview of public blockchain systems while making it a valuable resource for researchers, policymakers, and developers (8).

Rasolroveicy M., & Fokaefs M. (2022) studied the expenses and efficiencies of three different public blockchain platforms namely, Fantom, Avalanche, and Polygon, in the context of minting and transferring NFTs. In this task, the researchers meticulously use machine learning models and flawlessly predict transaction costs and throughput volume with the parameters employed for platform selection. The result of the experiment indicated the outperformance of Polygon network when compared with other platforms in terms of transaction cost and throughput (30).

Zhang Z., Guo B., Zhu L., Shen Y., Qin C. & Li C. (2022) introduced a public blockchain harmony mechanism meant for fault-tolerant distributed computation in low earth orbit, (LEO) a satellite communication system. To achieve this goal, they use a particular mechanism as they always depend on unspecific calculation, and the storage transaction results in directed acyclic graphs (DAGs), but it culminates in Directed Acyclic Graphs (DAGs). Their repeated experiments show the outstanding performance of the proposed blockchain, proving its efficiency against malicious applications and achieving higher speed in processing (31).

Fu J., Zhou W., Xu M., Si X., Yuan C. & Huang Y. (2021) introduce a new public blockchain protocol called SAC. It was designed mainly to address the repeatedly reported scalability issues in public blockchains. SAC leveraged the process of sharing aggregate signatures and cryptographic sortition to increase transaction rates while maintaining a constant consent signature length and this objective was achieved by the use of verifiable random function, decentralizing consensus representative selection. The study delivers a task performance analysis and demonstrates the possible applicability of SAC in mobile computation (32).

Zhang S., Wang T., Yang Q. & Wang H. (2020) present a public blockchain with high performance particularly designed to address privacy and efficiency challenges in existing public blockchains. These researchers introduced a scheme for an on-chain cryptography registration, based on various factors such as their experiment results, a subscribable layer-2 contract, fast blockchain dissemination, and an optimized and structured broadcast protocol to improve transaction speed. Zhang et. al. (2020) introduced a newer public blockchain with PPC-integrated security and consortium privacy with optimum flexibility to fit various applications,

3. MATERIALS AND METHODS USED

Scopus was chosen as this study's primary bibliographical data source because it covers a broader range of quality journals compared to other databases (33–35). The publications were retrieved using the keyword "Public Blockchain." There were no language restrictions; only journal articles, conference papers, and book chapters were considered. Seven hundred twenty-two documents were collected from 440 different sources from 2011 to 2024. Figure 1 illustrates the PRISMA approach to selecting papers for bibliometric analysis. It is a three-phase procedure in which we identify and extract the data for analysis initially from the databases. We excluded Reviews, Editorials, Books, Short Notes, and Surveys in the second phase. Documents included are Articles, Conference papers, and Book chapters. The findings were stored as "CSV" and RIS files, and bibliometric analysis was performed on the data using CiteSpace version 6.2.R3 (Advanced) and Bibloshiny software. The main aspects of this investigation are summarised in Table 1.

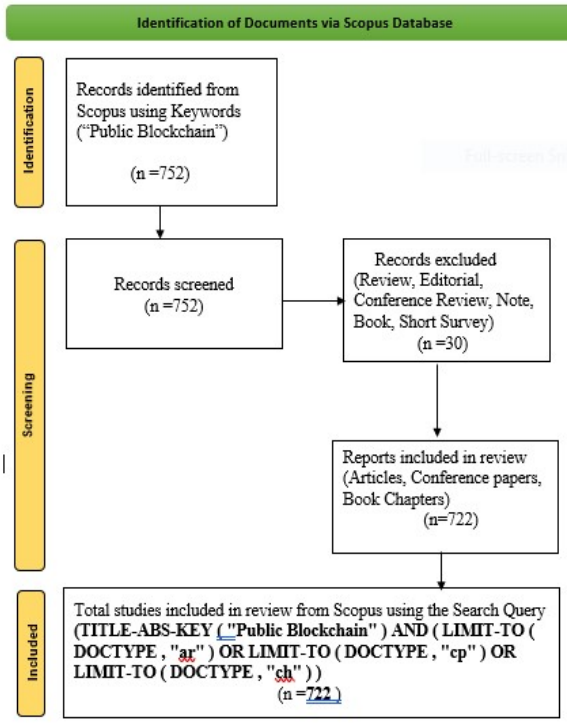

Figure 1: PRISMA Flow Diagram Used To Identify, Screen, And Include Papers In The Bibliometric Analysis.

Table 1. Critical Aspects Of The Investigation.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2011:2024
Sources (Journals, Books, etc)	440
Documents	722
Annual Growth Rate %	8.82
Document Average Age	2.16
Average citations per doc	14.87
References	20402
DOCUMENT CONTENTS	
Keywords Plus (ID)	3657
Author's Keywords (DE)	1740
AUTHORS	
Authors	2074
Authors of single-authored docs	37
AUTHORS COLLABORATION	
Single-authored docs	38
Co-Authors per Doc	3.67
International co-authorships %	22.71
DOCUMENT TYPES	
Article	291
book chapter	37
conference paper	394

4. RESULTS

4.1. Annual Scientific Production

The crucial journey of scientific production in the public blockchain during 2011- 2024 underscores its evolutionary milestones from inception to a peak in interest and potential stabilization. It was initially marked by minimal activity, with a single article published in 2011 and a complete absence of publications during 2012 - 2015; the field slowly garnered academic attention. A notable increase began in 2016, with a single publication indicating revived educational interest, which surged in 2017 with 17 articles, reflecting a growing engagement in blockchain research. The momentum continued to build, with a significant rise to 54 publications in 2018 and further growth through 2019 and 2020, reaching a peak in 2021 with 147 publications. This peak suggests blockchain technology's broadening scope and application in various sectors. However, a slight dip in publications in 2022 and 2023 indicates a shift towards more focused and quality-driven research, maintaining a high scholarly output.

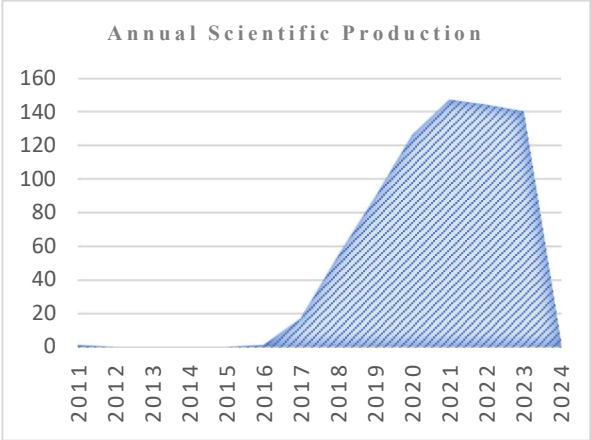

Figure 1: Annual scientific article production from 2011 to 2024

4.2. Most Relevant Authors

Figure 1 delineates the landscape of academic contributors within the public blockchain research

community, highlighting the most prolific authors by their publication count. Dominating the chart, "Liu Y," "Zhang Y," and "Wang Y" each have authored nine documents, positioning them as leading voices or central figures within the domain. Closely following are authors with seven contributions each, including "Chen L," "Kumar N," "Li J," "Li Y," "Li Z," "Vecchio M," and "Zhang J," which suggests a solid secondary tier of active researchers. The concentration of publications among these top-tier authors could imply a network of scholarly collaboration and thought leadership.

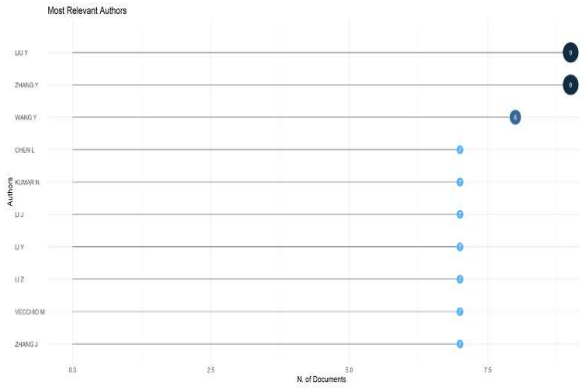

Figure 2 Notable Contributors In The Academic And Research Realm.

4.3. Countries' Scientific Production

Countries' scientific production reveals a global research landscape with varying contribution levels. China leads the chart with 667 publications, underscoring the country's massive investment and government support in public blockchain technology. India's 394 publications highlight the expanding IT sector's interest in blockchain, while the US-based 218 publications reflect its ever-growing role and constant technological innovation. Italy and South Korea demonstrate focused research efforts with 141 and 118 publications, respectively, attributing to dedicated academic programs and supportive technical infrastructure. Other countries like the UK, Australia, Canada, Singapore, and Japan supplemented the list with 105, 90, 72, 52, and 47 publications, indicating their share in the research communities and strategic emphasis on integrating blockchain technology in various sectors. This distribution shows a diverse and dynamic global research environment where both developing and developed nations heavily contribute to advancing public blockchain technology.

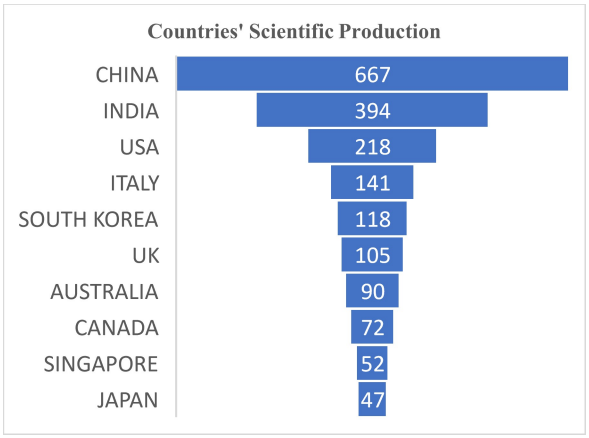

Figure 3 Countries' Scientific Production

4.4. Most Relevant Source

The top 20 most relevant sources in public blockchain research offer a window into the multidisciplinary nature and breadth of the field's academic discourse. The leading list is the "Lecture Notes in Computer Science" series, with 29 significant articles, underscoring its academic status and role in advancing blockchain education. "IEEE Access" follows with 25 articles, reflecting on the commitment of IEEE to disseminating open access to technical literature in blockchain. The conference proceedings, such as the 'ACM International Conference Proceeding Series' and the 'IEEE International Conference on Communications' highlight the active exchange of ideas and the latest developments within professional forums. Journals with a particular focus on 'Blockchain Research and Applications show various stages of impactful explorations made into specific aspects of the technology.

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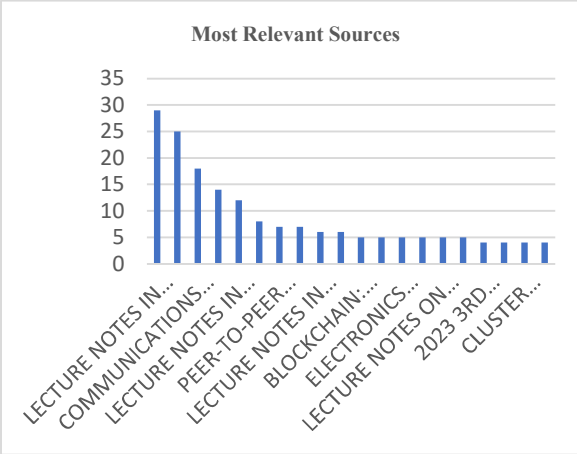

Figure 4 Most Relevant Sources

4.5. Trend Topics

The trend topics in public blockchain research during the 2018-2023 period highlight a vibrant and evolving academic landscape based on the focus shift over the years. The initial excitement about electronic money was reflected at large in the peaks of discussions held in 2018. After that, a growing interest in electronic document identification systems points to blockchain's potential in digital validation in 2020, too. The research into smart contracts began strongly in 2018, paving the way for deeper explorations into consensus protocols, which remained a subject of study through 2021, indicating a long-term interest in the foundational mechanics of blockchain technology. The intersection of blockchain with big data garnered significant attention in 2019, suggesting an exploration of how blockchain can handle large-scale data challenges. The persistent focus on blockchain from 2020 to 2022, with a striking 569 mentions, shows its centrality to the field, alongside specific interests in platforms like Ethereum and applications in the Internet of Things. The latest trends indicate a current and keen interest in the practical implementations of blockchain, such as in smart contracts, decentralization, and specific platforms like Hyperledger Fabric, as well as its role in filesystem management, pointing to a broadening of the technology's applications and research inquiry.

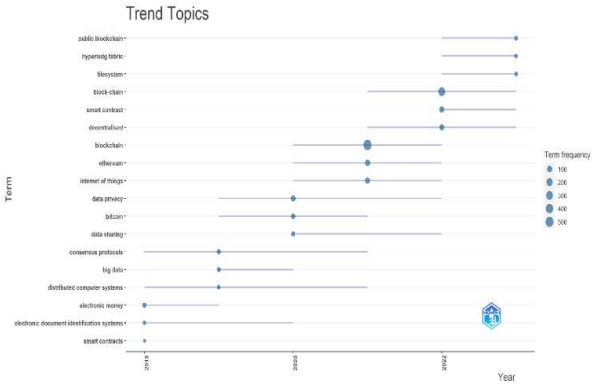

Figure 5 A Visual Indicating The Popularity Of Topics.

4.6. Thematic Map

The thematic map is a strategic diagram that categorizes research topics within a public blockchain based on two dimensions: 'Development degree (Density)' and 'Relevance degree (Centrality)'.

Basic Themes: Positioned in the lower right quadrant are "blockchain," "network security," and "digital storage," along with "block-chain," "Ethereum," and "smart contract." These are foundational concepts with high centrality, indicating they are well-developed and central to the field. They are likely to be the most studied and developed areas within public blockchain research, serving as the backbone for further exploration in the field. Niche Themes: In the upper left quadrant, "health care," "security analysis," "insurance," "power markets," "smart grid," and "smart power grids" are identified as niche themes. These have high development but lower centrality, suggesting they are well-developed but specialized areas that are important within specific subdomains of blockchain research. Emerging or Declining Themes: The lower left quadrant includes "information use," "information systems," and "privacy issue." These have low centrality and density, indicating they are either nascent and emerging areas of research that are not yet fully developed or declining in focus within the broader context of blockchain research. Motor Themes: In the upper right quadrant are "Internet of things," "cryptography," and "data privacy." These themes indicate they are mature and central to the field as they both have centrality and high development tendencies. They are likely to drive research across various domains within the blockchain, as motor themes do, and could be instrumental in advancing the field.

In the strategic diagram, the positioning of

themes indicates the proportional maturity and focus of research areas within the public blockchain. While basic themes remain foundational and widely researched, niche themes represent specialized knowledge areas, motor themes are mature and influential across the field, and emerging or declining themes indicate potential growth or reduction in research activity. The map offers a strategic overview of how various themes effectively contribute to the evolution of public blockchain research.

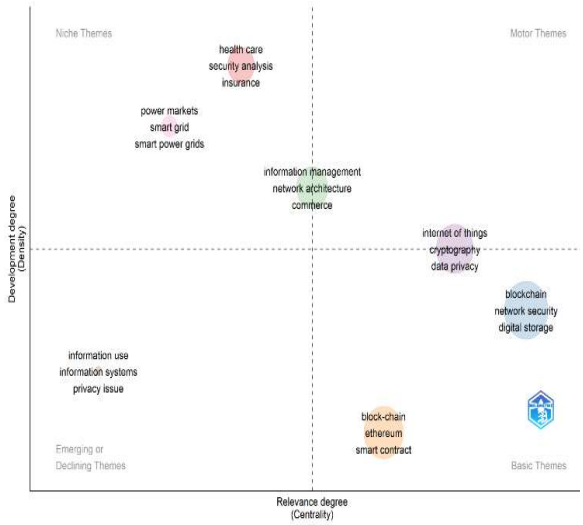

Figure 6 Thematic Representation Of All Keywords

4.7. Factorial Analysis

The factorial analysis of terms related to public blockchain research proposes a multi-dimensional view, revealing clusters that define the thematic contours of the field. The analysis precisely places foundational terms like 'Blockchain' and 'Ethereum' within a technical cluster, revealing their role in the technology. However, 'The Internet of things noticeably inclines towards application-oriented research and indicates its collaboration with blockchain in a broader but more multi-disciplinary context. We could identify the terms such as 'smart contract' and 'decentralised' with a strong technical orientation, stressing their centrality to core blockchain principles. Meanwhile, 'data privacy' and 'privacy-preserving' indicate their prominent significance across different aspects of blockchain research while standing out as significant terms spanning both technical and application domains. Despite 'Bitcoin' being a foundational element in the blockchain narrative, it records a lower centrality in current research trends. It signifies a shift in focus towards extensive and more diverse applications of blockchain technology. This factorial analysis not only underscores the intricacy within the field but also highlights blockchain research's evolving nature, which spans profound technical aspects to wide-ranging applications.

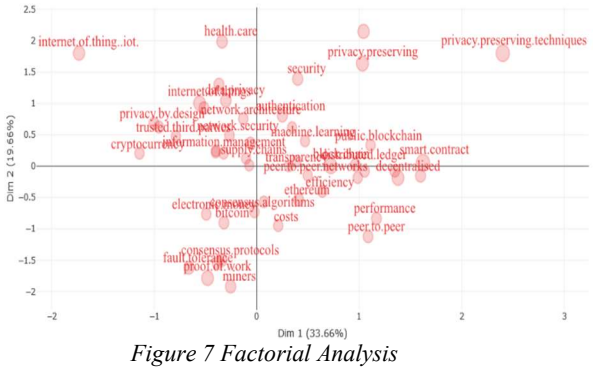

Figure 7 Factorial Analysis

4.8. Cited Reference

The picturization of cited references in public blockchain research provides a multi-dimensional view of the field's logical foundations and latest research directions. The picturization reveals a network of references, with nodes consisting of related topics, signifying the interconnections among pivotal works. The largest cluster, #0, is labeled 'secure modular smart contract platform', indicative of a significant focus on the development of robust and flexible intelligent contract technologies. This properly aligns with the high centrality and Christidis K.'s citation count (2016). His work on blockchains and smart contracts for the Internet of Things (IoT) is the most cited reference that serves as a critical intersection point for various research paths within blockchain technology. Satoshi Nakamoto appears with a 2019 reference in the data, typically associated with the seminal 2008 Bitcoin whitepaper, suggesting ongoing recognition and foundational relevance to the domain. Swan M. (2015) in cluster #11 with her work on blockchain as a blueprint for a new economy emphasises a strong interest in the extensive relevance of blockchain technology. Gilad Y. (2017) in cluster #10 is noted for work on scaling Byzantine agreements for cryptocurrencies, addressing the critical scalability issue in blockchain networks. Other clusters, such as #12 on "artificial intelligence" and #1 on "IoT security," underscore the interdisciplinary nature of blockchain

research, intersecting with AI and IoT security concerns. Cluster #6 focuses on "decentralized architecture," central to the promise of blockchain in decentralization, while Cluster #5 on "blockchain-based cloud storage" and Cluster #3 on "sharing economy" suggests the scope of the exploration of practical applications. The data table shows a range of topics,, from technical aspects like scalability, security, privacy protection methods, etc.,, to IoT applications and the sharing economy. The referred citations with high centrality scores, like that of Christidis K. (2016) and Nakamoto S. (2019), indicate their work has significantly shaped the research landscape and often bridges various topics within the domain.

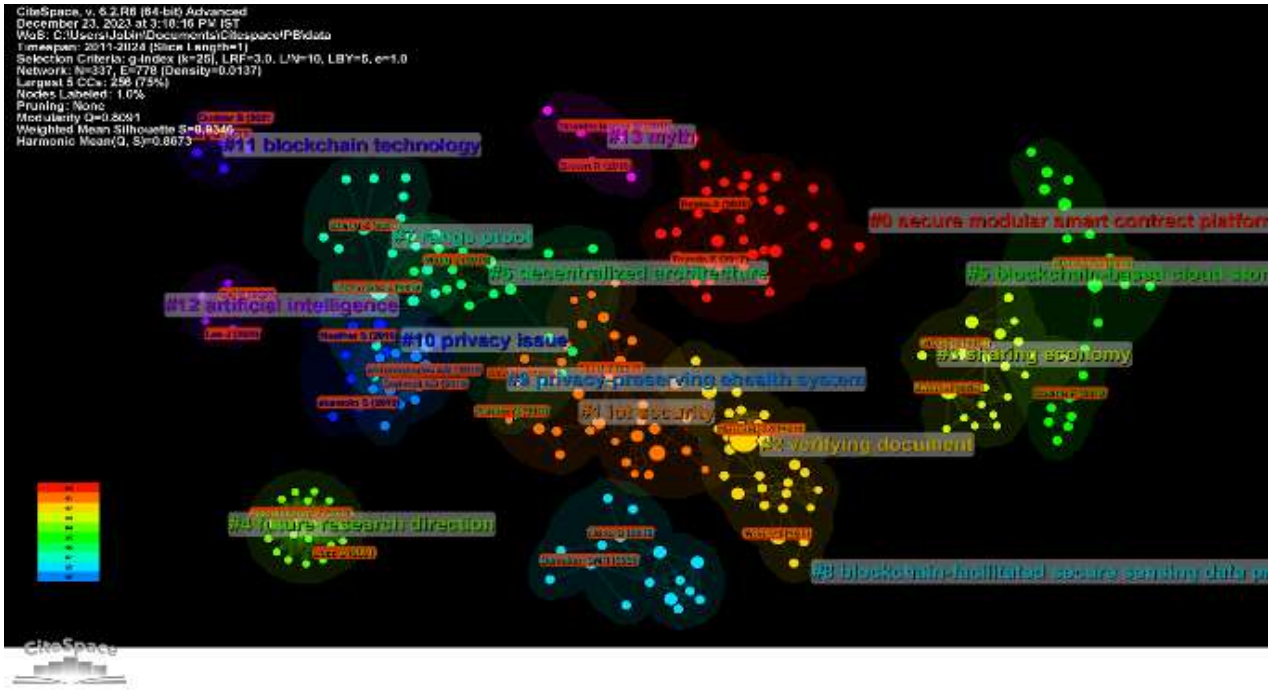

Figure 8 Clustered Networks Of Cited References In The Research Realm.

4.9. Cited Authors

In public blockchain research, the CiteSpace visualization of the cited authors provides visual proof of the field's logical structure and evolution controlled by foundational figures and prominent contributors. Among the great influential authors in the field, Satoshi Nakamoto, under the pseudonym of Nakamoto S., appears as the most influential one in 2017 in terms of citation count, seemingly for introducing Bitcoin, anchoring cluster #2 thought to represent the concept of blockchain. Likewise, the substantial citation counts of Wood G. and Buterin V., who are said to be closely behind Ethereum development, Bitcoin introduction, and cluster # 2 improvement projects, are recorded with due importance, considering the former's outstanding contribution to intelligent contracts and the latter's unpreceded contributions to the decentralized platforms are evident in clusters # 3 and # 4. Other prominent authors who contributed substantially to the applications, such as consensus mechanisms and blockchain security, include Zheng Z., Castro M., and Eyal I.

The visualization accentuates the undiminishing relevance of Akamoto S. and Luu L, who focus on smart contract security and, similarly, the notable contributions of Zhang Y. in recent advancements and the outstanding effort of Androulaki E. in privacy protection hugely contributes to the diverse but interconnected research domain that is captured by distinct clusters in the visualization of CiteSpace. As such, this configuration exposed a dynamic ever-expanding field with impactful research, starting from 2017, formed a foundation. Consequently, authors like Zheng Z. (2018) and Zhang Y. (2019)

pointed out newer developments upon this foundation, illustrating both the depth and vastness of blockchain research.

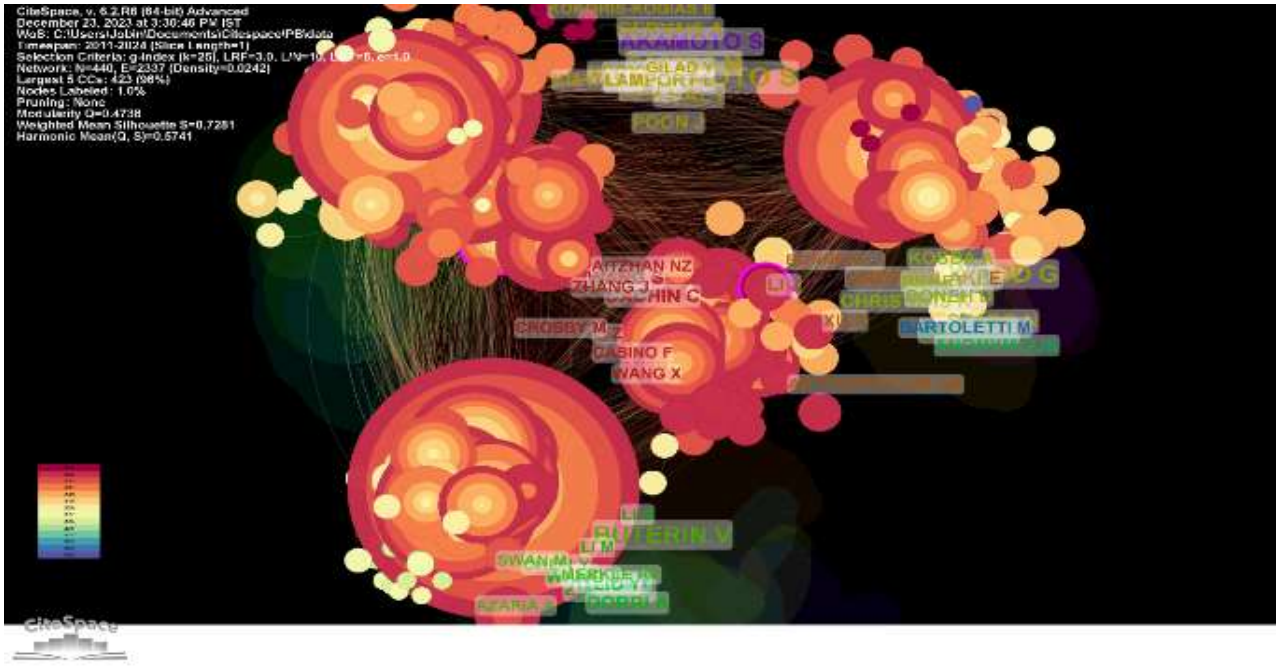

Figure 9 Clustered Networks Of Cited Authors In The Research Realm.

4.10. Co-occurrence of all Keywords

The clustered networks of co-occurrence of keywords in public blockchain research reveal diverse focus areas while distinct themes and citation patterns represent each cluster. The network consists of 16 clusters, with Cluster #0 being the largest, which focuses on "Edge Computing" in blockchain, and its integration in IoT and intelligent contracts highlighted the cluster focuses on "Edge Computing" in blockchain, and #1 labeled "Centralised System" that contrasts with blockchain's decentralized nature with emphasis on Ethereum and Bitcoin.

Cluster #2, "Mass E-Voting," signals the potentiality of blockchain in enhancing transparency and security in voting systems. Consortium blockchain, the theme of Cluster #3, points to the efficacy of collaborative blockchain systems, while Cluster #4 revisits "Edge Computing." The “Pricing Scheme" in Cluster #5 reflects on the economic aspects of blockchain as the Ethereum gas price does. It means that the performances of all these clusters underscore the increasing synergy of decentralized blockchain networks. When it comes to Cluster #6, with a focus on "Underlying Cryptography," shows the foundational role of cryptography in blockchain, whereas the "Cloud Environment" of Cluster #7 suggests cloud computing's integration with blockchain technology. Data-driven analysis in Cluster # 8 and Machine Learning in Cluster #9 signal the increasing use of advanced data techniques in blockchain. The "Trust Ring" in Cluster #10 and " the Formal Definition Innovation Mechanism" in Cluster #11 stress on the importance of trust and formal structures in blockchain and the singular focus of Clusters The particular focus of Clusters #12 to #15 on "Data Trading Model," "Outlook," "COVID-19 Vaccine Supply Chain," and "Efficient Public Blockchain Client" respectively, reflect specific applications of blockchain in various domains. The citation counts across these clusters, with the highest number in citations, focus on ‘Edge Computing’ and ‘Centralized System,’ and reveal the research community's emphasis on blockchain's technological and structural aspects. This network depicts a complex landscape where blockchain technology intersects with several fields like IoT, cryptography, cloud computing, and machine learning, signifying its versatile and evolving nature in public blockchain research.

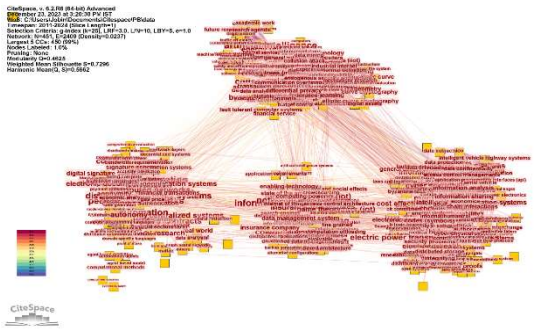

Figure 10 Network Visualisation Of Keywords

4.11. Keywords with Most Robust Citation Bursts

The top 20 keywords of most robust citation bursts during the period 2011 - 2024 in blockchain research reveal a comprehensive evolution of focal areas and technological developments in the field. Initially, in 2016, there was a definite interest in 'Bitcoin,' reflecting its role as the ground-breaking application of blockchain technology. This period also witnessed a steady rise in research related to 'distributed computer systems' and 'peer-to-peer networks,' the foundational elements of blockchain technology. A year later, in 2017, the focus shifted dramatically towards 'electronic money,' indicating a growing interest in digital currencies and 'data privacy.' This highlighted concerns and advancements in privacy within the blockchain space. In the same year, 'consensus protocols' emerged as a key area of the spotlight, which is essential for understanding the transaction validation in blockchain networks. Similarly, in 2018, the integration of blockchain with 'big data' and the 'Internet of Things (IoT)' displayed a move towards the application of blockchain in diverse technological domains, while 'fault tolerance' became a crucial factor for ensuring blockchain system resilience. As keywords like state-of-the-art, security and privacy, and proposed architecture indicated, 2019 marked a period of broad evaluation and advancement in the field. This year also brought attention to 'economic and social effects' and the contrast between 'centralized systems' and decentralized blockchain, along with a special focus on the role of 'miners' in blockchain networks. Entering 2020, 'privacy by design' in blockchain systems took center- stage, with reflection on a focus shift towards integration of privacy features at the design stage. Similarly, recent years, particularly from 2022 to 2024, have also seen a renewed and strong focus on 'privacy' and 'privacy-preserving techniques,' highlighting the crucial importance of these aspects in current blockchain research. In addition, the rising interest in 'Hyperledger Fabric' underscores the increasing emphasis on enterprise solutions and practical blockchain applications. Considering everything, these keywords portray a dynamic design of the blockchain research landscape. Although it starts with its initial association with cryptocurrencies, it displays all its far-reaching implications and latest applications across various sectors. This major shift reflects the technological development of blockchain and its appearance as a significant multidisciplinary research area with diverse and extensive significance.

Keywords	Year	Strength	Begin	End	2011 - 2024
bitcoin	2016	3.56	2016	2019	
distributed computer systems	2016	3.34	2016	2019	
peer to peer networks	2016	3.12	2016	2017	
electronic money	2017	11.52	2017	2019	
data privacy	2017	5.43	2017	2019	
consensus protocols	2017	3.42	2017	2019	
big data	2018	3.85	2018	2019	
internet of thing (iot)	2018	3.01	2018	2020	
fault tolerance	2018	2.98	2018	2019	
state of the art	2019	3.81	2019	2020	
security and privacy	2019	3.42	2019	2020	
proposed architectures	2019	3.38	2019	2020	
economic and social effects	2019	2.96	2019	2020	
centralized systems	2019	2.84	2019	2020	
miners	2019	2.72	2019	2021	
privacy by design	2020	8.49	2020	2021	
block chain	2011	22.27	2022	2024	
privacy	2022	3.75	2022	2024	
privacy preserving techniques	2021	3.54	2022	2024	
hyperledg fabric	2022	2.94	2022	2024	

Figure 11 Displays The 20 Keywords That Have The Strongest Citation Bursts

4.12. Country Collaborations

The timeline view of country collaborations demonstrates an intricate map of global collaborations in blockchain research, emphasizing the intricate web of academic partnerships across the globe. The network consists of 10 clusters, and the largest cluster, #1, with underlying Cryptography, has 18 members and a silhouette value of 0.854. It is labeled as underlying cryptography. The major citing article of the cluster is Abd-alrazaq, Aa (2021.0-JAN). The most cited members in this cluster are 85 United States, 45 United Kingdom, and 36 Canada. The second largest cluster (#1), Public Blockchain, has 13 members and a silhouette value 0.961. It is labeled as a public blockchain. The major citing article of the cluster is De,

collibus Fm (2022.0-JAN). The most mentioned members in this cluster are 171 China, 44 Italy, and 14 Bangladesh. The third largest cluster (#2), Blockchain-Based Electronic Voting SYSTEM, has 11 members and a silhouette value 0.774. It is labeled as a blockchain-based electronic voting system. The major citing article of the cluster is Anwar, ul Hassan C (2022.0-JAN). The most cited members in this cluster are 14 Saudi Arabia, 10 Romania, and 9 Pakistan. The 4th largest cluster (#3), Mechanism Design, has 10 members and a silhouette value of 0.877. It is labeled as a mechanism design. The major citing article of the cluster is Toyoda, K (2020.0-JAN). The most cited members in this cluster are 18 Singapore, 12 Norway, and 10 Indonesia. The 5th largest cluster (#4), Using Machine Learning, has 10 members and a silhouette value of 0.443. It is labeled as using machine learning. The major citing article of the cluster is Srivastava, V (2022.0-JAN). The most cited members in this cluster are 130 INDIA, 11 Malaysia, and 5 Viet Nam. The 6th largest cluster (#5), Key Agreement Protocol, has 6 members and a silhouette value of 0.903. It is labeled as a key agreement protocol. The major citing article of the cluster is Lansky, J (2021.0-JAN. The most cited members in this cluster are 46 South Korea, 8 Iran and 7 Taiwan.

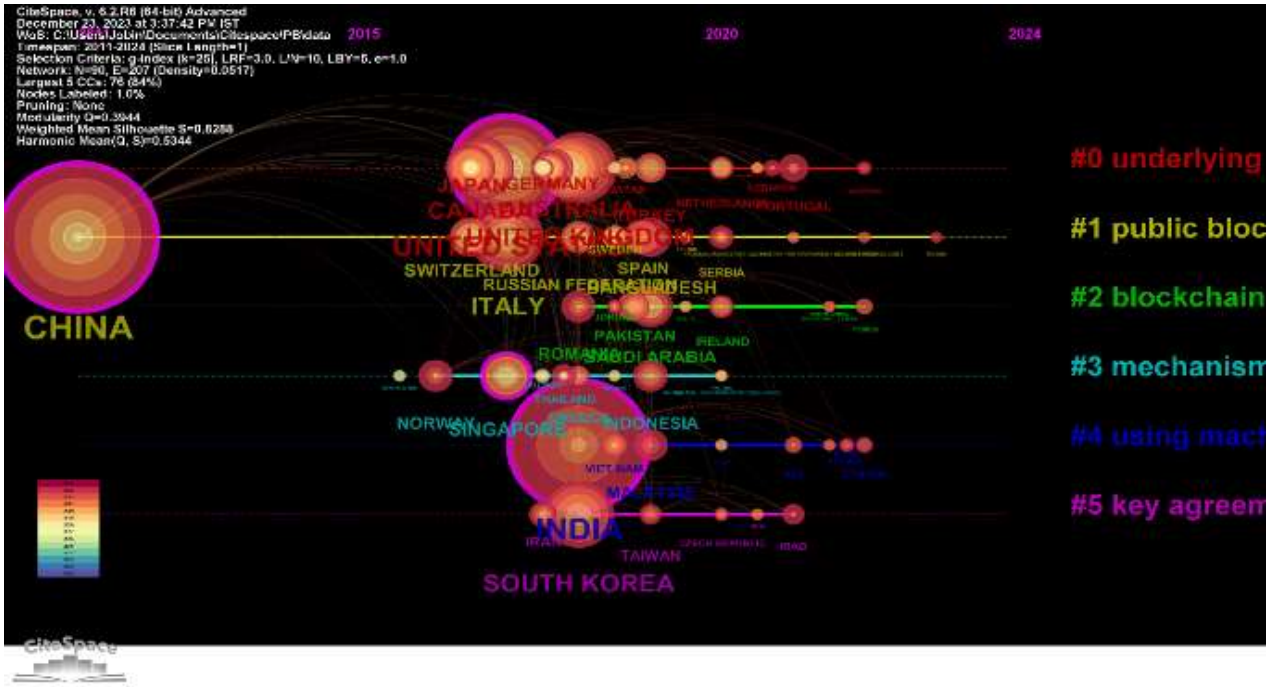

Figure 12 Timeline view of countries' collaborations

5. DISCUSSIONS

Bibliometric analysis of public blockchain research, spanning from 2011 to 2024, revealed a substantial body of work comprising 722 documents from 440 sources, with a notable annual growth rate of 8.82% and an average of 14.87 citations per document, indicating both a growing interest and significant scholarly impact in the field. The study, which encompassed a diverse range of document types, including articles, book chapters, and conference papers, highlighted extensive global collaboration, as evidenced by 2,074 authors contributing and a 22.71% rate of international co-authorships, underscoring the field's dynamic and globally interconnected nature. The scientific journey in public blockchain research from 2011 to 2024 showcases a trajectory from nascent interest, with a solitary article in 2011 and no publications from 2012 to 2015, to a peak in 2021 with 147 publications, followed by a slight decrease in 2022 and 2023, suggesting a shift from initial exploratory works to more focused, quality-driven research reflecting the field's maturity and the broadening applications of blockchain technology. Liu Y., Zhang Y., and Wang Y. emerge as top contributors, with nine publications each, displaying their roles as the most influential authors and thoughtful leaders in the field, as a

robust secondary tier of scholars, Chen L., Kumar N., Li J., Li Y., Li Z., Vecchio M., and Zhang J., each with seven notable contributions are actively present in the research. Leaders based in China demonstrate significant investment in blockchain technology with 667 impactful publications. India also confirms its second position in the row and reflects its role in innovation by showing an insatiable interest in the IT sector with 394 publications. Similar contributions by other countries- USA 218, Italy 141, and South Korea 118 display their focused research efforts. Apart from this, the UK, Australia, Canada, Singapore, and Japan have demonstrated their strategic blockchain integration across various sectors. The study emphasizes that the 'Lecture Notes in Computer Science' series seems most sought after among the top 20 sources in public blockchain research with 29 articles, underlining its academic importance and educational significance in blockchain, followed by 'IEEE Accesses with 25 articles, revealing IEEE's dedication to opening access to technical literature.

Process of the dynamic idea exchange and development in professional forums, while specialized journals such as 'Blockchain Research and Applications,' reflect a targeted investigation into specific areas of blockchain technology and the inclusion of conference emphasis the proceedings like 'ACM International Conference Proceeding Series' and 'IEEE International Conference on Communications.' Public blockchain research from 2018 to 2023 has evolved dynamically. It began with a focus on electronic money in 2018, which later shifted to electronic document identification systems, continued until 2020, and then to smart contracts and consensus protocols through 2021, reflecting an insatiable interest in blockchain's core mechanics. The exploration of platforms like Ethereum and applications in the Internet of Things (IoT) explains its expanding applications. The integration of blockchain with big data in 2019 and its central role in research from 2020 to 2022 with 569 signifies the exploration of platforms alongside, like Ethereum and applications in the Internet of Things, displaying its expanding applications. The latest trends shed light on a growing interest in practical implementations, including smart contracts, decentralization, and platforms such as Hyperledger Fabric and File System management, indicating an ever-widening scope of blockchain research and applications.

By categorizing, the thematic map reveals four distinct areas: essential themes like 'blockchain' and 'smart contract' in the lower right quadrant are well-developed and central concepts, the lower right quadrant represent well developed and major concepts; Niche themes such as 'healthcare' and 'smart power girls' in the upper left indicate well-developed yet specialized areas. Rising or declining themes like 'information use' in the lower left quadrant suggest nascent or waning areas; motor themes including 'internet of things' (IoT) represent developed and crucial topics. Thematic map effectively emphasizes the maturity, centrality, and development of various research areas within the public blockchain and offers strategic insights into the field's evolution. Cited reference network consists of 14 clusters. The top ranked item by citation counts in Christidis K (2016) is Cluster #2, with a citation count of 26. The second one is Nakamoto S (2019) in Cluster #7, with a citation count of 13. The third is Swan M (2015) in Cluster #3, with citation count of 11. The 4th is Gilad Y (2017) in Cluster #1, with a citation count of 10. The 5th is Zhou Q (2020) in Cluster #1, with a citation count of 9. The 6th is Poon J (2016) in Cluster #1, with citation count of 8. The 7th is Wood G (2014) in Cluster #2, with a citation count of 8. The 8th is Antonopoulos AM (2018) in Cluster #9, with citation counts 7. The 9th is Monrat AA (2019) in Cluster #5, with citation counts 7. The 10th is Dwivedi AD (2019) in Cluster #9, with citation counts 6. The cited journals network consists of 18 clusters. The top ranked item by citation counts is Nakamoto S (2017) in Cluster #2, with citation counts 231. The second one is Wood G (2017) in Cluster #3, with a citation count of 132. The third is Buterin V (2017) in Cluster #4, with citation count of 115. The 4th is Akamoto S (2016) in Cluster #12, with citation count of 75. The 5th is Zheng Z (2018) in Cluster #6, with a citation count of 66. The 6th is Castro M (2018) in Cluster #2, with citation counts 59. The 7th is Eyal I (2017) in Cluster #2, with citation count of 55. The 8th is Luu L (2017) in Cluster #2, with citation counts of 49. The 9th is Zhang Y (2019) in Cluster #5, with a citation count of 45. The 10th is Androulaki E (2018) in Cluster #1, with citation counts 42. The Co-occurrence network consists of 16 clusters, and most frequent keywords are "Blockchain," "blockchain," "smart contract," "Ethereum," "network security," "Internet of Things," "decentralised," "digital storage," "cryptography," and "data privacy," reflecting the technology's core aspects and emerging areas of

interest. The country collaboration network consists of 10 clusters, and the top-ranked item by citation counts is China (2011) in Cluster #1, with a citation count of 171. The second one is India (2018) in Cluster #4, with a citation count of 130. The third is the United States (2017) in Cluster #0, with a citation count of 85. The 4th is South Korea (2018) in Cluster #5, with a citation count of 46. The 5th is the United Kingdom (2018) in Cluster #0, with a citation count of 45. The 6th is Italy (2017) in Cluster #1, with citation count of 44. The 7th is Canada (2017) in Cluster #0, with a citation count of 36. The 8th is Australia (2018) in Cluster #0, with citation counts 33. The 9th is JAPAN (2017) in Cluster #0, with a citation count of 20. The 10th is Singapore (2017) in Cluster #3, with citation counts 18.

6. RESEARCH GAPS AND PRACTICAL IMPLICATIONS

Gaps remain in comprehensive research on blockchain integration with other developing technologies like artificial intelligence (AI) and machine learning (ML), especially in practical applications, despite the exploration of blockchain's intersection with big data and the Internet of Things (IoT). The thematic map trend topics of public blockchain research reveal several research gaps. Whether they are emerging or declining themes, such as "information use," "information systems," and "privacy issues," located in the lower left quadrant with low centrality and density, signify potential areas with the scope of further exploration, particularly how blockchain can enhance information systems and address privacy concerns across various domains. Niche themes like "health care," "security analysis," and "smart grids" show steady growth but lower centrality, showing a research opportunity in integrating these specialized areas largely into mainstream blockchain research and applications. Besides, the persistent interest in basic blockchain concepts calls for long-term outcome studies to assess their feasibility and socio-economic impact over time.

From a practical standpoint, the persistent focus on electronic document identification and smart contracts in blockchain research have impactful implications for sectors such as Legal, Financial, and Real-estate where authentication and contract automation are crucial. There are practical applications for enhancing data security in patient records and streamlining insurance claim processes in the healthcare and insurance sectors, identified as niche themes. Identifying declining themes signifies a need for innovation in these areas to ensure the inclusiveness of all critical aspects like information privacy and system usability. Internet of Things (IoT) 's categorization as a motor theme underscores its primary role in blockchain research, proposing practical implications for developing secure and efficient IoT applications by blockchain integration as in smart home systems and supply chain management. Finally, the high centrality and development of themes like cryptography and data privacy highlight their importance in practical blockchain applications, calling for the strategic focus of industries and policymakers on enhancing data security and privacy in blockchain implementations. These practical implications highlight the vibrant nature of blockchain research, providing opportunities for advancements across both the foundational and specialized domains.

Problems and Open Research Issues

The bibliometric analysis conducted on public blockchain research not only highlights the field's advancements but also underscores several pressing challenges and gaps that provide fertile ground for future studies. Key technical challenges include scalability, where the increase in transactions significantly slows down processes; security vulnerabilities, especially with the integration of smart contracts; and high energy consumption inherent in Proof of Work (PoW) systems. These issues suggest opportunities for developing more efficient consensus algorithms, enhancing cryptographic security measures, and exploring sustainable blockchain architectures. Furthermore, the study reveals critical thematic gaps such as the need for improved interoperability between disparate blockchain systems, and the lack of comprehensive research on the legal, regulatory, and socio-economic implications of blockchain technology. Addressing these challenges requires a multidisciplinary approach involving collaboration between technologists, legal scholars, and economists to foster the development of blockchain technologies that are secure, efficient, and aligned with global standards and needs. This opens several avenues for research that could potentially refine the deployment of public blockchains and broaden their application across various sectors.

Limitations

The study relies solely on data from Scopus, which, although extensive, does not encompass all existing literature and may omit relevant publications indexed by other databases. This could potentially bias the findings towards journals and conferences that are more commonly indexed by Scopus and overlook significant contributions available through other platforms. Secondly, the use of bibliometric software tools like Biblioshiny and CiteSpace, while facilitating detailed quantitative analysis, limits the exploration to quantitative data; qualitative nuances such as the impact of research on policy-making or practice implementation are not captured.

7. CONCLUSION

The study indicates an abrupt shift from the early interests in digital currencies to broader applications in various sectors. The main research areas have evolved, with significant contributions from leading countries like China, India, and the USA. The bibliometric analysis of public blockchain research reveals a rich and diverse academic landscape of rapid evolution of themes and an expansion of global collaborations. Evaluating most cited authors and documents highlights influential works and thoughtful leaders in the field. They identified research gaps, particularly in emerging and niche areas, pointing to potential future research directions. The practical implications of this study underline the relevance of blockchain technology in various applications, from digital authentication to intelligent contracts, indicating its growing relevance in today's digital world.

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