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Blockchain applications in management: A bibliometric analysis and literature review

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ABSTRACT

Blockchain has gained substantial recognition for its ability to induce transformation and innovation in existing business models and frameworks. Consequently, the application of this technology to the management domain and its processes has attracted increasing interest from academia and industry. Although research addressing the use of blockchain in management has gained momentum, this field presents a discontinuous overview of the current scope and boundary of the knowledge thereon. This study addresses this lacuna using bibliometric analyses to synthesize the prior literature. Data from *Scopus* 586 articles, entailing contributions from 72 countries, 273 journals, 1016 organizations, and 1284 authors, were analyzed. The findings indicate a maturing research focus on blockchain applications in specific managerial sectors, such as finance and supply chain management. However, this field's conceptual evolution is posited to be in its infancy in other sectors, such as for managing luxury goods and counterfeit products. Further, the thematic classification of the extant literature led to the identification of the following four major themes of research: *strategy and regulation, enablement and implication, multi-domain deployment,* and *the inefficiencies of bitcoin*. These findings are used to propose directions for further research in this field, such as the need for methodological advancement and theoretical grounding.

1. Introduction

Blockchain technology was originally introduced to the global community via bitcoin (Nakamoto, 2008) and was initially relegated for use as a cryptographic mechanism for disseminating bitcoin and associated cryptocurrency transactions (Naughton, 2016; Islam et al., 2019a, 2019b). However, the past five years have seen rapid growth in blockchain's application across multiple sectors, such as supply chain management (Saberi et al., 2019; Kshetri, 2018) and the Internet of things (IoT) (Jaoude and Saade, 2019; Novo, 2018; Reyna et al., 2018). Moreover, a recent report by Statista (2020) indicates that the global market for blockchain technology has grown rapidly in the past three years and is estimated to exceed USD 39 billion by 2025. This growth can be attributed to blockchain's capacity to create a transparent and trustworthy multi-stakeholder platform for digital transactions and transaction-oriented processes that function without unnecessary intermediaries (Böhme et al., 2015; Iansiti and Lakhani, 2017; Yli-Huumo et al., 2016). Scholars have begun to allude to blockchain as a foundational technology (Iansiti and Lakhani, 2017). Since this recognition, there has been a gradual progression in academic and practitioner research on blockchain and its possible applications (Forni and Meulen, 2016; Tandon et al., 2020). However, blockchain's application-oriented development is in its infancy with little understanding of institutional complexities surrounding its adoption (Janssen et al., 2020; Swan, 2015), and we hold that there are two main gaps in the current literature.

First, prior research on blockchain is mainly oriented toward financial transactions (Urquhart, 2016) and cryptocurrency, especially bitcoin (Bariviera, 2017; Corbet et al., 2018). This can be attributed to the fact that studies focusing on the application of blockchain technology beyond cryptocurrency have mainly appeared after 2015 (Miau and Yang, 2018; Yli-Huumo et al., 2016). Consequently, few studies have

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focused on assimilating information about how blockchain has contributed to improvements in management beyond the financial domain. We argue that this is a significant gap as it constrains our understanding of blockchain's application to other domains and suggests the need to expand the research scope.

However, to expand the scope of knowledge, it is imperative to first understand the existing boundaries of such knowledge. Prior scholars have attempted to delineate the intellectual boundaries of the research on blockchain through systematic literature reviews (SLRs). For instance, Jaoude and Saade (2019) presented a summary of the existing literature on blockchain applications across multiple domains. O'Donoghue et al. (2019) discussed the trade-offs and vulnerabilities involved in blockchain system design. Further, other scholars have also reviewed blockchain's applicability in specific sectors, such as healthcare (Agbo et al., 2019; Hölbl et al., 2018). For example, Tandon et al. (2020) studied the evolving nature of blockchain and its applicability to healthcare. The authors suggest that despite its capacity to improve prevalent healthcare standards, current knowledge is constrained by significant issues related to performance and implementation costs. Hasselgren et al. (2020) analyzed 39 articles to present a statistical summary of popular blockchain platforms and targeted areas for improvement in the context of healthcare. However, these SLRs have focused mainly on understanding blockchain's cross-sectoral applicability or the viability of different blockchain platforms for specific sectors, such as healthcare. We argue that this is a second gap as there is a lack of a holistic perspective, and adoption of a narrow focus, in studying the specific contexts of blockchain applications. Consequently, we posit a limited understanding of emergent research themes, focal application areas, and potential avenues for the future application of blockchain technology (Miau and Yang, 2018).

We argue that it is critical to address these gaps as scholars suggest that blockchain's widespread application may potentially restructure current legal (Swan, 2017), social (Swan, 2015, 2017), and business economies (Naughton, 2016; Xu et al., 2018). For example, Risius and Spohrer (2017) maintain that there is limited knowledge to effectively promulgate the multi-domain deployment of blockchain beyond finance and cryptocurrencies (Yli-Huumo et al., 2016). Moreover, studies such as Mendling et al. (2018) and White (2017) have also suggested an imperative need to expand the current scope of knowledge on blockchain applications in management and business process-related areas. Our study aims to address this need by discussing the following three broad research questions (RQs): **RQ1**. What is the present status of the research on blockchain applications in the management sector and its related sectors? **RQ2**.What research contexts and themes in this domain have been explored in the existing literature? **RQ3**. What avenues or themes can be addressed in future research?

Our study differs from the existing research in two ways. First, we focus attention on the application of blockchain in management (and related areas), which has been relatively less investigated compared to other areas, such as healthcare. We also adopt a more comprehensive perspective and study blockchain applications beyond finance and cryptocurrencies. Second, we adopt a two-level methodological approach to address these questions. We apply bibliometric analyses to gain a holistic understanding of blockchain applications in management by charting this research field's evolution and knowledge structure (Caviggioli and Ughetto, 2019). To further augment the findings, we apply content analysis to identify and examine the thematic cores of the existing research. Prior scholars have adopted a similar approach (e.g., Gurzki and Woisetschläger, 2017) in other contexts, such as sustainable manufacturing (Bhatt et al., 2020), applications of big data (Khanra et al., 2020), and eco-tourism (Khanra et al., 2021). While there are prior bibliometric-based studies on blockchain (e.g., Miau and Yang, 2018), to the best of our knowledge, none adopt such a two-pronged approach.

Our study's findings can enable the development of a coherent picture of the emergent research on blockchain applications in management and aid the advancement of both theory and practice. Our findings derived from the bibliometric analyses enable scholars to better understand the complexity and inter-disciplinary nature of prior research on blockchain applications in the management domain. Furthermore, through the content analysis, we identify several agendas for future research that scholars can address. For example, as suggested by Dan-vila-del-Valle et al. (2020), the insights derived from bibliometric studies can offer scholars a quantitatively grounded foundation for conducting a meta-analysis to further advance the field. Industry-based practitioners can also use the findings to understand the current scope of blockchain's application in management to identify opportunities for its improved implementation and further extend its application in related fields.

The remainder of the paper is structured as follows: Sections two and three present a brief overview of blockchain applications and bibliometric analyses, respectively. Next, section four discusses the methodology applied in this study and reports descriptive statistics on the research profile. Furthermore, the results of the bibliometric analyses are discoursed in section five, followed by an exhaustive discussion on the findings and future avenues of research in section six. The manuscript culminates with a summary of the study's contributions to theory and practice and its limitations in Section 7.

2. Blockchain application in management

Blockchain refers to an immutable chain of blocks, wherein each block holds information (or data) (Naughton, 2016; Swan, 2015). The blocks are linearly added to the chain in chronological order using cryptographic signatures (Naughton, 2016; Swan, 2015). These blocks construct a public and digital ledger of timestamped and updated transaction records, which may be securely distributed across a peer-to-peer network (Mendling et al., 2018). Thus, blockchain combines cryptography, smart contracts, peer-to-peer networks, consensus, and market mechanisms to create a secure computational infrastructure for inter-institutional data sharing (Mendling et al., 2018). However, blockchain's major innovation pertains to the decentralized nature of data sharing (Agbo et al., 2019; Swan, 2015; Yli-Huumo et al., 2016).

Every block on the ledger is encoded with an arithmetically produced code, referred to as a hash, which secures the blockchain against any falsification or tampering. This security is attributed to the partial determination of the blockchain through the hash of a previous block (Mendling et al., 2018; White, 2017). Thus, hashes are critical elements for establishing authenticated transactions (White, 2017). The transaction authentication and alignment of individual blocks in the chain are validated by miners' consensus (Agbo et al., 2019; Crosby et al., 2016). Thus, blockchain enables the decentralization and avoidance of a single point of failure in a trustless system by incorporating peer-to-peer consensus (Agbo et al., 2019; Swan, 2015). In terms of business- or management-related issues, smart contracts are a critical element of blockchain architecture with significant implications. These contracts are employed to create and execute contractual transactions among inter-organizational parties in a trustless manner and subject to pre-determined rules or criteria (Mendling et al., 2018; Yli-Huumo et al., 2016). Due to these elements, blockchain is posited to hold significant implications for applications across multiple knowledge-based and industrial domains (Miau and Yang, 2018).

The evolving applications of blockchain have been categorized into three tiers by Swan (2015). The first tier is referred to as blockchain 1.0, which focuses on currency; the second is called blockchain 2.0 and focuses on the deployment of contracts in the economic- and market-oriented milieu; the last and current tier is blockchain 3.0, which focuses on areas such as art, culture, education, and government (Swan, 2015). Recent years have also witnessed discussion centered on integrating blockchain in areas such as supply chains (Kamble et al., 2019), healthcare (Casado-Vara and Corchado, 2019), crowdfunding (Cai, 2018), and banking (Guo and Liang, 2016). However, it is posited that the extant research is focused on technical issues (Tandon et al., 2020),

such as performance (Mamoshina et al., 2018) or scalability (Quaini et al., 2018). Research focused on non-technical issues, that is, with an orientation toward management-related issues, is limited in terms of available information and posited to reflect the degree of fragmentation (Risius and Spohrer, 2017; Yli-Huumo et al., 2016). In fact, Tandon et al. (2020) discuss the need to adopt a more holistic and strategic perspective on blockchain's adoption and implementation to address cross-cultural and cross-institutional differences. These studies suggest a need to streamline the existing research in the field to identify extant gaps and a prospective scope of research. For this purpose, bibliometric methods of analysis are utilized in this study.

3. Bibliometric analyses

Bibliometric analysis was introduced by Pritchard (1969) and has gained ground as a scientific method for understanding a research field's temporal evolution from a multi-disciplinary perspective (Bhatt et al., 2020; Caviggioli and Ughetto, 2019; Khanra et al., 2020, 2021). Bibliometric analysis facilitates a comprehensive understanding of a research area and the mapping of its boundaries and the identification of influential authors and new directions for future research (Donthu et al., 2020; Leung et al., 2017; Xu et al., 2018). This technique has been employed by scholars across multiple domains, such as manufacturing (Caviggioli and Ughetto, 2019), arts-based management (Ferreira, 2018), marketing (Gurzki and Woisetschläger, 2017), social media or networks (Leung et al., 2017; Shiau et al., 2017), finance (Corbet et al., 2018) as well as technology and innovation (Li et al., 2018a; van Oorschot et al., 2018).

The choice of the bibliometric technique was prompted by its ability to establish the intellectual structure of a field without subjective bias (Xue et al., 2018). Scholars have suggested that a bibliometric technique is a cross-disciplinary method enabling the effective mapping of the directions and themes addressed during the development of a field of research (Khanra et al., 2020, 2021; Liao et al., 2018; Martínez-López et al., 2018). Consequently, our study focuses on understanding how research oriented toward understanding the application of blockchain in management and related areas has evolved since the origin of this technology.

In this study, bibliometric analysis is carried out using bibliographic coupling, co-occurrence, and network analysis. Our approach is similar to that followed by Khanra et al. (2020), who applied bibliometric analyses to delineate the intellectual structure of, gaps within, and future research directions for the research on big data analytics and enterprises.

Each of these techniques has not only inherent strengths but also certain weaknesses, which may be addressed by their concurrent application to a problem, as shown by prior bibliometric studies (Bhatt et al., 2020; Ferreira, 2018; Khanra et al., 2021, 2020; Leung et al., 2017; Xu et al., 2018). The description, strengths, weaknesses, and complementarity of each of these techniques are discussed in Table 1. To answer RQ1 and develop a holistic profile of the research status in this field, the techniques of bibliographic coupling, co-occurrence, co-authorship, citation, and co-citation analyses have been utilized. To understand the evolution of this field and focal areas that have been investigated by prior scholars (RQ2), dynamic co-citation and co-word analyses have been conducted. PageRank and citation analyses have been performed to identify the top 10 influential publications in each focal area or research theme. Content analysis was employed to explain the key issues in each area. Based on the results of the dynamic co-citation, coupling, and citation analyses, potential avenues for future research have been proposed in response to RQ3.

4. Methods

This study's focus pertains to blockchain applications in business management across sectors such as economics, accounting, finance, decision sciences, social sciences, energy management, and environmental science and management. This study follows a methodological approach similar to that of Khanra et al. (2021, 2020), Fahimnia et al. (2015), and Ferreira (2018). Based on these studies, articles that explore the field of blockchain application in aforementioned domains have been scanned, analyzed, and curated to assimilate an appropriate dataset.

4.1. Database curation

We employed a two-step approach to identify the articles to be analyzed and reviewed to accomplish this study's purposes. In the first step, appropriate search terms were defined for mining the *Scopus* database for relevant articles. This database was chosen due to its comprehensive coverage of peer-reviewed research in reputable journals and its pervasive presence in the academic community (Caviggioli and Ughetto, 2019; Donthu et al., 2020; Fahimnia et al., 2015). In the second step, we employed specific criteria to determine the inclusion of articles in our database for the bibliometric and content analyses.

4.1.1. Identifying keywords for database search

The keyword selection was based on a preliminary review of the available literature. A Google Scholar search was conducted with the keyword "blockchain," and the first 50 studies were briefly reviewed to identify other terms that have been synonymously or prolifically applied in the extant literature. Further, previously published SLRs on blockchain and articles published in journals ranked ABS3 (and above) were reviewed to explore potential keywords for the database search. Based on the review, the terms "ethereum" and "distributed ledger technology" were also considered to be viable keywords.

To further establish the viability of these keywords, we invited a panel of three experts from academia who have published extensively in the field of information systems, especially on blockchain. These experts were apprised of the RQs and asked to review the appropriateness of the chosen keywords. Based on their suggestion, the keyword "smart contracts" was also included in the database search. Thus, the keywords used for collecting data were limited to "blockchain," "distributed ledger technology," "smart contracts," and "ethereum." The search strings "blockchain or ethereum" OR "blockchain or distributed ledger technology" OR "blockchain or smart contracts" were selected to scan the chosen database (Agbo et al., 2019; Jaoude and Saade, 2019) on August 30, 2019.

4.1.2. Selecting articles for the database

To curate relevant research for this study, we limited our search of *Scopus* to include only those documents that were categorized as articles and excluded all other document types, such as reviews, conference papers, editorials, and book chapters. No range was specified in terms of the publication year to ascertain that all studies since the introduction of the term "blockchain" were considered for inclusion in the final dataset. Next, we included only those articles in the database published in peer-reviewed journals across the categories of business, management & accounting, social sciences, economics, econometrics & finance, decision sciences, energy, and environmental science. This inclusion criterion was applied to meet the objective of our study to consider management and related areas. Thus, we excluded other study domains, such as engineering and law. Lastly, we also applied an inclusion criterion for the language of publication and considered only those articles that were published in the English language.

The three search strings and these article selection criteria were utilized to create a comprehensive database of 586 documents (refer to Table 2). The results were stored in research information system (RIS) and comma-separated value (CSV) formats for further analysis with appropriate citation and bibliographic information.

Table 1
Applied techniques and their strengths and weaknesses.

Technique	Description (Reference)	Strength	Weakness	Complemented by
Bibliographic coupling	Assesses the occurrence of a standard reference to a document in the bibliographies of two or more publications (Ferreira, 2018; Kessler, 1963).	• Lends insights into the current and prospective research boundaries of a particular subject matter (Boyack and Klavans, 2010; Li et al., 2018a). • Assumes that higher numbers of shared references between publications are indicative of a shared and stronger intellectual foundation (Li et al., 2018a).	• Retrospective direction of referencing. • Potential clustering of more recent but few old documents/ publications (van Oorschot et al., 2018).	Co-citation analysis may provide a more forward-based outlook (Ferreira, 2018; Leung et al., 2017).
Co-word (co-occurrence)	Measures the co-occurrence of keywords (Callon et al., 1991).	Enables the visualization of core content of publications (Leung et al., 2017; Vallaster et al., 2019). Potential identification of emergent publication or research trends.	• Temporal changes in the use of keywords may produce a certain degree of inherent instability for outcomes (Leung et al., 2017).	Concurrent use of co-citation may provide a more refined understanding of a field's development and intellectual configuration (Chang et al., 2015; Leung et al., 2017).
Co-authorship analysis	Measures the most productive set of documents and identifies units with the highest degree of joint publications (Martínez-López et al., 2018).	Assists in ascertaining the degree of joint research among authors, institutions, and countries. Can enable scholars to determine degree of joint productivity.	• Relatively lesser attention has been paid to visualization of co-authorship networks (Van Eck and Waltman, 2014).	–
Citation analysis	Asses Evaluates the level of acceptance of a publication via a quantified assessment of its reference by other published reports (Ding and Cronin, 2011; Xu et al., 2018).	• Assists in understanding the influence and popularity of individual documents and collaborative network of citations.	• Scholars have raised concerns about a substantial difference between a publication's popularity and prestige (Ding and Cronin, 2011). • May offer limited meaningfulness of results unless comparisons are held among researchers in similar career stages or the same field of research (Agarwal et al., 2016). • Citation trends across different fields may vary (Agarwal et al., 2016).	Concurrent use of prestige analysis may offer a more comprehensive understanding of its impact.
Prestige analysis PageRank analysis	Assesses the occurrence of a publication's citation by other highly regarded publications (Ding and Cronin, 2011; Xu et al., 2018).	• Assists in the comprehensive evaluation of the scholarly impact of a publication. • PageRank analysis can assist in the concurrent analysis of a publication's prestige and popularity.	• Only considers impact created via citations in well-regarded publications.	Citation analysis.
Co-citation analysis	Identifies occurrences where two articles are independently cited by one or multiple articles (Shiau et al., 2017).	• May be performed to configure the primary issues and concerns of a particular field of study (Small, 1973). • Relationships between different disciplines may be explicated. Exploration of these relationships may yield interesting results and usually cannot be explored via other methods (Wallin, 2005). • Effective clustering of documents with older publication dates (van Oorschot et al., 2018). • Enhanced measure of exploring thematic and semantic similarity among analyzed documents (Small, 1973; Shiau et al., 2017).	• Limited in its representation of the contents of cited publications.	Co-word analysis.
Dynamic co-citation analysis	Assists in explicating core areas and trends in the temporal development of a research field.	• Facilitates an understanding of the evolution of a field of research over time. • Can enable scholars to understand the most popular and prestigious publications in specific clusters.	• Limited in its representation of the contents of cited publications.	Co-word analysis (for identifying focal themes addressed by articles). PageRank and citation analysis (for identifying popular articles in each cluster).

Note: PageRank analysis is an extension of the original algorithm by Brin and Page (1999), which was designed to prioritize webpages based on a Google search. Explanation for PageRank analysis: Assuming that a publication (A_0) received a forward citation from n number of publications, namely, A_1, A_2, …, A_n, that is cited by $\gamma(A_1)$, $\gamma(A_2)$, …, $\gamma(A_n)$, respectively. The PageRank score of A_0, which is expressed as $PR(A_0)$, is provided by the following equation, when the fraction δ adjusts for the damping factor of the random walk while propagating through the chain of citations (Brin and Page, 1998; Xu et al., 2018).

$$PR(A0) = \frac{(1-\delta)}{n} + \delta\left[\frac{PR(A1)}{\gamma(A1)} + \frac{PR(A2)}{\gamma(A2)} + \cdots + \frac{PR(An)}{\gamma(An)}\right].$$

Table 2
Search results.

Search keywords	Search results (no. of papers) Initial	Refined	Inclusion criteria
Blockchain or ethereum or distributed ledger technology or smart contract	1658	586	Focus on management & allied areas, English language journals, articles only
Blockchain	1719	550	
Smart contract		246	
Ethereum	196	68	
Distributed ledger tech	195	1	

4.2. Initial data statistics

The 586 articles included in the final dataset were published between 2015 and 2019 across 273 journals, which indicates that the application of blockchain to management and related areas is a very recent phenomenon (refer to Fig. 1). Statistics show that social sciences (29%), business, management, and accounting (32%) as well as economics and finance (1%) have implemented significant application of blockchain. However, the use of blockchain also seems to have become prevalent in the domains of energy (6%) and decision science (7%) in recent years although with comparatively lesser intensity (refer to Fig. 2).

Researchers in this field have utilized a diverse range of publication outlets, including journals related to accounting, information management, strategy, and sustainability. However, only 27 of these journals have contributed five or more articles to this domain, which accounts for approximately 41% of the contribution to the total literature (refer to Table 3). This finding suggests that although an increasing number of studies are adopting blockchain across various domains, the publication of these studies is not relegated to a few journals and is significantly dispersed.

The descriptive statistics about bibliographic information obtained from *Scopus* can also help explain this research domain's scope in terms of authors' contributions and geographical boundaries. According to the *Scopus* database, three authors are identified as leading contributors, with five articles by each of the following authors: D. Roubaud (Montpellier Business School, France), F. Wang (National University of Defense Technology), and Y. Yuan (Institute of Automation Chinese Academy of Sciences). The analysis of authors' geo-local affiliations suggests that the United States of America (U.S.A., 135) and the United Kingdom (U.K., 82) are the leading countries in terms of the number of articles that contribute to this field (refer to Table 4). These two countries account for approximately 37% of the total number of publications in this area, followed by China (62) and India (47).

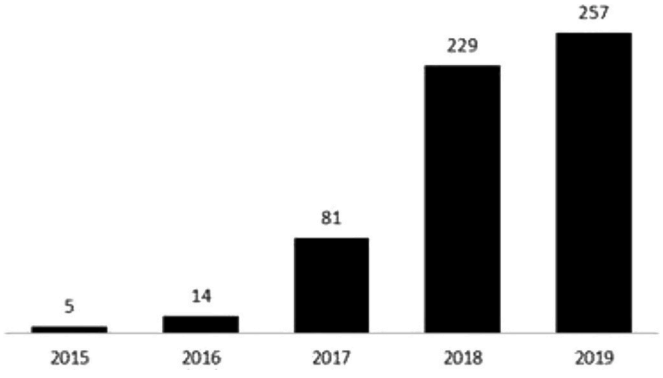


Fig. 1. Number of articles published per year.

5. Analysis

Prior research has employed multiple software packages to conduct bibliometric and citation analyses. The most commonly utilized software includes Bibexcel (Fahimnia et al., 2015), Gephi (Fahimnia et al., 2015; Xu et al., 2018), VOSviewer (Caviggioli and Ughetto, 2019; Ferreira, 2018; van Oorschot et al., 2018), Pajek (Persson et al., 2009), and CiteSpace (Li et al., 2018a). We utilize two popular platforms, namely, VOSviewer and Gephi, for our study, which is an approach that has also been followed by recent bibliometric studies (Khanra et al., 2020, 2021). While conducting the analysis, we mainly referred to the manuals for these software (Van Eck and Waltman, 2014, 2018; Bastien et al., 2009) as well as the studies of Fahimnia et al. (2015), Caviggioli and Ughetto (2019), and Khanra et al. (2020, 2021) for analyzing the data and reporting results.

Bibliographic coupling was conducted via VOSviewer, which enables an efficient investigation of large datasets and provides a range of innovative data visualization options (Fahimnia et al., 2015; Van Eck and Waltman, 2014). The network analysis of publications was performed via citation analysis, co-citation, and the topical clustering of data using VOSviewer and Gephi. The addition of Gephi in the analysis is based on its flexibility and specialized capabilities for filtering and clustering data (Xu et al., 2018). VOSviewer automatically creates clusters by assigning one node (publication, author, etc.) to one cluster by applying association strength normalization and the visualization of similarities (VOS) mapping technique (Van Eck and Waltman, 2014). The number of clusters may be affected by the resolution, and therefore optimal resolutions for each network analysis were determined according to the prominence and clarity of the clusters that emerged during the analysis.

5.1. Bibliographic coupling

The analyses included 273 journals, 72 countries, and 1016 organizations, which were ranked according to total link strength (TLS). TLS measures the strength of the extant links of a researcher or article with other researchers and articles (Vallaster et al., 2019; Van Eck and Waltman, 2014). Specific threshold criteria were applied in each analysis to ensure the appropriateness of the included data. The analysis of the coupling strengths between institutions and countries suggests significant contributions of 175 of a total of 1284 authors included in this study. The analysis also suggests a particularly noteworthy contribution of authors based in developed countries, such as the U.S.A, the U.K., and Germany (refer to Table 5). However, some developing countries, such as India, are also making significant contributions to the discussion on blockchain application in management.

5.2. Co-occurrence analysis (co-word analysis)

A co-occurrence analysis was conducted with 1541 authors and 1473 indexed keywords to understand the core intellectual topic addressed by the extant research. Among the author keywords depicted in Fig. 3, bitcoin and cryptocurrency emerged as significant keywords in the most integrated network, which can be explained by studying the interlinking lines between the keywords. These lines represent the strength and the relevance of the links between the nodes (keywords) (Donthu et al., 2020). This result was expected due to blockchain's inception as a bitcoin dissemination mechanism (Nakamoto, 2008). However, other prominent combinations include "blockchain-smart contracts," "blockchain—electronic money" and "blockchain—supply chain" (Figs. 3 and 4). These linkages indicate the rising importance of specific elements of this technology that have been useful in other non-financial fields, such as supply chain management. The threshold for this analysis was limited to the inclusion of keywords that occur a minimum of four times. The TLS for the top 10 authors and the index keywords are reported in Table 6.

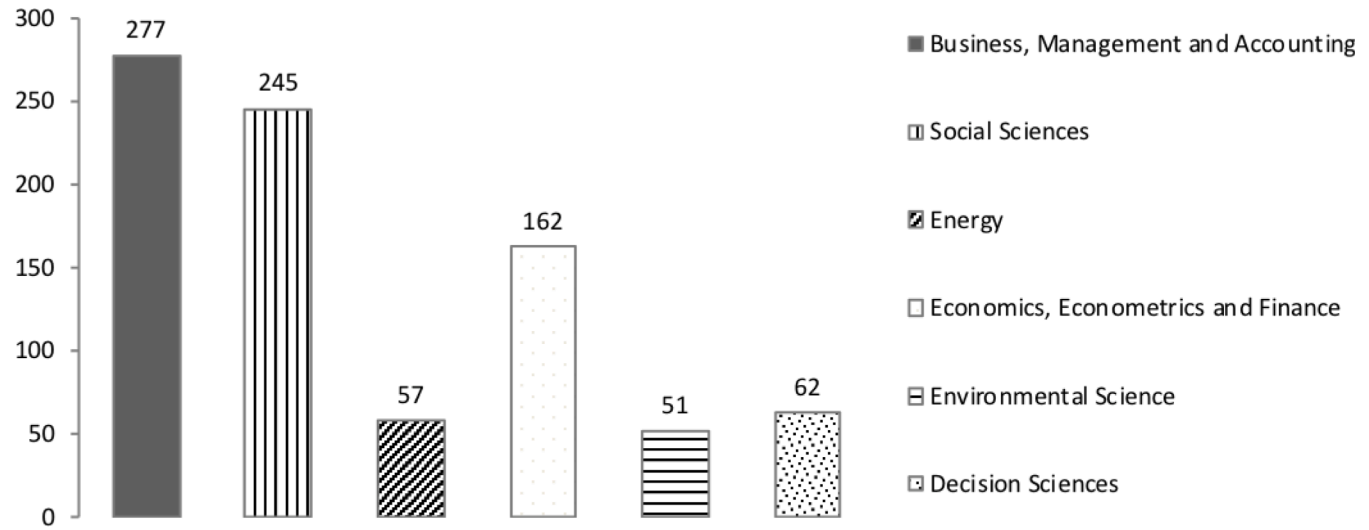


Fig. 2. Contribution by subject area. Note: Some articles were included in more than one area due to which total number of articles in this figure exceeds total nmber of aricles included in the final dataset

Table 3
Publishing contribution of top 10 journals to the field ($N = 586$).

Journal title	2015	2016	2017	2018	2019
International Journal of Recent Technology and Engineering				2	23
Sustainability Switzerland				12	2
Strategic Change			11	1	2
Computer Law and Security Review			2	9	2
Economist United Kingdom	2	1	4	5	0
Energies			1	5	5
IEEE Security and Privacy	1			8	2
Information Services and Use				10	
Computers and Security				1	8
International Journal of Information Management				1	8

Table 4
Top 10 countries by contribution to the field ($N = 586$).

Country	No. of studies
U.S.A.	135
U.K.	82
China	62
India	47
Germany	37
Australia	36
Russian Federation	35
Italy	21
Netherlands	21
Canada	19

Table 5
Bibliographic coupling of contributing authors, countries, and organizations.

S No.	Top 10 authors	Top 10 countries	Top 10 organizations
1	L. Xuan, Hunan University (294.23)	U.S.A (2484.14)	Wharton University, U.S.A. (182.67)
2	X. Wang, Qingdao Academy (283.12)	U.K. (2277.21)	University of Michigan, Law, U.S.A. (182.67)
3	A. Gunasekaran, California State University (280.28)	China (1488.23)	The University of Minnesota, U.S.A. (172.33)
4	Z. Li, Zhejiang University (271.10)	Germany (1322.84)	Old Dominion University, U.S.A. (172.33)
5	J. Wang, Chongqing University (213.91)	Australia (1059.67)	The University of Cambridge, U.K. (172.27)
6	M. Kouhizadeh, Worcester Polytechnic Institute (193.72)	India (909.38)	Nanyang Technological University, Singapore (172.27)
7	R. Owen, Middlesex University (185.28)	The Netherlands (888.11)	The University of Surrey, U.K. (169.50)
8	N. Cornell, University of Michigan, Law (182.67)	France (759.65)	National Institute of Industrial Engineering, India (165.60)
9	K. Werbach, Wharton University (182.67)	Singapore (665.28)	California State University, U.S.A. (165.60)
10	K-K, R. Choo, the University of Texas at San Antonio (180.42)	Italy (574.94)	The University of Manchester, U.K. (163.00)

Note: Threshold criteria: minimum five citations, TLS indicated in parentheses.

As illustrated in Figs. 3 and 4, the significant author and indexed keywords indicate that the focal areas of the extant research primarily pertain to fintech, cryptocurrency, and smart contracts. These findings suggest the academic community's interest in exploring blockchain's potential applicability for transaction-oriented managerial processes across different areas, such as finance, supply chain, manufacturing, and decision making. There seems to be increasing interest in blockchain's potential application in sustainability, resource conservation, and renewable energy. Furthermore, keywords such as cybercrime, microgrids, and crowdfunding also indicate an emerging research interest in blockchain's potential application in advanced and niche fields. Similarly, the index keywords show enhanced research focus on managing information, supply chain, and energy management while focusing on research protocols and related issues, such as consensus protocols, ethereum, and algorithms.

5.3. Network analysis

Co-authorship and citation analyses were employed to further understand the structure of scholarly contributions in this field. The co-authorship analysis indicates the presence of five major collaborative clusters and measures the extent of joint publications between authors, contributing to knowledge expansion in this field of study (Caviggioli and Ughetto, 2019). The TLS measures and links among the top five authors in each cluster are indicated in Table 7. The most prominent and clear co-authorship clusters were obtained at a resolution of 1.0 (refer to Fig. 5). The network connections were determined to be slightly

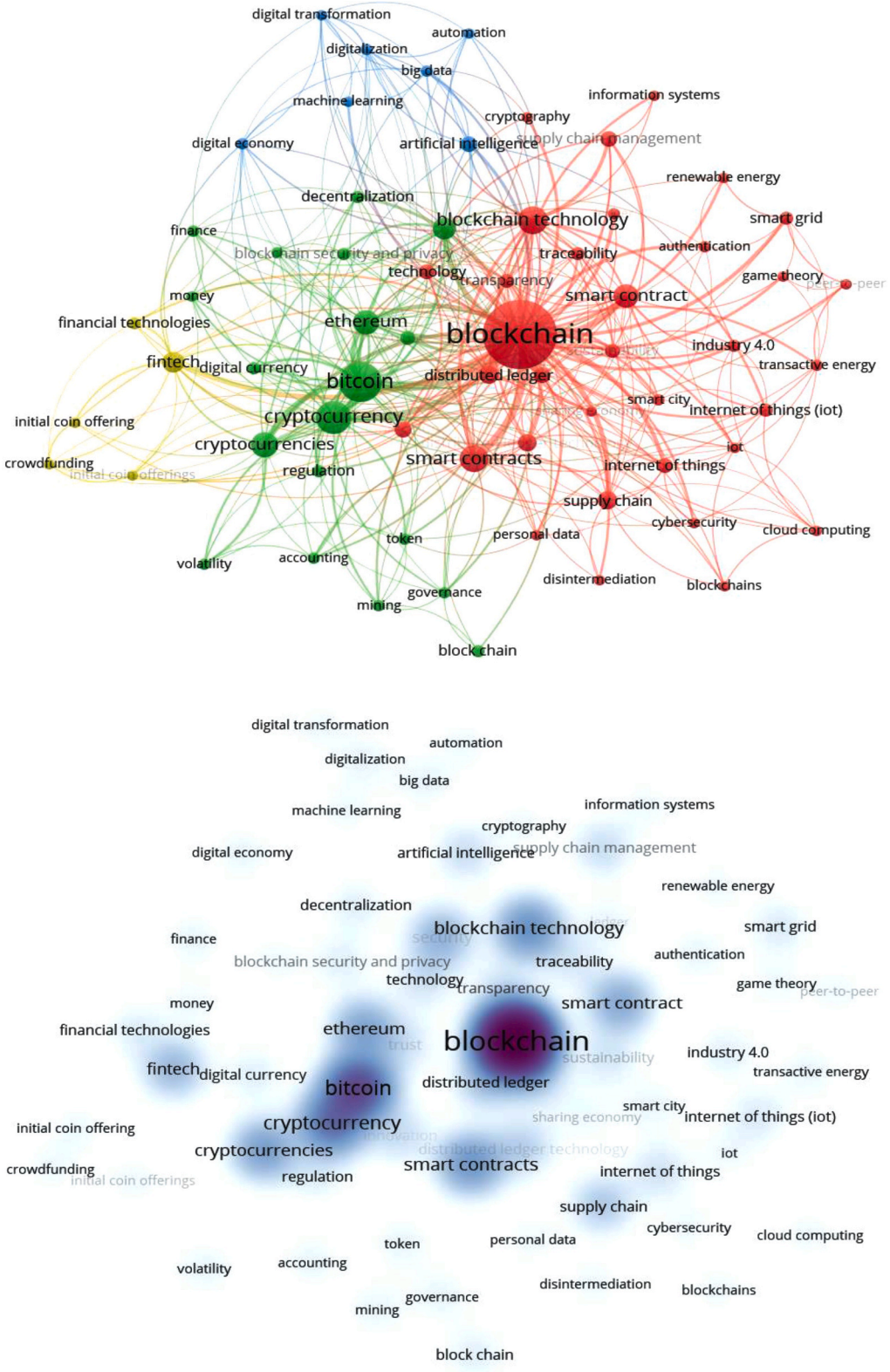


Fig. 3. Network and density diagrams for author keywords. Note: Threshold criteria of minimum 4 keywords, resolution = 0.8.

different from the results of the coupling analysis. Strongly collaborative authors from cluster 1 (19 authors, green) include F-Y. Wang (National University of Defense Technology, China) and X. Wang (Qingdao Academy, China). In cluster 2 (12 authors, blue), the most productive authors include W. Viriyasitavat (Chulalongkorn University, Thailand), Y. Wang (Cardiff University, U.K), and J. Wang (Chongqing University, China). In cluster 3 (7 authors, yellow) J. Li (Guangdong University of Technology, China) and K. K-R. Choo (University of Texas, San Antonio, U.S.A.) emerge as strong contributors. Cluster 4 (19 authors, red) indicates the productivity of Y. Zhang (Beihang University, China) and X. Liu (Fuzhou University, China). In contrast, in cluster 5 (7 authors, purple) Y. Li (Shaanxi Normal University, China) and Y, Zhao (Shaanxi

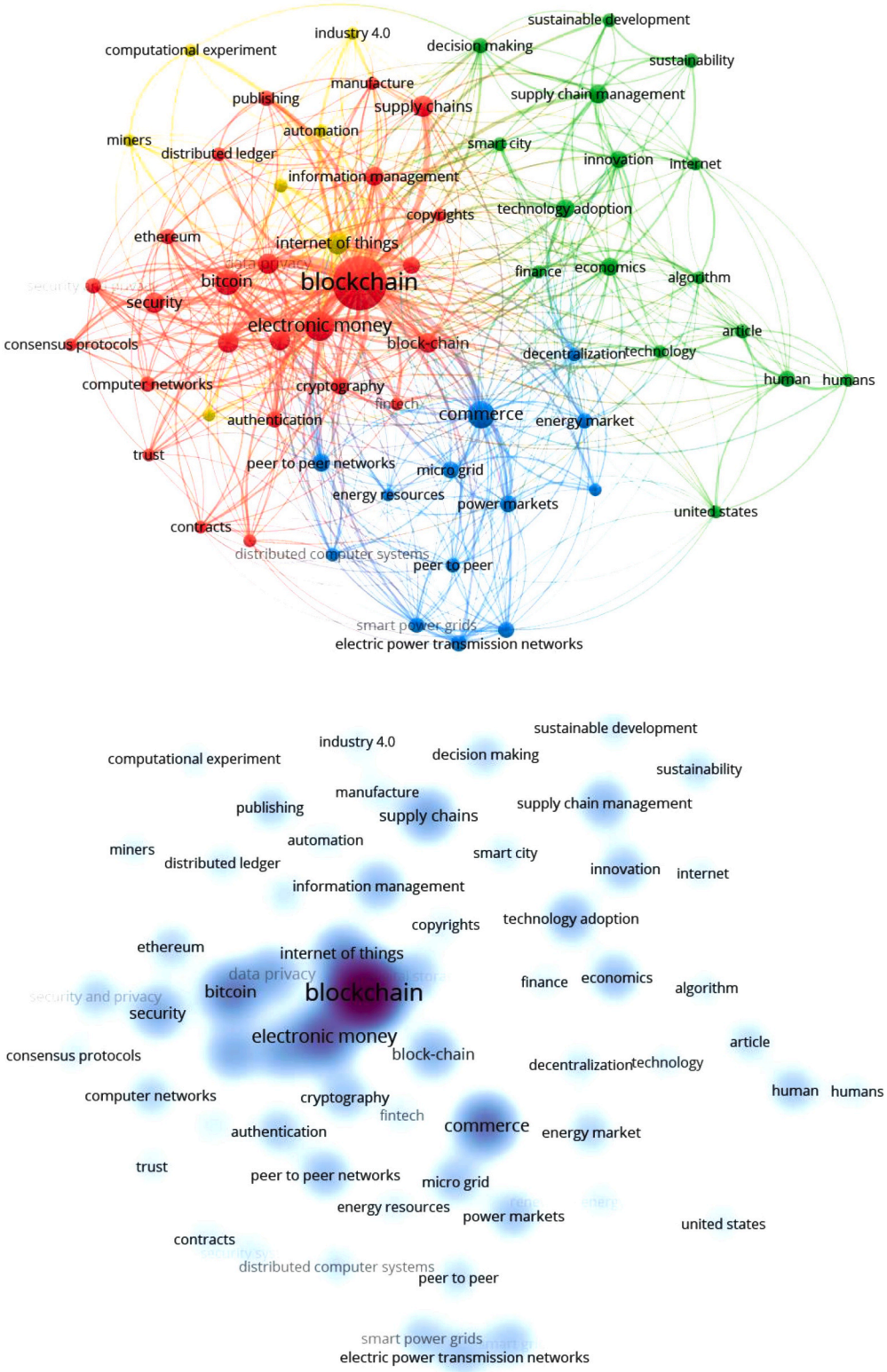


Fig. 4. Network and density diagrams for index keywords. Note: Threshold criteria of minimum of 5 keywords, resolution = 0.8.

Normal University, China) emerge as collaborative authors.

A few of these authors also figure in the top 10 authors indicated in bibliographic coupling (refer to Table 5). Furthermore, many of these authors are based in geographically similar areas, especially in Southeast Asian countries such as China and Thailand. This finding indicates the significance of the geographic locations of contributing authors who may prefer collaborating, and networking with authors who are based in proximate locations.

The co-authorship analysis, based on 1016 organizations, indicates the presence of two clusters that represent 21 strongly connected organizations (refer to Fig. 6). Cluster 1 (red) includes organizations from both practitioner and academic communities based in Australia and European countries such as Denmark, Italy, and Germany. Cluster 2 includes only two organizations—Eindhoven University of Technology

Table 6
TLS for author and index keywords.

S. No.	Author keyword	TLS	Index keyword	TLS
1	Blockchain	311	Blockchain	138
2	Bitcoin	87	Electronic money	34
3	Cryptocurrency	55	Commerce	28
4	Blockchain technology	39	Bitcoin	24
5	Smart contract	36	Internet of things (IoT)	17
6	Ethereum	28	Supply chains	16
7	Security	22	Network security	15
8	Fintech	20	Smart contracts	14
9	Distributed ledger	15	Security	14
10	Supply chain	15	Data privacy	14

(Netherlands) and the University of California, Los Angeles (UCLA, U.S.A.). Organizations in cluster 1 have a total of 19 links (TLS = 1.0), Eindhoven University has 20 links (TLS = 2.0), and UCLA has one link (TLS = 1.0).

The network diagram for the co-authorship analysis according to countries shows that 31 countries can be categorized into four main clusters (Fig. 7). The TLS measures of the key nodes in each cluster are shown in Table 8. Cluster 1 (red) has 10 countries, cluster 2 (green) has nine countries, cluster 3 (blue) includes seven countries, and cluster 4 (yellow) has five countries (Fig. 7). Herein, India (cluster 1), the U.S.A. (cluster 2), the Russian Federation (cluster 3), and China (cluster 4) are indicated to be the most influential according to node size illustrated in Fig. 7. These clusters also appear as strongly connected in the network, indicating a higher degree of citations among the publications that originate in these countries.

5.3.1. *Citation analysis*

Citation analysis was executed by VOSviewer to understand the status of the research on blockchain applications in the context of significant authors, countries, and organizations (refer to Table 9). In terms of countries, the U.S.A, the U.K., and China are among the top 10 contributors to this field's most cited articles. This finding suggests that authors in these countries may be addressing contemporary and globally relevant research topics in this field. In most cases, the identified institutions reflect affiliations of highly cited articles in the field, such as the Karlsruhe Institute of Technology (Mengelkamp et al., 2018) and the University of Cambridge (Sikorski et al., 2017). In terms of institutions, the citation analysis identifies the significant contributions of the University of Cambridge and Nanyang Technological University, which were also represented in the results of bibliographic coupling (Table 5). However, to reiterate, bibliographic coupling represents a more effective clustering of recent documents, indicating the shared intellectual foundation of the coupled documents. In contrast, citation analysis is a measure of the acceptance of a published document. The representation of the results from the bibliographic coupling in the results of the

Table 7
TLS and links for the co-authorship analysis of authors.

	Links	TLS		Links	TLS		Links	TLS
Cluster 1 (green)			**Cluster 2 (blue)**			**Cluster 3 (yellow)**		
Wang, X.	20	4	Wang, J.	13	3	Li, J.	5	4
Wang, F.-Y.	16	5	Xu, L.D.	4	3	Wu, J.	3	3
Yuan, Y.	16	5	Viriyasitavat, W.	2	3	Choo, K.-K.R.	3	2
Lu, Q.	12	2	Wang, Y.	4	2	Lee, J.	2	1
Yang, W.	5	2	Li, L.	3	2	Chen, L.	2	1
Cluster 4 (red)			**Cluster 5 (purple)**					
Liu, X.	8	4	Li, Y.	6	3			
Li, Z.	6	3	Zhao, Y.	3	2			
Zhang, Y.	6	3	Chen, Z.	3	1			
Wang, W.M.	6	2	Luo, J.	3	1			
Huang, G.Q.	6	2	Wu, Y.	3	1			

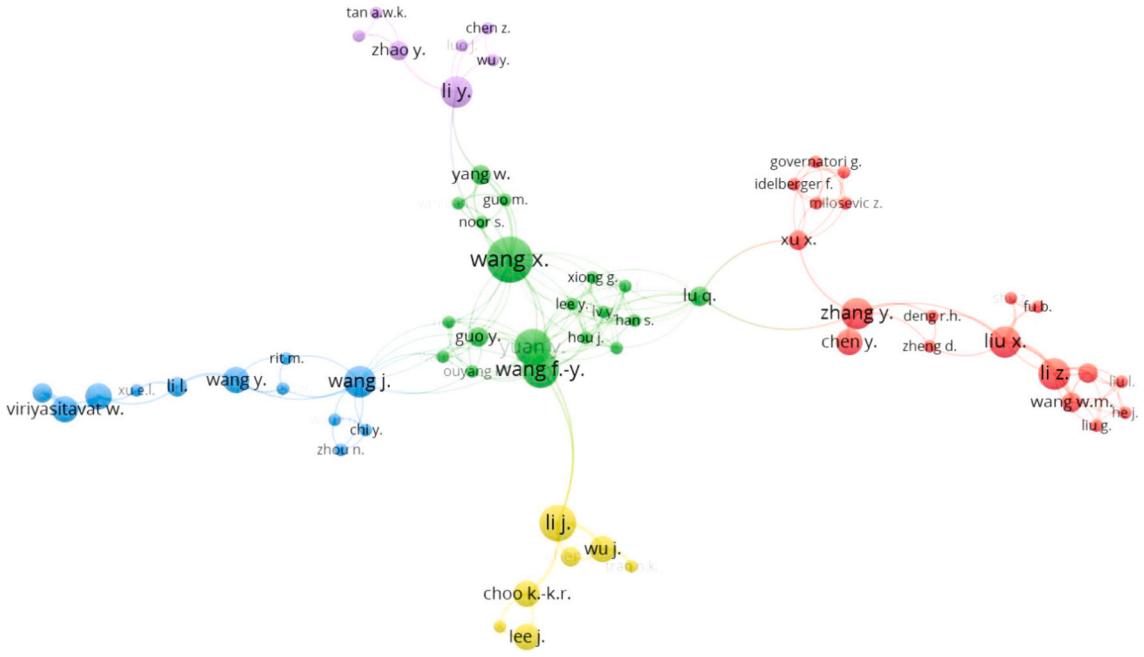


Fig. 5. Co-authorship analysis of authors. Note: Threshold criteria—minimum of five citations; resolution—1.0; 64 of 285 authors are connected.

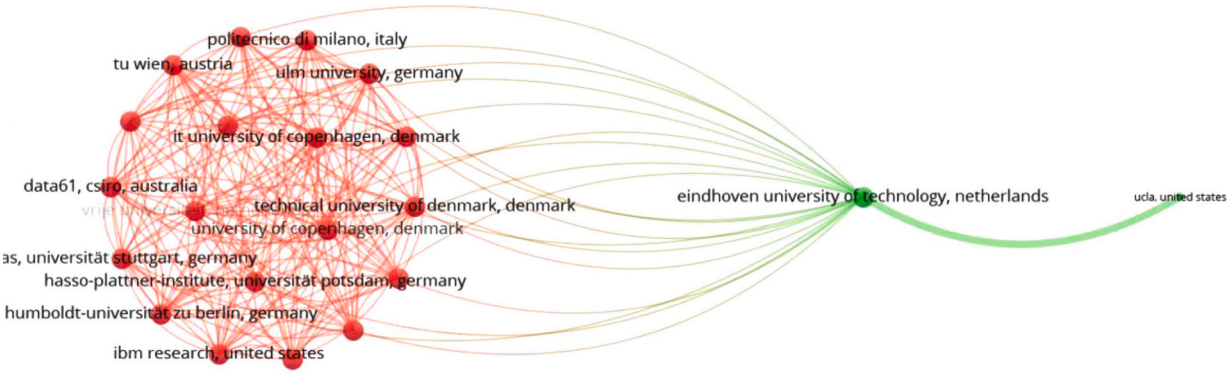


Fig. 6. Co-authorship analysis according to organizations. Note: resolution—1.0.

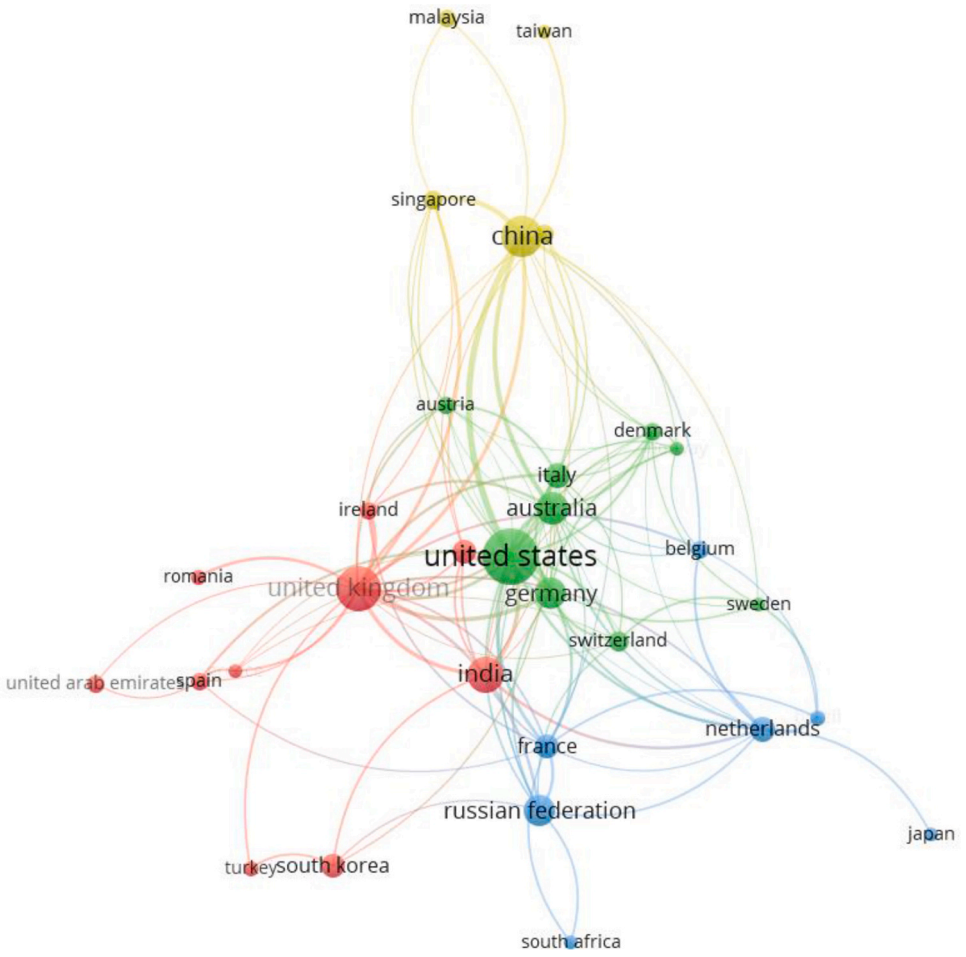


Fig. 7. Co-authorship analysis according to country. Note: Threshold criteria of minimum of 5 documents, resolution of 1.0.

citation analysis indicates that these universities, University of Cambridge and Nanyang Technological University, have produced widely accepted as well as popular publications in recent times and have significantly contributed to the development of the research boundaries and the intellectual structure of this domain. Thus, this analysis's results validate previously identified top organizations and authors who work on blockchain applications in management.

The top 10 popular and well-regarded articles in this network have been recognized by global citations, local citations, and PageRank measures (refer to Table 10). The citation measures of local citations and global citations measure the number of citations received by an article within the network and in the entire *Scopus* database, respectively. These measures indicate the popularity of articles that pertain to state-of-the-art applications of blockchain in different sectors, such as energy (Mengelkamp et al., 2018), smart cities (Higgins and Sandner, 2019), and records management (Kshetri, 2017). This finding suggests that significant attention has been attracted by area-specific articles in this domain, leading to a large number of citations.

In contrast, PageRank indicates the degree of prestige enjoyed by an article, whereas a citation examines the degree to which the pairs of articles (or nodes) in the network are connected to each other (Fahimnia et al., 2015). These articles may be innately linked to conceptual evolution, as well as theoretical and practical implications for proposed applications across different sectors and themes. It is interesting to note

Table 8
TLS and links for co-authorship analysis according to country.

	Links	TLS		Links	TLS
Cluster 1 (red)			**Cluster 2 (green)**		
India	9	12	U.S.A.	18	38
Canada	6	7	Australia	16	19
Ireland	5	8	Germany	13	18
Spain	5	4	Italy	12	10
Greece	5	3	Denmark	11	6
Cluster 3 (blue)			**Cluster 4 (yellow)**		
Russian Federation	10	19	China	14	31
Netherlands	13	13	Singapore	7	10
France	12	13	Hong Kong	6	9
Belgium	7	6	Malaysia	2	1
Brazil	4	4	Taiwan	1	1

the exemplary prestige of articles related to economics (Böhme et al., 2015), the regulatory aspects of blockchain enablement (Ølnes et al., 2017; Ying et al., 2018), and the comprehensive discussion on blockchain technology with the scope of its application (Iansiti and Lakhani, 2017).

5.3.2. *Dynamic co-citation analysis*

Citation and dynamic co-citation analyses can help researchers to follow the evolution of a field of research (Fahimnia et al., 2015; Xu et al., 2018). In this study, the application of blockchain in management and related domains is explored. Using Gephi's modularity tool, which is based on a Louvain algorithm (Fahimnia et al., 2015), 169 nodes (articles) and 606 edges (co-citation combinations) were detected in the citation network of the analyzed sample. Furthermore, dynamic co-citation analysis led to the identification of four dynamic co-citation clusters that exhibit 132 nodes (78.11%) and 499 edges (82.34%), which encompass a significant number of articles from the dataset across four classes of modularity (Fahimnia et al., 2015) (refer to Fig. 8).

The analysis follows the growth of this research over a decade and assimilates its evolution in periods of two years from 2009 to mid-2019. According to Fig. 8, it is shown that research focused on the managerial applications of blockchain is continually growing and that academic interest in this field has shown significant growth since 2013. The inception of this research field can be traced to 2009, which is one year after the introduction of bitcoin and blockchain by Nakamoto (2008). From 2009 to 2013, this research theme is primarily relegated to cluster 1 (black), as shown in Fig. 8. This cluster includes 24.26% of all the nodes included in the co-citation analysis. However, from 2013 to 2015, this field witnessed the introduction of academic text that may be categorized into three new clusters.

Cluster 2 (blue) includes 21.3% of the co-cited articles, which are focused on discussing the implications of the mainstream deployment of blockchain in management. Concurrently, 20.71% of the articles are centered in cluster 3 (red); these articles discuss the multiple managerial areas, or processes, in which blockchain may find application(s). Between 2015 and 2017, another theme of research emerged in this field; this theme focuses on bitcoin's inefficiencies and the market volatility associated with cryptocurrencies (cluster 4, green).

Based on the analysis, it is posited that until 2013, the growth of this field of research was linearly focused on one theme. However, from 2013 onward, multiple research themes concurrently emerged and showed rapid growth in the number of articles published. However, from 2017 onward, this research field underwent consolidation without the emergence of new thematic research areas. Instead, past research seems to have focused on highly specific issues associated with cryptocurrencies and blockchain implementation.

6. Discussion

The bibliometric analyses of the research focused on applying blockchain in management and its related areas led us to identify specific aspects that merit further discussion. These aspects include the conceptual evolution, the methodologies, and the emergent focal research areas discussed in the extant literature.

6.1. *Conceptual development of the research field*

This research domain's evolution is depicted in Fig. 8, which traces

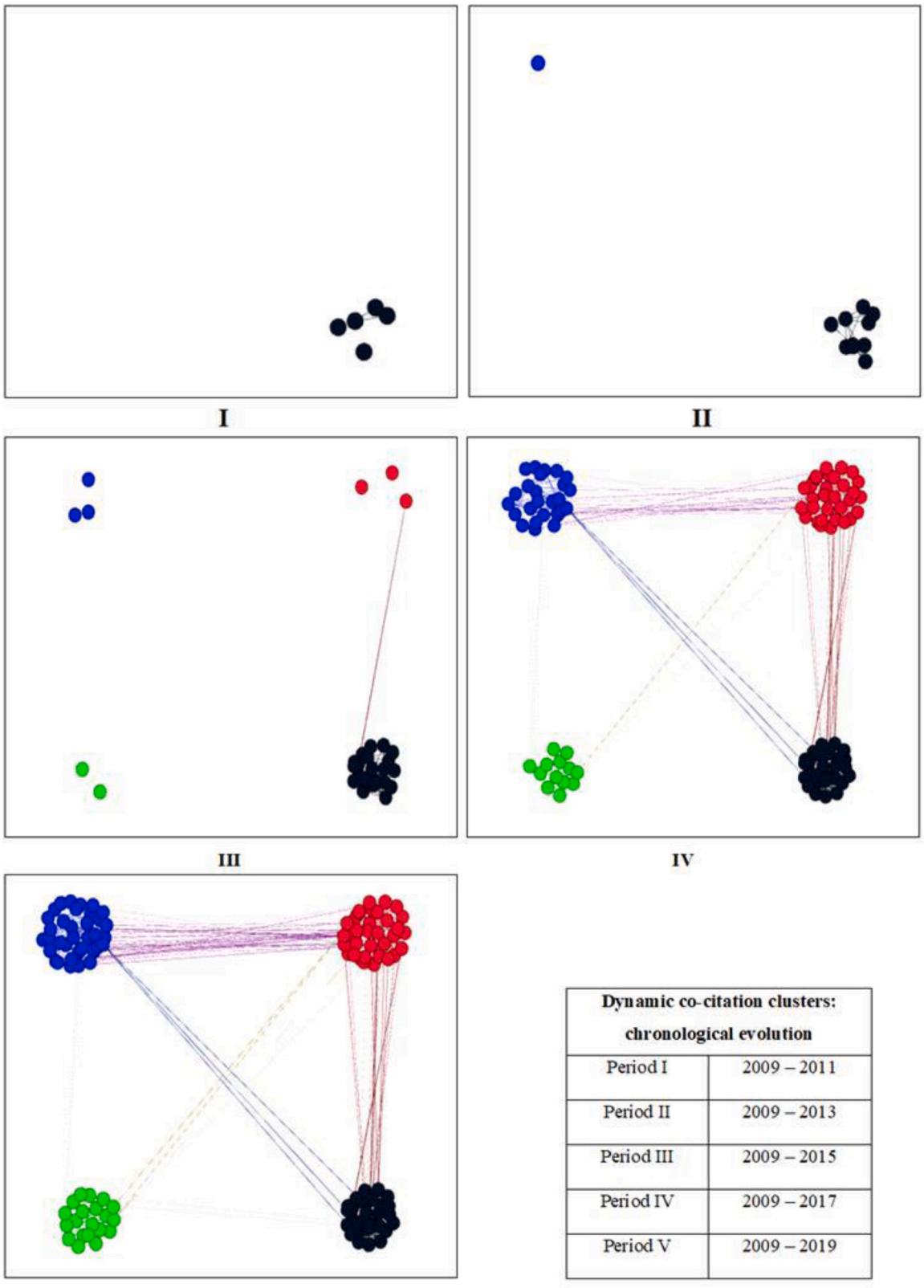
Table 9
Citation analysis for top 10 authors, countries, and organizations.

Author	Citations (TLS)	Country	Citations (TLS)	Organization	Citations (TLS)
Kraft, M.	140 (100)	U.S.A.	935 (274)	University of Cambridge, U.K.	140 (61)
Sikorski, J.J.	140 (100)	U.K.	413 (221)	Nanyang Technological University, Singapore	140 (61)
Haughton, J.	111 (64)	India	22 (158)	Swansea University, U.K.	11 (60)
Dwivedi, Y.K.	12 (63)	China	318 (141)	Manipal Global Education Services, India	11 (60)
Wang, X.	39 (57)	The Netherlands	63 (99)	Simplifi, India	11 (60)
Kshetri, Nir	69(50)	Germany	344 (98)	Tamil Nadu e-Governance Agency, India	11 (60)
Akella, V.	11 (50)	Singapore	246 (75)	City University of Hong Kong	51 (33)
Hughes, L.	11 (50)	Canada	174 (72)	Karlsruhe Institute of Technology, Germany	131 (27)
Misra, S.K.	11 (50)	Australia	202 (68)	L03 Energy, U.S.A.	131 (27)
Raghavan, V.	11 (50)	Hong Kong	98 (55)	Rutgers—the State University of New Jersey, U.S.A.	33 (27)

Note: TLS applied as the ranking measure; threshold criteria: minimum of one document; 10 citations.

Table 10
Top 10 articles according to citations and PageRank.

Top articles according to citations			Top articles according to PageRank			
Author (year)	Global	Local	Author (year)	PageRank	Global	Local
Mengelkamp et al. (2018)	248	131	Böhme et al. (2015)	0.019	641	12
Sikorski et al. (2017)	175	111	Iansiti and Lakhani (2017)	0.015	596	18
Xu et al. (2018)	178	92	(Ali et al., 2013)	0.014	194	2
Lemieux (2016)	171	63	Francisco and Swanson (2018)	0.014	56	8
Sun et al. (2016)	116	57	Ølnes et al. (2017)	0.013	119	10
Li and Wang (2017)	125	51	Ying et al. (2018)	0.011	39	9
Corbet et al. (2018)	149	51	Christidis and Devetsikiotis (2016)	0.011	1097	21
Mendling et al. (2018)	132	51	Doguet (2013)	0.010	11	2
Kshetri (2017)	188	50	Kshetri (2018)	0.010	155	12
(Hayes, (2019))	159	40	Underwood (2016)	0.010	342	11



Dynamic co-citation clusters: chronological evolution	
Period I	2009 – 2011
Period II	2009 – 2013
Period III	2009 – 2015
Period IV	2009 – 2017
Period V	2009 – 2019

Fig. 8. Dynamic co-citation analysis: Chronological evolution of the field.

the growth of articles published in this field in five distinct two-year periods over the past decade. Further, Table 11 details the additions in the number of visible nodes (articles) and edges (links) that have occurred for each cluster.

The field's overall evolution has been influenced by the significant issues raised by researchers over the past decade. The research on blockchain's application in management was initiated within the financial domain due to its inherent utilization for cryptocurrencies and the posited applicability of blockchain's elements for improving business models and strategic management. We maintain that this

Table 11
Increase in number of articles and co-citations in clusters.

Period		Cluster 1 (black)	Cluster 2 (blue)	Cluster 3 (red)	Cluster 4 (green)
2009–2011	Nodes	5	0	0	0
	Edges	3	0	0	0
2009–2013	Nodes	12	1	0	0
	Edges	20	0	0	0
2009–2015	Nodes	30	3	3	2
	Edges	113	0	0	0
2009–2017	Nodes	41	26	32	13
	Edges	175	70	68	21
2009–2019	Nodes	41	36	35	20
	Edges	175	117	89	52

Note: Edges here represent only edges within a cluster.

supposition facilitated more diverse research on blockchain's application to other management domains, leading to the concurrent development of clusters 2, 3, and 4. Over time, more nuanced discussions on topics associated with each cluster have emerged, leading to the adoption of a multi-domain perspective. However, the research seems to have re-focused attention on bitcoin in the most recent cluster (4) as deeper research has led to the identification of previously less known or unknown problems and issues.

A review of these clusters' development indicates that the initial studies in this research domain acknowledged the potential profitability of blockchain (Teece, 2010), and the field originated via a discussion of bitcoin for financial strategy and regulation. Studies also discussed the scope of this technology's applicability in management and associated issues, such as the business model and process flexibility (Baden-Fuller and Morgan, 2010; Chesbrough, 2010). In its next phase, the domain evolved to a theoretical discussion of the challenges and positive implications of utilizing blockchain in non-financial avenues of management in cluster 2. This was subsequent to the identification of the essential elements of blockchain as well as smart contracts and their potential contribution in promulgating the advancement of management processes in the first cluster.. In the evolution between 2013 and 2015, blockchain-oriented management research achieved a multi-domain perspective with the emergence of focal research areas (refer to Fig. 8). Consequently, in cluster 3, frameworks were proposed to aid the potential multi-domain deployment of blockchain with particular reference to the challenges that organizations in this process may face. During this time, the research scope was expanded to include issues such as regulatory (Tsukerman, 2015; Walch, 2015) and technical aspects (Ali et al., 2013) to incorporate blockchain within existing business models and operations (Kiviat, 2015).

Concurrent to the growth in research scope, blockchain was recognized as a potentially disruptive technology with widespread implications for revolutionizing the industry (Aste et al., 2017). Consequently, the field rapidly evolved to witness the inception and promulgation of discussions on the implications of cross-enterprise blockchain application for issues such as executing government processes (Ølnes et al., 2017), poverty alleviation (Kshetri, 2017), resource conservation (Saberi et al., 2018), and the authentication of luxury goods (Fanning and Centers, 2016), among others. The emergence of cluster four indicates a change in the trends of emergent research. In the last two years, the most cited and prestigious articles (refer to Table 10) in this field have re-focused on bitcoin and specific market-related issues that pertain to this cryptocurrency, which was the point of origin for the domain. This indicates a maturation of finance-related blockchain and bitcoin research, which may be argued to be a discussion of the results of blockchain's real-life applications and suggests that the field has evolved to adopt a narrower focus.

In terms of inter-cluster influence, the edges that link the clusters (composed of individual nodes or articles) may denote the measure of impact among the clusters (Fahimnia et al., 2015). Table 12 lists the number of visible edges that have occurred between the clusters in the past decade. As shown in Fig. 8 and Table 12, until 2015, cluster 1 (black) generated a limited influence on cluster 3 (red). This indicates that the articles that discussed blockchain in terms of strategic management and application influenced the articles that discussed the multi-domain deployment of this technology.

From 2016 to 2017, there is an intense increase in publications in all four clusters (Fig. 8) and evident growth in the number of edges that appear between cluster 1 (black) and cluster 3 (red) and between cluster 2 (blue) and cluster 3 (red). This growth indicates that the articles published in cluster 1 significantly influence the publications that appear in clusters 2 and 3. Similarly, cluster 2 has significantly influenced the proliferation of research centered in cluster 3. This influence is understandable as the strategic management (cluster 1) of any technology will influence its deployment across multiple domains (cluster 3). Comparatively, there is minimal inter-cluster influence between cluster 1 (black) and cluster 2 (blue), between cluster 3 (red) and cluster 4 (green), and between cluster 2 (blue) and cluster 4 (green). We contend that this limited influence may be attributed to the fact that cluster 4 primarily discusses bitcoin's inefficiencies—the originating point for blockchain—which could only offer limited insights to authors who are focused on research themes addressed by clusters 3 and 2.

Our contention is supported by the findings of the dynamic co-citation analysis (2018–2019), which revealed that the inter-cluster influence seems to have strengthened more between cluster 1 and cluster 3 and between cluster 2 and cluster 3 as the number of edges between these clusters has increased. In comparison, the edges between cluster 3 (red) and cluster 4 (green) have only marginally increased. Further, there is evidence of some influence of research between cluster 1 (black) and cluster 4 (green) in this period, which may be attributed to a discussion on the inefficient contribution of bitcoin toward the strategic management of portfolio diversification and risk management among organizations in the financial sector.

Thus, the current status of the research related to blockchain application in management-related areas may be considered to be on the verge of amalgamation and growth. This study may provide future researchers with insight into pertinent issues that affect other managerial domains that require similar detailed analyses.

6.2. *Methodologies and frameworks*

Content analysis of articles that were identified via citation and dynamic co-citation analyses was employed to develop insights into the methodologies adopted by the extant researchers. The analyses suggest a strong emphasis on qualitative methodological approaches within the extant literature, such as systematic reviews (Yli-Huumo et al., 2016) as well as theoretically oriented (Abeyratne and Monfared, 2016; Teece, 2010) and narrative discussions (Ali et al., 2013; Böhme et al., 2015). Case studies (Kshetri, 2018; Ying et al., 2018) and industry-based examples (Underwood, 2016; Vovchenko et al., 2017) also emerge as popular methods for elucidating the specifics of blockchain and its applicability. Furthermore, few studies in this domain have proposed conceptual frameworks based on experimentation with existing models, such as IBM's component business modeling (Chesbrough, 2010). Additionally, some studies have developed algorithms and frameworks based on current concepts (Sikorski et al., 2017) and technologies, such as edge computing (Li et al., 2018b) and IoT (Zhang and Wen, 2017).

Additionally, it was found that empirical investigations into the application of blockchain in the managerial domain were primarily limited to articles that address issues pertaining to the financial sector. For instance, time-series (Tiwari et al., 2018), the Jarqe-Bera test (Brauneis and Mestel, 2018; Tiwari et al., 2018), generalized autoregressive conditional heteroscedasticity (GARCH) models (Dyhrberg, 2016; Katsiampa, 2017), and the Ljung–Box test (Nadarajah and Chu, 2017; Urquhart, 2016) have been employed by studies that examine the efficiency and volatility of bitcoin. Recent studies in the financial sector

Table 12
Increase in edges between clusters.

Year	Cluster	Black	Blue	Red	Green	Year	Cluster	Black	Blue	Red	Green
2009 – 2011 (I)	Black	–	–	–	–	2009 – 2013 (II)	Black	–	–	–	–
	Blue	0	–	–	–		Blue	0	–	–	–
	Red	0	0	–	–		Red	0	0	–	–
	Green	0	0	0	–		Green	0	0	0	–
2009 – 2015 (III)	Black	–	0	0	0	2009 – 2017 (IV)	Black	–	–	–	–
	Blue	0	–	0	0		Blue	3	–	–	–
	Red	2	0	–	0		Red	19	20	–	–
	Green	0	0	0	–		Green	0	1	2	–
2009 – 2019 (V)	Black	–	–	–	–						
	Blue	3	–	–	–						
	Red	20	33	–	–						
	Green	2	1	4	–						

have also applied advanced techniques, such as detrended fluctuation analysis (DFA) (Bariviera, 2017) and the dynamic conditional correlation model (Bouri et al., 2017).

However, we maintain that a lacuna exists in the utilization of theoretically grounded frameworks in the extant literature. Among the studies reviewed, one article expressly indicated the use of theory—specifically, the unified theory of acceptance and use of technology (UTAUT)—for developing the foundation of its investigation (Francisco and Swanson, 2018). For instance, techno-determinism theory may be employed to understand how blockchain, as a technological innovation, has predominantly affected the content, formation, change, and development of society as an organization (Dorr, 2017). Furthermore, blockchain may be explored from the perspective of a problem-oriented innovation system to understand its applicability in solving the macro-level problems faced by society (Ghazinoory et al., 2020). The mobilization of organizational resources and stakeholders' commitment is another aspect of blockchain application which may benefit from theoretically grounded examinations in the future, such as actor-network theory (Callon, 1986). Thus, these theories may help researchers to explore novel facets of blockchain application in management via previously validated theoretical lenses.

6.3. Thematic classification

6.3.1. Thematic cluster identification and content analysis

New research is continually added to the current body of knowledge with the growing applications of blockchain in management-related areas. Concurrently, the focal themes of research have also evolved, and the co-citation analysis can assist in delineating these thematic foci. The co-citation analysis allows for the identification of specific models in a literature network based on the degree of semantic similarities (Cavaiggioli and Ughetto, 2019; Khanra et al., 2020; Shiau et al., 2017). Semantic similarity is measured by a comparative assessment of intra-cluster vis-à-vis inter-cluster links and follows the Louvain algorithm's modularity index (Khanra et al., 2020, 2021). The dynamic co-citation analysis facilitates each identified cluster's temporal evolution, giving us insights into the conceptual development of the investigated field of research.

Based on the analysis, four thematic areas are delineated based on the four clusters identified via the dynamic co-citation analysis. The most prestigious articles published in each cluster (see Table 13) may be considered indicators of the thematic focus that this domain has drawn. Consequently, the 10 most prestigious articles from each cluster have been examined using content analysis to derive each reviewed article's primary insights and objectives (Bhatt et al., 2020). These derived insights were used to understand the thematic evolution of this research field over the past decade.

6.3.2. Cluster 1: strategy and regulation

The content analysis of articles published at the inception of this research field suggests that the original focus of academic discussion was centered on the strategic and regulatory issues that affect bitcoin and blockchain implementation. For instance, the studies indicate that an organization's consideration toward incorporating novel developments, such as bitcoin, should demonstrate potential commercial viability (Chesbrough, 2010). Furthermore, these technologies should have the potential to positively impact the business processes involved in the strategic models of organizations (Chesbrough, 2010). Concurrently, organizations should also consider their dynamism (Baden-Fuller and Morgan, 2010) and strategic agility (Chesbrough, 2010) to ensure that the implementation of this innovative technology remains profitable (Teece, 2010). Doguet (2013) maintains that for bitcoin and its underlying technology of blockchain, the strategic challenge in sustaining its profitable implementation would primarily relate to maintaining a critical mass of stakeholders. Similarly, Ali et al. (2013) suggest that for bitcoin to achieve systemic acceptance, another strategic challenge relates to exploring measures for dissuading data attacks (Walch, 2015),

Table 13
Top 10 prestigious publications according to thematic clusters.

S. no	Article	PageRank	Article	PageRank
	Cluster 1		**Cluster 2**	
1	Böhme et al. (2015)	0.019119	Iansiti and Lakhani (2017)	0.014957
2	Ali et al. (2013)	0.013719	Ølnes et al. (2017)	0.012589
3	Doguet (2013)	0.010448	Ying et al. (2018)	0.011427
4	Baden-Fuller and Morgan (2010)	0.009240	Kshetri (2018)	0.010252
5	Chesbrough (2010)	0.008063	Aste et al. (2017)	0.009014
6	Zhang and Wen (2017)	0.005940	Pazaitis et al. (2017)	0.008498
7	Walch (2015)	0.005831	Aung and Chang (2014)	0.007789
8	Kiviat (2015)	0.004540	Kshetri (2017)	0.006903
9	Teece (2010)	0.002774	Apte and Petrovsky (2016)	0.006596
10	Tsukerman (2015)	0.002090	Fanning and Centers (2016)	0.006505
	Cluster 3		**Cluster 4**	
1	Francisco and Swanson (2018)	0.013579	Corbet et al. (2018)	0.009699
2	Underwood (2016)	0.009282	Sikorski et al. (2017)	0.009243
3	Saberi et al. (2018)	0.007637	Urquhart (2016)	0.008785
4	Abeyratne and Monfared (2016)	0.007172	Nadarajah and Chu (2017)	0.007884
5	Li et al. (2018b)	0.007165	Brauneis and Mestel (2018)	0.007199
6	Crosby et al. (2016)	0.005649	Bouri et al. (2017)	0.006501
7	Yli-Huumo et al. (2016)	0.004391	Bariviera (2017)	0.006416
8	Vovchenko et al. (2017)	0.004041	Tiwari et al. (2018)	0.006394
9	Umarovich et al. (2017)	0.004041	Katsiampa (2017)	0.006280
10	Toyoda et al. (2017)	0.003418	Dyhrberg (2016)	0.005527

fraudulent data mining, or transactions by stakeholders (Böhme et al., 2015; Doguet, 2013). This challenge would also affect blockchain's applicability (i.e., distributed ledger technology) since it is the key innovation offered by the launch of bitcoin (Ali et al., 2013; Kiviat, 2015).

According to Kiviat (2015), blockchain can potentially create significant and diverse implications for financial sectors, such as its application to digital asset management. Zhang and Wen (2017) suggest that blockchain may be merged with other technologies, such as IoT, to develop dynamic, efficient, and cost-effective business models for digital organizations. However, the successful implementation of these blockchain-based models would significantly depend on resolving operational and security assumptions to verify blockchain-based transactions (Böhme et al., 2015). The regulation of bitcoin and its transactions are among these operational challenges (Kiviat, 2015). For instance, according to Tsukerman (2015), inculcating improved trust in the transactions of cryptocurrencies, such as bitcoin, by removing the anonymity associated with its processes would be an imperative measure for counteracting negative perceptions surrounding its use. Correspondingly, Walch (2015) mentions operational risks, such as undiscovered bugs, that would need to be addressed before blockchain's potential as an infrastructural pillar of financial markets may be realized. Thus, before extending blockchain's applicability to other managerial processes, organizations would need to undertake a strategic cost-benefit analysis (Walch, 2015). Concurrently, given the potential for global blockchain-based transactions, these organizations would also need to explore and enforce regulatory mechanisms on the domestic level (Doguet, 2013) to avoid the malicious use of blockchain-based organizational processes (Böhme et al., 2015).

6.3.3. Cluster 2: enablement and implication

The articles within this cluster primarily discuss the unique characteristics of blockchain, their applicability for managerial processes, and the advantages and challenges of blockchain's integration within a business's framework. Aste et al. (2017) refer to blockchain as a disruptive technology and a part of the Fourth Industrial Revolution. This technology has gained recognition for its ability to induce significant value actualization in the business process (Pazaitis et al., 2017). However, this is contingent on the successful resolution of the complexities and coordination involved in its implementation (Iansiti and Lakhani, 2017). Blockchain may be an effectual transformative technology (Fanning and Centers, 2016; Ølnes et al., 2017). However, according to O'Donoghue et al. (2019) and Ølnes et al. (2017), organizations considering its execution would have to consider contextual trade-offs based on organizational needs, potential benefits, and associated costs.

Blockchain's widespread applications in the industry may lead to several social, organizational, technological, and economic implications (Kshetri, 2017, 2018; Ølnes et al., 2017; Ying et al., 2018). These implications may be attributed to its innate capability of inducing the social sharing of resources (Pazaitis et al., 2017). The application of blockchain in managerial processes has been considered to create several advantages for industries and economies (Iansiti and Lakhani, 2017). These advantages may include the availability of immutable and verifiable information (Aste et al., 2017), risk reduction (Kshetri, 2018), the democratization of information exchange (Ying et al., 2018), the transparency of logistical or supply chains (Apte and Petrovsky, 2016; Aung and Chang, 2014), and the ease of execution for administrative processes (Ølnes et al., 2017) and decision making due to smart contracts (Iansiti and Lakhani, 2017). The extant literature has delineated several use cases to discuss the advantages of blockchain implementation in contexts such as crowdsourcing (Kshetri, 2017), food supply chains (Aung and Chang, 2014), the management of employee benefits (Ying et al., 2018), and governance (Pazaitis et al., 2017)

Conversely, the implementation of blockchain can be subject to several challenges, for which Ølnes et al. (2017) recommend a regulatory role to be assumed by stakeholders, such as governmental organizations. These challenges may be attributed to the inherent complexities of the technology, the organization, or even the industrial or sectoral environment within which the organization exists. For instance, an industry's prior exposure to blockchain may determine its progressive rate of dissemination across incumbent organizations (Iansiti and Lakhani, 2017). This dissemination may also be affected by factors such as the lack of users' awareness about the technology (Kshetri, 2017; Ying et al., 2018), organizational flexibility (Ølnes et al., 2017), and normative pressure (Kshetri, 2018). In the context of the complexities of the technology, the significant challenges may relate to collusion attacks (Apte and Petrovsky, 2016), a lack of regulatory compliance (Kshetri, 2017), the high consumption of energy (Aste et al., 2017), and computational intensity (Fanning and Centers, 2016).

6.3.4. Cluster 3: multi-domain deployment

Blockchain has the potential to lend transparency to the processes within which it is implemented due to its distinctive characteristic of utilizing smart contracts (Saberi et al., 2018; Underwood, 2016), distributed consensus, and anonymity (Crosby et al., 2016). Due to these characteristics, this technology has attracted attention as an accelerator (Underwood, 2016), which can also usher the development of contemporaneous financial infrastructure (Umarovich et al., 2017). These characteristics have been regarded as a critical reason for the rapid adoption of blockchain in the financial sector (Vovchenko et al., 2017).

These characteristics have also been proposed as reasons for blockchain's application to solving issues that affect non-financial business sectors, such as counterfeit products, music, and IoT (Abeyratne and Monfared, 2016; Crosby et al., 2016). Studies have also proposed frameworks for the application of blockchain in managing environmental supply chains (Saberi et al., 2018), supply chain traceability (Francisco and Swanson, 2018), product ownership (Toyoda et al., 2017), and creating an open ecosystem for manufacturing (Li et al., 2018b). These studies indicate blockchain's potential for increasing the flexibility and scalability of existing business processes (Li et al., 2018b). However, after conducting a systematic review of the extant literature, Yli-Huumo et al. (2016) suggest that a limited number of studies aim to understand blockchain's applicability apart from bitcoin. Further, research utilizing different theoretical bases (Francisco and Swanson, 2018) is required to understand the challenges of the multi-domain deployment of blockchain (Saberi et al., 2018; Yli-Huumo et al., 2016), especially in the context of developing countries (Underwood, 2016)

6.3.5. Cluster 4: inefficiencies of bitcoin

The articles in this cluster are focused on understanding the application of blockchain in terms of financial markets, specifically, its original inception as the foundational technology for bitcoin. Additionally, one top-cited article in this cluster, a study by Sikorski et al. (2017), discusses its utility for engineering processes; the potential for inducing increased profitability; and the further applicability of smart contracts, IoT, etc. However, Sikorski et al. (2017) also posit their findings to have implications for other commodities, transactions, and pricing models and to be useful for financial markets in general.

As a cryptocurrency, bitcoin's efficiency as a market instrument is a highly debated topic (Urquhart, 2016). For instance, Nadarajah and Chu (2017) argue that bitcoin's current market efficiency may be ascertained as weak. Similarly, Tiwari et al. (2018) also contribute toward establishing bitcoin as a market-efficient asset. Contrarily, Urquhart (2016) and Brauneis and Mestel (2018) suggest that bitcoin is currently inefficient but has the potential to exhibit market efficiency in the future. This debate has gained further attention due to the concurrent discussion about the significant differences in considering bitcoin as an asset compared to other existing financial or economic assets (Corbet et al., 2018; Dyhrberg, 2016). For instance, Corbet et al. (2018) and Bouri et al. (2017) suggest that bitcoin offers benefits of diversification

because of its decoupling from external shocks. Similarly, Katsiampa (2017) suggests that bitcoin may be utilized for portfolio diversification and risk management. Furthermore, the academic discussion is also centered on volatility as a vital aspect of the financial market in terms of bitcoin (Bariviera, 2017). These studies suggest the imperative need to consider the temporal connotations associated with cryptocurrencies, particularly bitcoin (Bariviera, 2017; Bouri et al., 2017). It may also benefit researchers to holistically address the factors that may affect the valuation of cryptocurrencies, such as bitcoin, by amalgamating the existing methods of its technical examination with pertinent economic theories (Li and Wang, 2017).

6.4. Future research agendas

Based on the review and the findings derived from the analyses, the following five research agendas have been proposed to advance the literature on blockchain's applications in management:

1) **Broadening the sectoral scope of understanding.** First, the co-word analysis suggests that extant literature has made significant strides in understanding the extent to which blockchain may be applied in finance and supply chain management. While research on these two sectoral contexts may be considered to be maturing, several other application contexts may be explored by future researchers. Based on content analysis of the dynamic co-citation clusters, we maintain that methodologies and frameworks developed by prior scholars to enable blockchain deployment (refer to Section 6.3.2) may be applied to other contexts. This application could allow future scholars to test the multi-domain applicability of previously proposed frameworks and engender significant theoretical and practical contributions to this field. For instance, studies may explore the applicability of the product-ownership framework proposed by Toyoda et al. (2017) in the context of other sectors with similar concerns, such as pharmaceutics. Similarly, the knowledge and services framework proposed by Li et al. (2018b) may be tested for their applicability in different manufacturing scenarios, such as automobiles or construction.
2) **Applications for emerging nations.** Based on the results obtained from country-wise analyses of bibliographic coupling, co-authorship, and citations, we argue that there is a presence of geographic-specificity in terms of research based in developed countries, such as the U.K. and U.S.A., and few developing countries, such as India and China. Further, the thematic discussion of cluster 2 indicates that the application of blockchain to governance or administrative processes need further investigation, especially in the context of developing or underdeveloped countries. Thus, future scholars may focus on investigating the benefits of blockchain's application in managerial domains in the context of more emerging and underdeveloped nations to advance the current body of knowledge.
3) **Effect of the business environment.** Content analysis of dynamic co-citation clusters in terms of previously adopted methodologies suggests that extant literature has primarily focused on the development of the technology, i.e., protocols, algorithms, and use cases (refer to Section 6.2). Based on the analysis, we identified a significant lacuna about a lack of studies investigating the effect of environmental factors on the implementation of inter and intra-institutional deployment of blockchain. Thus, we propose the need for research directed at exploration and empirical testing of non-technical, organizational, and environmental conditions that may preclude or encourage cross-industry implementation of blockchain by future scholars.
4) **Potential for explicating consumers' perspectives.** The content analysis revealed another potential area for future investigation, which relates to the exploration of users' perspectives on blockchain applications and their awareness of this technology. A review of the top publications in each dynamic co-citation cluster revealed a significant gap in understanding the factors that drive or inhibit users' adoption of blockchain. Thus, to realize its potential for inducing societal change (Mäntymäki et al., 2020; Saberi et al., 2018), empirical investigations need to be conducted to identify and explore factors that may affect user adoption and resistance to widespread implementation of blockchain. These factors may include data privacy and security concerns, which are steadily gaining importance, and thus, future research frameworks may consider their inclusion. We suggest that these studies may be conducted for individuals, such as investors or patients, and organizational users, such as hospitals and financial managers.
5) **Potential for integrating theoretical grounding.** The analysis of methodologies and frameworks tested in extant literature (refer to Section 6.2) suggests that only a few studies have considered investigating frameworks that are grounded in theories, such as UTAUT and diffusion of innovation (Francisco and Swanson, 2018) theories. We suggest that future research may consider developing frameworks based on other appropriate theories. For instance, behavioral resistance theory (Claudy et al., 2015) may be applied to explain individual users' reticence in adopting blockchain.

7. Conclusion

This study attempts to provide a synthesized overview of the extant research that focuses on the application of blockchain in management and related sectors. The analysis was performed to answer the RQs proposed for this study. To answer **RQ1**, bibliographic coupling, co-occurrence analysis, and network analyses were employed to present a comprehensive outlook of the leading articles, authors, and organizations focused on examining the applicability of blockchain to management and related sectors. In response to **RQ2**, insights derived from the co-word, co-citation, and dynamic co-citation analyses were utilized to clarify the thematic classification of the extant body of literature. Furthermore, insights gained from bibliographic coupling, citation analyses and the content analysis of the top publications identified via the dynamic co-citation analysis were employed to discuss possible agendas that may be addressed by future researchers in response to **RQ3**. Our findings offer significant contributions to the literature and raise several implications for both theory and practice.

7.1. Theoretical implications

Based on the findings, we offer five theoretical implications for advancing further research on the application of blockchain in management.

First, our findings enable researchers to understand the current boundaries and scope of research in this domain. Consequently, researchers may use our results to focus attention on the lesser-investigated and novel issues to facilitate the deeper adoption of blockchain in managerial domains. Second, researchers may benefit from identifying prominent researchers and institutions in this field as potential collaborators and guiding forces for advancing the research in this field.

Third, the findings from the content analysis of thematic clusters identified through the co-citation and dynamic co-citation analyses provide researchers with critical information on prestigious and influential articles that may be seen as the foundations of this research field. Future researchers will benefit from this information. These articles can be used as a base to promote more nuanced research directed at the specific issues identified from the network, citation, and co-citation analyses. Fourth, the content analysis of the identified thematic clusters allows us to propose significant research agendas that may be addressed by future scholars. Lastly, our study may also be applied as a base for promoting methodological advancements in future studies by undertaking research based on mathematical modeling and empirical investigations.

7.2. Practical implications

This study's findings may also be of practical interest to industry-based researchers who wish to further develop the current body of knowledge. Based on the analysis, we proffer five practical implications for managers and organizational policy makers for facilitating the implementation and adoption of blockchain.

First, the study implies that practitioners, such as managers, looking after the technological advancements in an organization, may utilize our research to understand the broad scope of blockchain's applicability in managing business processes and operations across diverse sectors and managerial domains. Second, these practitioners may apply the findings of prestigious studies, which have been identified by network analyses, to discuss the design choices and trade-offs that may address major hindrances in blockchain's implementation as discussed in the prior literature.

Third, the findings imply the need to practically investigate the societal, organizational, and environmental factors that affect blockchain's implementation. Fourth, the results suggest the need to consider the legal and ethical dimensions of blockchain's application to organizational data management and related processes. Thus, this study calls for the focus of organizational policy makers and professionals engaged in the legal and information technology domains to examine these factors. Lastly, we believe that industry-based practitioners may benefit from utilizing bibliometrics to delineate the research boundaries of individual areas of interest concerning a more nuanced application of blockchain in different managerial domains, such as human resources, data management, and financial management.

7.3. Limitations and future scope for research

This study was limited by some methodological constraints, which may be addressed by future studies. First, this study was based on an analysis of a singular database, that of *Scopus*, which limited the sectoral scope of publications. Future bibliometric studies may consider the inclusion of other databases, such as Web of Science . IEEE, or PsycINFO. Second, we did not consider the inclusion of literature published in sources other than academic journals, such as conference proceedings, books, and trade magazines. Third, we precluded studies that pertain to the legal sector, which may complement the insights derived from this study. Future studies may consider a more comprehensive approach toward the source and domain of publications, which may help develop a more inclusive outlook for applying blockchain in the management domain. Lastly, although the analysis provides a comprehensive overview of the research domain, it precludes detailed knowledge that may be provided by more detail-oriented analyses, such as systematic reviews or meta-analysis. Despite these limitations, this study offers valuable insights for researchers in this field, who may address these limitations in future work while addressing the potential agendas proposed in this study.

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