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# Blockchain implications for auditing: a systematic literature review and bibliometric analysis

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**Abstract.** Blockchain technology, smart contracts, and asset tokenization have relevant implications for the auditing environment. This paper evaluates the current stage of blockchain application in auditing, analyzing scientific publications and identifying the impact of what is already a reality and the potential effects of its improvements in audit professionals' activities performance. The article considers the proposals and suggestions on the leading research indexed by the Scopus and Web of Science databases. We analyzed 374 papers on the topic of blockchain and provide a summary and analysis of the current state of auditing research. The bibliometric analysis was performed using the Bibliometrix R Package and the VOSviewer software. After a systematic study of abstracts and a general review of the papers to only include those directly related to our work's objectives, we found 78 papers. The work results in a framework of potential and effective implications of blockchain technology for auditing, pointing out several new challenges in terms of skills and knowledge needed in this new reality of audit professionals.

Keywords: Blockchain, audit, systematic literature review, bibliometric analysis, digital transformation.

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# 1. INTRODUCTION

Blockchain technology (BCT) seems to be the next step in the digital age for the areas of accounting, finance, and auditing (Bonsón & Bednárová, 2019). Therefore, within a few years, it is expected that audit reports will be producible in a fully automated manner (Abreu et al., 2018).

This technology seems to have the ability to reduce trading costs, increase the speed of transaction settlement, reduce fraud risk, and improve the auditability of transactions precisely by allowing traceability of operations (Abreu et al., 2018).

Because of these features, BCT can bring significant benefits and change the current paradigms for accounting and auditing (Dai & Vasarhelyi, 2017). The Big Four audit companies are very interested in what can impact the auditing ecosystem (Atik & Kelten, 2021).

For example, KPMG's Spark Project includes blockchain, artificial intelligence, data analytics, cloud computing, and machine learning to improve accounting services for enterprises in addition to developing its digital ledger services in association with Microsoft (Henage, 2020).

Deloitte created Rubix, a platform that allows its teams and clients to build customized blockchain-based and smart contract applications for any use case (Atik & Kelten, 2021).

PwC launched Blockchain Validation Solution as a read-only node to apply appropriate controls and continuous testing of all transactions (Zemánková, 2019).

PwC is also investing in VeChain, a cryptocurrency startup that specializes in web services and supply chains (Bonyuet, 2020).

EY released Blockchain Analyzer, which captures all transaction data from a firm's multiple blockchain ledgers. The system enables audit, tax, and transaction monitoring. EY also launched Crypto-Asset Accounting and Tax software to assist U.S. firms in reporting their crypto-asset transaction when filing their tax returns (Bonyuet, 2020).

As reported by the Big Four, BCT will affect companies in many ways, including the following:

- KPMG (2018) discussed blockchain effects on internal controls and business processes.

- PwC (2020) exploited the impact BCT can have on the global economy.
- Deloitte (2020) deals with the technical analysis of the main blockchains and proposed some considerations concerning its "dimensions."
- At its Global Blockchain Summit, EY (2022) discussed strategy, technology, and transformation and presented the EY OpsChain Public Finance Manager, a tool to integrate blockchain into the companies.

Despite these perspectives and the existence of other literature reviews on the implications of blockchain in accounting and auditing (Schmitz & Leoni, 2019; Bonsón & Bednárová, 2019; Lombardi et al., 2021; Bellucci et al., 2022), there is a gap in the literature regarding the consolidation of what is identified as a potential effect and what already impacts the audit ecosystem.

Thus, we reviewed the literature available in Scopus and Web of Science (WoS). However, this part of the work is only the means for identifying the most important research because the main purpose of the research is focused on discussions conducted in the selected works.

Thus, when we analyzed the implications of BCT for auditing, bringing together the effects on audit professionals' activities performance and BCT's potential effects in the future, our findings resulted in a table of implications with 11 clusters defined by the consensus of several authors.

Beyond this introduction, this paper presents in the next chapter a background of related works on BCT applied to auditing followed by the research methodology. Subsequently, through a bibliometric analysis and systematic literature review (SLR), we present the implications of blockchain for auditing and finally the discussion and conclusion.

## 2. BACKGROUND ON BLOCKCHAIN TECHNOLOGY FOR AUDITING

The bitcoin platform proposed by the anonymous Nakamoto (2008) is the first decentralized cryptocurrency transfer system. It is based on cryptographic proof-of-work, digital signatures, and a peer-to-peer network and is referred to as a blockchain (Kaaniche et al., 2018).

As part of this digital transformation, BCT is considered the fifth disruptive paradigm of the computing era after the mainframe development in the 1970s, personal computers in the 1980s, the internet in the 1990s, and social media in the 2000s (Wieninger et al., 2019).

A blockchain can be defined as a purely distributed peer-to-peer system in the form of a ledger that uses an algorithm that adds informational content into ordered and connected data blocks (Schmitz & Leoni, 2019), ensuring the inviolability of previous blocks through cryptographic technology (Fuller & Markelevich, 2020).

All operations performed in blockchain are checked, released, and stored in a block connected to the previous blocks, which only admits the recording after checking if all information is authentic and true (Tapscott & Tapscott, 2016).

Due to its decentralized nature and the fact that each node has its copy of the ledger (Rozario & Thomas, 2019), blockchain fraud is unlikely to occur because participating nodes can access the blockchain transactions as they were published.

This feature of technology through a permanent and encrypted conference generating a kind of sequential record of transactions makes it attractive for accounting and auditing purposes (Rozario & Thomas, 2019). Though literature on the subject is quite scarce (Bonsón & Bednárová, 2019), both researchers and business partners have recently begun to investigate (Frizzo-Barker et al., 2020).

## 3. RESEARCH METHOD

To obtain the basis of scientific production that relates to research in auditing with the use of BCT, searches for relevant works were made on the Scopus and WoS platforms searching the terms "audit* and blockchain" or "audit* and 'distributed ledger technology'" (Scopus: by articles, abstracts, and keywords; WoS: by topic).

The databases include publications by various scientific research institutions that are widely recognized worldwide (Marques & Santos, 2017).

In the Scopus database, on January 20, 2022, a total of 1,233 documents were found, which were limited to subject areas of "Decision Sciences," "Business, Management, and Accounting," "Economics, Econometrics, and Finance"; by "conference paper" and "articles"; resulting in 284 documents as shown in Table 1.

| Subject area | Number of docs. | % |
|---|---|---|
| Business, Management and Accounting | 49 | 17.2 |
| Decision Sciences | 71 | 25.0 |
| Engineering | 39 | 13.7 |
| Computer Science | 71 | 25.0 |
| Economics, Econometrics and Finance | 14 | 4.9 |
| Mathematics | 11 | 3.9 |
| Medicine | 8 | 2.8 |
| Physics and Astronomy | 3 | 1.1 |
| Social Sciences | 13 | 4.6 |
| Other Disciplines | 5 | 1.8 |
| Total | 284 | 100.0 |

Table 1. Studies by subject areas of the 284 listed in Scopus

On January 24, 2022, the general search in the WoS database with the same parameters returned 777 results refined to the areas shown in Table 2 below; we found 189 results.

| Subject area | Number of docs. | % |
|---|---|---|
| Business Finance | 51 | 27.0 |
| Management | 28 | 14.8 |
| Engineering Multidisciplinary | 19 | 10.0 |
| Business | 19 | 10.0 |
| Economics | 7 | 3.7 |
| Multidisciplinary Sciences | 3 | 1.6 |
| Other subjects | 62 | 32.8 |
| Total | 189 | 100.0 |

Table 2. Studies by subject areas of the 189 papers listed in WoS

Reported to these six selected areas in WoS that may have affinities with the audit theme, all papers produced between 2017 and 2022.

We then conducted a bibliometric study in the Bibliometrix R-package, which provides a set of tools for quantitative research in bibliometrics and scientometrics with statistical algorithms, high-quality numerical routines, and integrated data visualization (Aria & Cuccurullo, 2017).

After the download of the BibTex extension files of the 284 papers from Scopus and 189 from WoS, the automated process using R was conducted according to the following steps:

(1) Directory indication containing files extracted from Scopus and WoS in format “bibtex” for reading and conversion.

(2) Conversion of “bibtex” files.

(3) Merging the files from the two sources into a single file and removing duplicates.

(4) Reading and forming a new database in R.

(5) Analysis of results in biblioshiny online tool.

Both files were merged via R into a single file with 374 articles once 99 duplicated documents had been removed. The resulting file then served as the basis for the analysis conducted in Bibliometrix and the VOSviewer software for our analysis of citations (Bellucci et al., 2022).

After that, a detailed verification was completed to define the papers as references of implications of the technology for the auditing area according to the following steps:

- Step 1. Excluding papers linked to computing and information technology left 69 Scopus and 94 WoS papers to be studied.
- Step 2. Manual and detailed analysis of the papers: we found 88 papers (32 from Scopus + 56 from WoS) with a focus on auditing, as shown in Table 3.

| Year | Scopus | | WoS | | Analyzed - (repeated) |
|---|---|---|---|---|---|
| | step 1 | step 2 | step 1 | step 2 | |
| 2017 | - | - | 2 | 2 | 2 |
| 2018 | 10 | 3 | 4 | 2 | 5 |
| 2019 | 13 | 5 | 24 | 13 | 18 - (3) = 15 |
| 2020 | 21 | 10 | 27 | 16 | 26 - (2) = 24 |
| 2021 | 23 | 13 | 37 | 23 | 36 - (5) = 31 |
| 2022 | 2 | 1 | - | - | 1 |
| Total | 69 | 32 | 94 | 56 | 88 - (10) = 78 |

Table 3. Papers selected from Scopus and WoS (audit related areas)

Since 10 papers were common to both the Scopus and WoS databases (repeated), a total of 78 papers contributed to the objectives of this research, which formed the clusters of implications in Chapter 5.

The SLR research method aims to identify, evaluate, and synthesize all research relevant to a topic area, a phenomenon of interest, or a research question (Tran et al., 2021) according to the bibliometric parameters viewed in Chapter 5.

In order to define the implications of the BCT for the audit, the selected papers were ranked by their relevance. If an implication was found and it already appeared on the list of previously read papers, it was not necessarily included in the implications table.

The criteria to include or exclude the papers in our research were papers being published in audit or accounting journals and directly related to the theme, aligned with the international standards on auditing, and identified through a general reading of the abstract and main parts of the papers.

The study utilized the characteristics of qualitative research regarding the objectives and approach to the research issue, as an exploratory methodology (Frizzo-Barker et al., 2020) since blockchain applied to auditing is a very recent area of research.

## 4. BIBLIOMETRIC STUDY – DESCRIPTIVE RESULTS

In this paper, bibliometric study parameters are used to analyze the relevance of BCT for auditing in the Scopus and WoS databases, representing the relevant research in the accounting area worldwide. The bibliometric analysis describes the investigation of an amount of published research in a certain database. For this purpose, we follow the concept of metaknowledge, which encourages analytical pattern analysis of disseminated knowledge to highlight regularities in scientific claims (Evans & Foster, 2011).

The initial search in the Scopus and WoS was performed in accordance with Tables 1 and 2.

In the R Software, the analyses were performed through the function Biblioshiny, which is the command to access the Bibliometrix online tool (Aria & Cuccurullo, 2017), resulting in the basis of the analyses completed in this paper as described in Table 4.

Thus, the bibliometric study was done with all 374 documents, employing the R-package Bibliometrix and the VOSviewer software in accordance with Bellucci et al. (2022).

| Description | Results |
|---|---|
| MAIN INFORMATION ABOUT DATA | |
| Timespan | 2016 - 2022 |
| Sources | 241 |
| Documents | 374 |
| Average years from publication | 2.24 |
| Average citations per documents | 9.88 |
| Average citations per year per doc | 2.492 |
| References | 9073 |
| DOCUMENT TYPES | |
| Article | 162 |
| Article; early access | 4 |
| Article; proceeding papers | 2 |
| Conference papers | 173 |
| Proceeding papers | 33 |

Table 4. Main information about data and document types

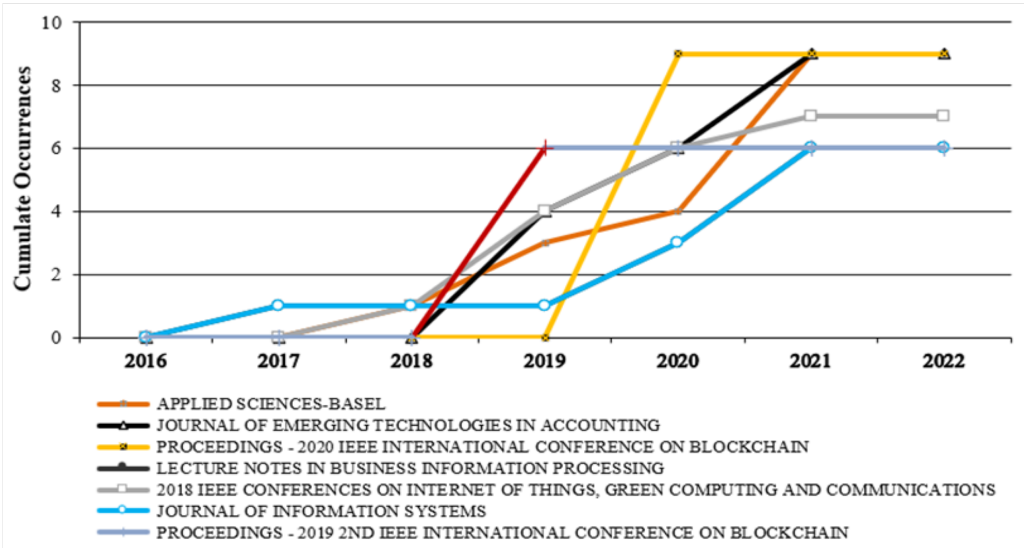
Of the 374 articles produced, we consider only the 162 journal articles from the sample, to highlight greater scientific rigor, obtained by publications in indexed journals. We list the 80% highest scientific production by country in Table 5 below.

| Country | Authors Freq. | N. Papers |
|---|---|---|
| China | 100 | 34 |
| USA | 87 | 25 |
| UK | 53 | 13 |
| India | 50 | 13 |
| Italy | 30 | 11 |
| Japan | 25 | 4 |
| South Korea | 19 | 8 |
| Australia | 18 | 4 |
| Germany | 18 | 3 |
| Canada | 14 | 2 |
| Spain | 14 | 5 |
| France | 9 | 3 |
| Pakistan | 9 | 3 |
| Belgium | 8 | 2 |
| Total | 454 | 130 |

Table 5. Papers/authors per country

The production of these countries refers to 454 authors who are mainly from China, the US, the UK, India, Italy, and Japan, where there are more than 20 publications involving the studied theme.

The general data analysis by geographic region (Dervis, 2019) revealed that the papers on BCT have been quickly increasing in number in recent years, as shown in Figure 1.




Source: Scopus and WoS (from bibliometrix).

Figure 1. Blockchain papers (Source: Growth Dynamics)

Only two papers in this research area were published in 2013, but the total reached nearly 400 works published in 2017 and 2018 (Dabbagh et al., 2019).

The main sources began their editions from 2016 to 2018. The Journal of Emerging Technologies in Accounting and the Applied Sciences-Based accumulated the most publications until 2022 (28 and 26 cumulated papers, respectively), surpassed in volume only by the Institute of Electrical and Electronics Engineers (IEEE) International Conference (totaling 35).

## 4.1. Analyses of text data

Although the theme of blockchain emerged after the Bitcoin whitepaper published by Satoshi Nakamoto in 2009, only in 2016 were scientific papers published in the area of auditing.

From the research conducted in cited databases, the data extraction resulted in a file to be used in VOSviewer (software to create maps based on network data and that allows the visualization and analysis of such maps), which can be seen as a network, overlay, and density visualization (Du et al., 2021).

Initially, we created a map on VOSviewer based on bibliographic data from database files of both Scopus and WoS merged by Bibliometrix into a single file in comma-separated value format.

For the network analysis in the VOSviewer, to understand the structure of scholarly contributions in the studied field (Tandon et al., 2021) by selecting a minimum of 10 occurrences in 374 selected papers, the term "auditing" is more linked to the blockchain, accounting, and smart contracts, as shown in Figure 2.

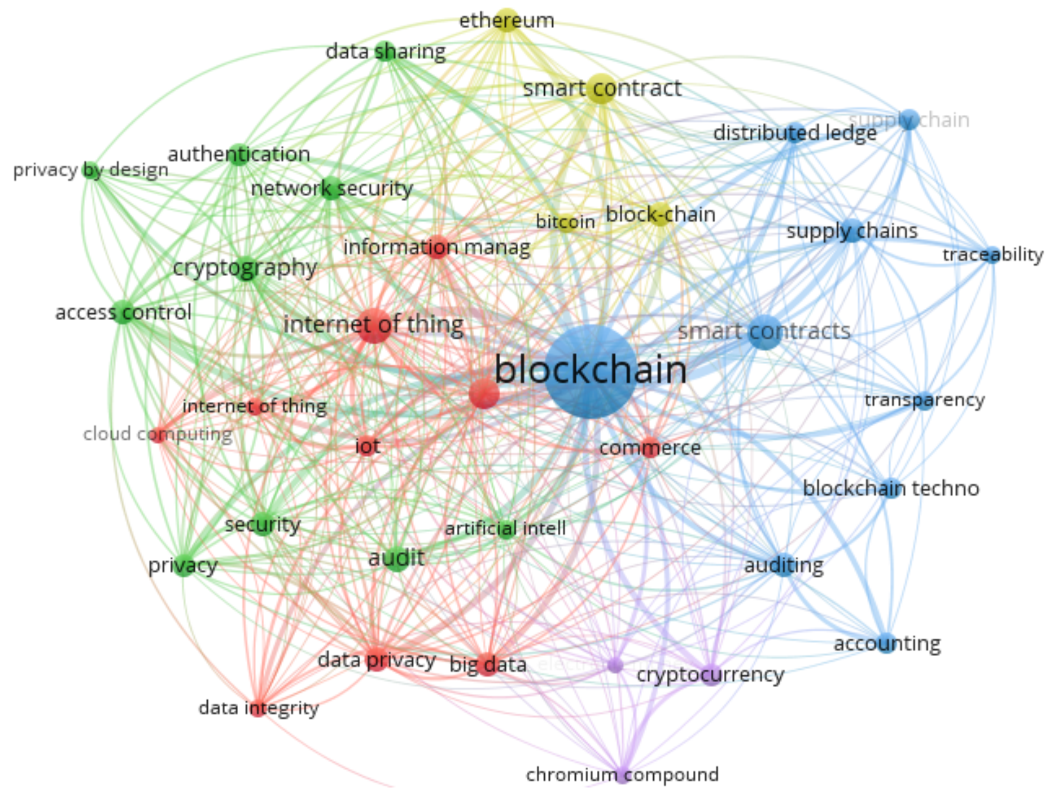



Figure 2. Keyword Co-Occurrences Map (Source: Scopus)

The parameters in VOSviewer were set as the keywords were grouped into different clusters according to their co-occurrence relationship. The clusters in the network maps of the periods were then compared with each other (Du et al., 2021).

To analyze how the different authors' keywords connect in the papers, we developed a Sankey diagram in Bibliometrix, which is shown in Figure 3.

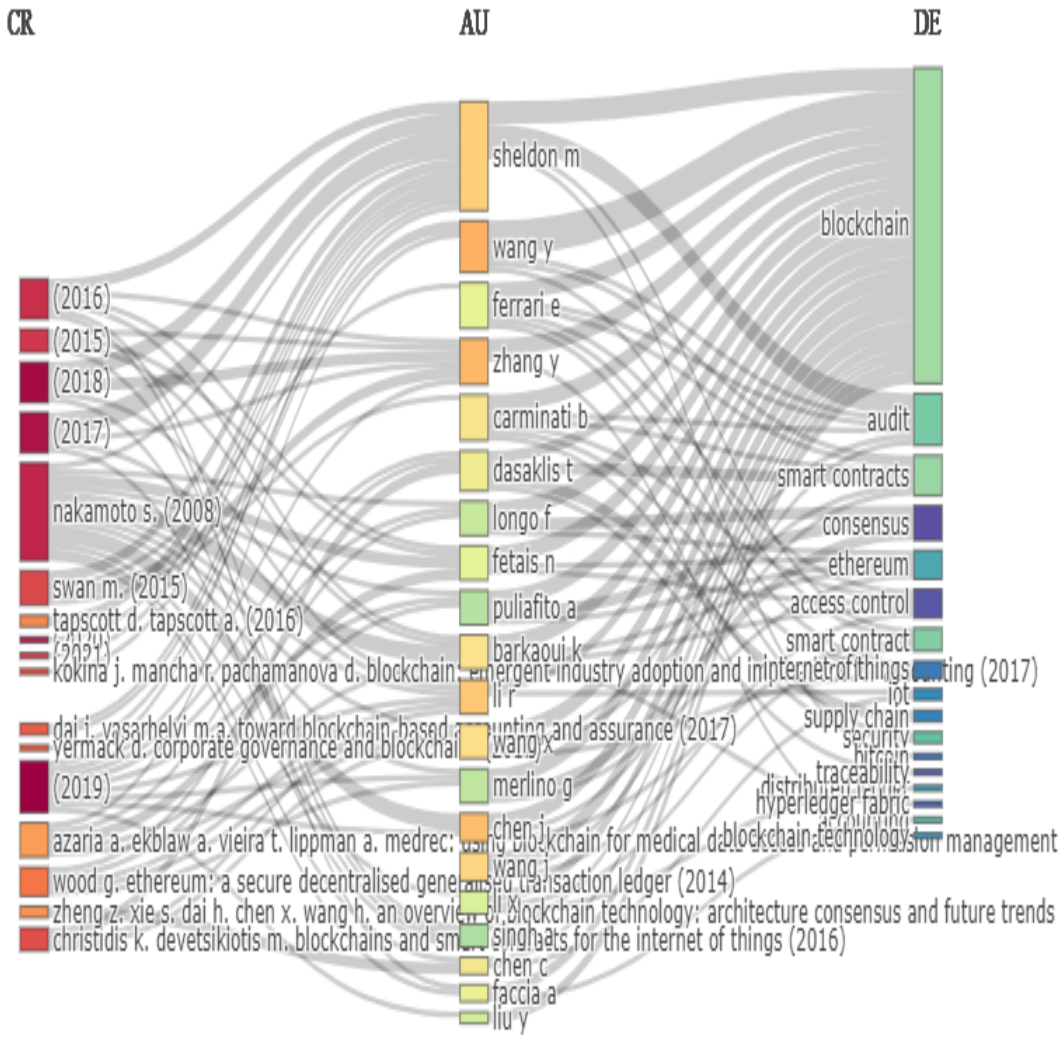



Figure 3. Three-Field Plot in Biblioshiny: Authors (AU) – Cited References (CR) – Keywords (DE) (Source: Scopus and WoS)

In the Sankey diagram, the size of the boxes is proportional to the frequency of the theme's occurrences, and the flows connect each box showing the evolution traces of the theme, and the thicker the connecting line, the greater the connection between the two themes (Xiao et al., 2022).

Figure 3 shows that the most used keywords are "blockchain," "audit," and "smart contracts," linked mainly to the most cited reference, that is Sheldon's (2019) paper.

The map produced by VOSviewer for analysis of cocitations by references identifies the relationships between papers from the relatedness of items determined based on the number of times they are cited together.

The map presented in Figure 4 describes the links between two papers when both are cited by the same document (those that were references to the authors found) based on the authors most frequently cited by the group indicated in clusters in different colors.

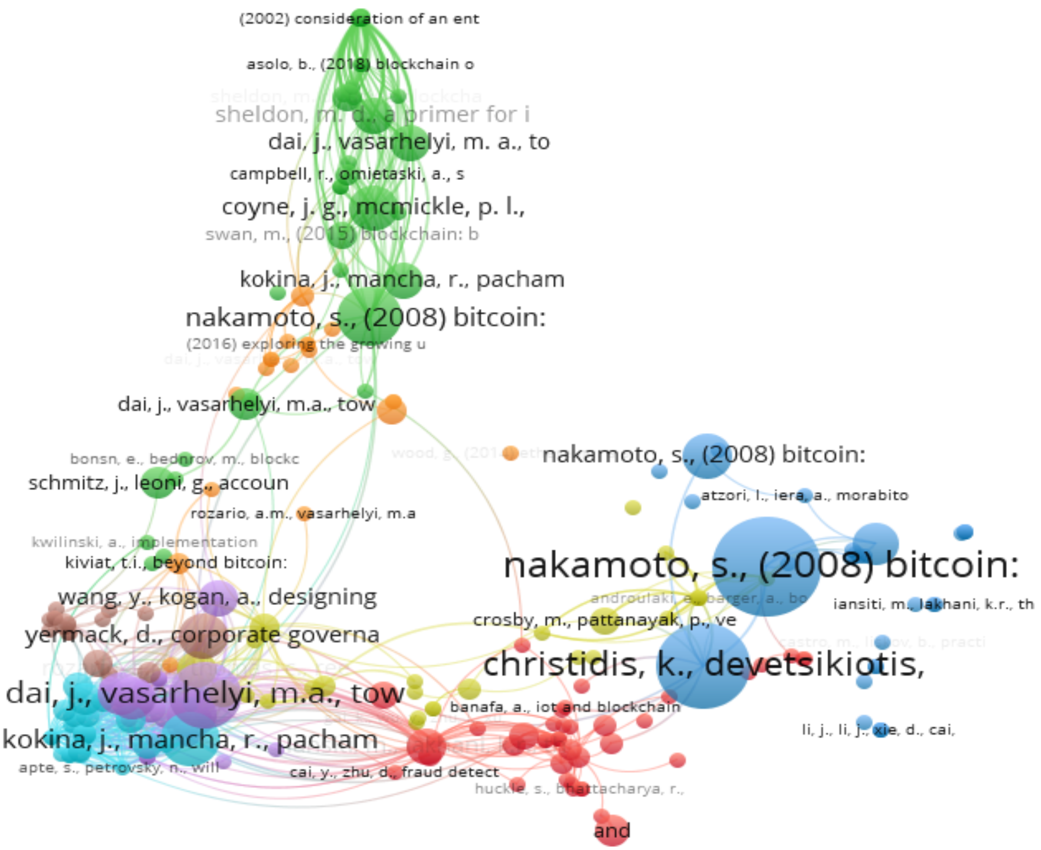



Figure 4. Cocitations by References Map (Source: Scopus and WoS)

The map from cited 374 papers resulted in 9,092 cocitations. When limited to a minimum of two citations of a reference, the map obtains 245 cited references. The most important cocitations are the whitepaper of Satoshi Nakamoto, which is the pseudonym of the supposed creator of bitcoin, whose identity is still unknown.

Additionally, it is necessary to highlight the works of Dai and Vasarhelyi (2017), Schmitz and Leoni (2019), O'Leary (2017), Demirkan et al. (2020), and Bonsón and Bednárová (2019) not only in terms of cocitations but regarding their impact on the scientific environment and by relevance based on subsequent research in the auditing area.

### 4.2. Analyses of citations, co-citations, and relationships

Based on the archive extracted from the Scopus and WoS platforms, after the unique selection of specific publications related to the auditing area in the works involving BCT and that meet the objectives of this paper, the top 10 cited papers are described in Table 6.

| Title | Authors | Authors Country | Source | Pub. Year | Total citations |
|---|---|---|---|---|---|
| Toward Blockchain-Based Accounting and Assurance | Dai, J., Vasarhelyi, A. | USA | Journal of Information Systems | 2017 | 158 |
| Configuring blockchain architectures for transaction information in blockchain consortiums: The case of accounting and supply chain systems | O'Leary, E. | USA | Intelligent Systems in Accounting Finance & Management | 2017 | 86 |
| Designing confidentiality-preserving Blockchain-based transaction processing systems | Wang, S., Kogan, A | USA, China | International Journal of Accounting Information Systems | 2018 | 58 |
| Accounting and Auditing at the Time of Blockchain Technology: A Research Agenda | Schmitz, J., Leoni, G. | Australia | Australian Accounting Review | 2019 | 48 |
| Blockchain Technology and Its Potential Effects on Accounting: A Systematic Literature Review | Atik, A., Kelten, S. | Turkey | Istanbul Business Research | 2021 | 36 |
| Blockchain technology in the future of business cyber security and accounting | Demirkan, S., Demirkan, I., McKee, A. | USA | Journal of Management Analytics | 2020 | 30 |
| Blockchain and its implications for accounting and auditing | Bonsón, E, Bednárová, M. | Spain | Meditari Accountancy Research | 2019 | 29 |
| Establishing a secure, transparent, and autonomous blockchain of custody for renewable energy credits and carbon credits | Ashley, J., Johnson, S. | USA | IEEE Engineering Management Review | 2018 | 28 |
| Impacts of digitization on auditing: A Delphi study for Germany | Tiberius, V., Hirth, S. | Germany | Journal of International Accounting Auditing and Taxation | 2019 | 26 |
| Blockchain as the Database Engine in the Accounting System | Tan, B., Low, KY | Singapore | Australian Accounting Review | 2019 | 23 |

Table 6. Most-cited papers on blockchain to auditing

The most cited papers on both platforms (Scopus and WoS) are two papers published in 2017. Among the 10 most cited works, only one is from 2020 and one from 2021, with the rest being produced in 2017 to 2019 and mainly coming from the US.

## 5. BLOCKCHAIN IMPLICATIONS FOR AUDITING

While much has developed in recent years in the digital technologies field, the operationalization of audits maintains a traditional sampling approach, and evolution seems to be necessary for an automated environment (Rozario & Vasarhelyi, 2018).

Given this necessary evolution, we sought to build clusters of implications of BCT for auditing based on the literature review from the following criteria and procedures:

- Potential implications are those for which application to the daily life of entities cannot be effectively evaluated or for which research does not define its complete stage of development.
- Effective implications: influences that already affect the activity of companies and therefore must be considered in the definition of audit procedures as well as

  - If a company uses an asset linked to the blockchain and it is therefore possible to track it anywhere just for the auditor to know the public key or wallet, which affects the audit (transparency/real-time auditing/auditor's new professional roles).

  - If a company holds some digital asset in the blockchain such as a nonfungible token or cryptocurrency.

Considering the 78 works in Table 3 and other citations in the paper, the sampling resulted in 44 references to the implications for auditing, as shown in Table 7.

The references included in Table 8 establish the implications of BCT for auditing based on reference papers by relevance. When the same topic is discussed in more than one paper, the least relevant documents are only mentioned if they add some specific aspect to the subject.

| N. | Authors (alphabetical order) | | | | |
|---|---|---|---|---|---|
| 1. | Ahmad et al., 2019 | 16. | Du et al., 2021 | 31. | Pimentel et al., 2021 |
| 2. | Ashley & Johnson, 2018 | 17. | EY, 2022 | 32. | PwC, 2020 |
| 3. | Atik & Kelten, 2021 | 18. | Faccia et al., 2019 | 33. | Reniers et al., 2019 |
| 4. | Bonsón & Bednárová, 2019 | 19. | Fuller & Markelevich, 2020 | 34. | Roszkowska, 2020 |
| 5. | Bonyuet, 2020 | 20. | Grigg, 2004 | 35. | Rozario & Thomas, 2019 |
| 6. | Broby & Paul, 2017 | 21. | IFRSC, 2019 | 36. | Rozario & Vasarhelyi, 2018 |
| 7. | Buterin, 2014 | 22. | Kend & Nguyen, 2020 | 37. | Schmitz & Leoni, 2019 |
| 8. | Cai, 2021 | 23. | KPMG, 2018 | 38. | Silva et al., 2020 |
| 9. | Carlson, 2019 | 24. | Li et al., 2019 | 39. | Stark, 2016 |
| 10. | Cong & He, 2019 | 25. | Liu et al., 2019 | 40. | Sutton & Samavi, 2017 |
| 11. | Dabbagh et al., 2019 | 26. | Lombardi et al., 2021 | 41. | Vincent & Wilkins, 2020 |
| 12. | Dai et al., 2019 | 27. | McCallig et al., 2019 | 42. | White et al., 2020 |
| 13. | Dai & Vasarhelyi, 2017 | 28. | Mylrea & Gourisetti, 2018 | 43. | Xiao et al., 2022 |
| 14. | Deloitte, 2020 | 29. | O'Leary, 2017 | 44. | Zhang et al., 2019 |
| 15. | Demirkan et al., 2020 | 30. | Peters et al., 2018 | 45. | Zemánková, 2019 |

Table 7. References of implications on BCT for auditing

| **Implications** | **Potential** | **Effective** | **Source -** Ref. N. Tab. 7 |
|---|---|---|---|
| Governance, transparency, and trust | | X | (Bonsón & Bednárová, 2019), (Schmitz & Leoni, 2019), (Cong & He, 2019), (Roszkowska, 2020), (Fuller & Markelevich, 2020), (Atik & Kelten, 2021) (KPMG, 2018), (PwC, 2020) |
| Real time auditing/Auditing Internet of Things (IoT) | | X | (Schmitz & Leoni, 2019), (Rozario & Thomas, 2019), (Rozario & Vasarhelyi, 2018), (Dabbagh et al., 2019), (Du et al., 2021), (Atik & Kelten, 2021), (Liu et al., 2019), (Mylrea & Gourisetti, 2018), (Bonyuet, 2020) |
| Auditor's new professional roles | | X | (Schmitz & Leoni, 2019), (O'Leary, 2017), (Demirkan et al., 2020), (Mylrea & Gourisetti, 2018), (Kend & Nguyen, 2020), (Bonyuet, 2020), (White et al., 2020), (Grigg, 2004) |
| Blockchain Smart Contracts/Smart Audit Procedures/Audit 4.0 | X | | (Dai & Vasarhelyi, 2017), (Schmitz & Leoni, 2019), (Rozario & Thomas, 2019), (Buterin, 2014), (Rozario & Vasarhelyi, 2018), (Dai et al., 2019), (Dabbagh et al., 2019), (Du et al., 2021), (White et al., 2020), (Lombardi et al., 2021), (Cai, 2021), (Cong & He, 2019), (Bonyuet, 2020), (EY, 2022) |
| Distributed consensual accounting records - Decentralized audit trail | X | | (Bonsón & Bednárová, 2019), (Peters et al., 2018), (Grigg, 2004) |
| Triple-Entry bookkeeping in Blockchain | X | | (Bonsón & Bednárová, 2019), (Atik & Kelten, 2021), (Cai, 2021), (Faccia et al., 2019) |
| Permissioned Access to Auditor/Privacy in Access | X | | (Rozario & Thomas, 2019), (Zhang et al., 2019), (Carlson, 2019), (McCallig et al., 2019) |

| | | | |
|---|---|---|---|
| Auditor as a limiting factor to 51% attack | X | | (Liu et al., 2019), (Bonyuet, 2020) |
| Audited companies with cryptocurrency holdings/Investment in digital assets | | X | (Broby & Paul, 2017), (Zhang et al., 2019), (Vincent & Wilkins, 2020), (IFRS Committee, 2019), (EY, 2022), (Deloitte, 2020), (Pimentel et al., 2021) |
| Blockchain Enabled Privacy Audit Logs | X | | (Sutton & Samavi, 2017), (Reniers et al., 2019), (Ahmad et al., 2019) |
| Tokenization and its effects for Auditing | | X | (Stark, 2016), (Li et al., 2019), (Xiao et al., 2022), (Roszkowska, 2020), (Fuller & Markelevich, 2020), (Silva et al., 2020), (Ashley & Johnson, 2018), (Dai et al., 2019), (Zemánková, 2019), (EY, 2022) |

Table 8. Implications clusters of BCT for Auditing

The identified implications were listed in the following 11 items grouped into categories of subheadings found via similarities in the research:

*Governance, transparency, and trust*

Blockchain offers more transparency in the supply chain and enables knowledge of the "story" of an asset (Bonsón & Bednárová, 2019). Blockchain can significantly improve governance and transparency by providing stakeholders with immediate access to accounting data (Schmitz & Leoni, 2019).

Blockchain can provide trusted digital payments, and players in the financial industry are also actively adopting BCT to address the payment problem (Cong & He, 2019).

Auditors also benefit from more reliable data and spend less time verifying the accuracy, as Deloitte has stated since 2016 (Fuller & Markelevich, 2020).

In the audit blockchain ecosystem, cryptography can be used to design which node can see what information so that it can solve participants' privacy concerns (Atik & Kelten, 2021).

As an effective advantage from the perspective of using BCT in the well-known Enron case, it was viewed that the internet of things (IoT) and smart contracts make most of the accounting data impossible for the company to manipulate (Roszkowska, 2020).

Blockchain could allow audit firms to revolutionize their ability to share data and reporting activity between the firm and its clients (KPMG, 2018).

The contracts do not need to be signed in person, and the technology automatically creates an audit trail. With its tracking abilities, the technology can help quickly unwind disputes and exposures in a trusted way (PwC, 2020).

*Real-time auditing and auditing the internet of things*

Following the initial proposal for the automation of the continuous audit by Vasarhelyi and Halper (1991), audit software such as IDEA or ACL, and the application of more improved statistical methods as well as the use of algorithms, the smart contracts blockchain represents the natural advance for the next generation of audit data analysis (Rozario & Vasarhelyi, 2018).

The complete application of smart contracts and the production of intelligent audit procedures that autonomously perform predictive models (Rozario & Vasarhelyi, 2018) will only make it possible to complete an application if companies begin to register all their transactions on the blockchain, which seems unlikely to happen (Schmitz & Leoni, 2019).

On the other hand, the progressive adoption of the automation methodology and continuous computerized procedures is increasing in business organizations but lacks the same development in the auditing field because the adoption of continuous auditing by external auditors is practically non-existent (Rozario & Thomas, 2019).

Through instant confirmation of transactions, BCT allows continuous monitoring (Liu et al., 2019; Bonyuet, 2020). Through the execution of smart contracts and running of automated auditing tools, every transaction is audited (Dabbagh et al., 2019). CA is more efficient than traditional auditing, and its accuracy is high (Du et al., 2021), but it can still be considered an early stage and a potential application of BCT given its complexity.

Once IoT handles online equipment and devices, blockchain-distributed ledger technology can improve the auditing of IoT environments, providing means for auditing and tracking the who, what, when, and where of the software and hardware supply chain as well as the data being exchanged (Mylrea & Gourisetti, 2018). This means that auditing IoT will make it possible to conduct constant monitoring, enabling real-time auditing.

The Big Four audit companies also have great interest in BCT. The number of projects based on BCT, cloud computing, artificial intelligence, machine learning, and IoT has been increasing rapidly (e.g., Henage, 2020; Atik & Kelten, 2021).

*Auditors' new professional roles*

There are advocates of various negative effects of BCT on the accounting and auditing profession (Demirkan et al., 2020; Grigg, 2004). To other researchers, the argument that auditors are becoming obsolete is not evident, but their functions are likely to change due to automation progressivity and BCT (Schmitz & Leoni, 2019).

The focus of an audit will shift from records tracking to complex analyses. A Deloitte report sponsored by AICPA, CPA Canada, and Waterloo University reveals potential new roles for accountants, such as auditing smart contracts and oracles, auditing blockchain, and granting authorized blockchain access (Bonyuet, 2020).

Despite this, a study in Australia shows that auditors do not clearly understand the potential that blockchain technologies could offer in the auditing profession (Kend & Nguyen, 2020).

Certainly, the BCT brings new challenges and business to auditors, such as reviewing certain transactions, verifying the existence of digital assets, and comparing the consistency between blockchain and the real world (O'Leary, 2017; White et al., 2020).

The auditor's intervention is required to certify that the information recorded in the distributed ledger is accurate (Mylrea & Gourisetti, 2018) as a kind of "reality certifier." When it comes to blockchain, it seems clear that the auditor's role is to ensure that what is recorded in the ledger corresponds to the physical reality.

*Blockchain smart contracts as smart audit procedures/audit 4.0*

A smart contract is a computerized programming code that performs previously inserted operations in the algorithm to operate depending on conditions to be implemented in the future, as cited by Szabo (1994).

The evolution predicted by Szabo (1997) came with distributed accounting (Tapscott & Tapscott, 2016) as the greatest benefit of blockchain and the enabler of smart contracts (Bonyuet, 2020).

Several platforms such as Ethereum (Buterin, 2014), Lightning, and Stellar (Cong & He, 2019) allow the programming of smart contracts in blockchain, simply connecting them to the network and bearing the costs of creating and moving tokens.

Smart contracts can perform audit procedures based on predefined parameters (EY, 2022). The auditing of smart contract controls includes verifying and testing the smart contracts (White et al., 2020). Rozario and Vasarhelyi (2018) propose that auditors can preprogram intelligent audit procedures as "IF-THEN" rules and then upload them to the blockchain.

Smart contracts can detect and measure damage to inventory and other assets and potentially automate the accounting measurement of these assets by applying intelligent audit procedures (Kaaniche et al., 2018; Schmitz & Leoni, 2019; Rozario & Thomas, 2019).

Smart contracts enable Audit 4.0 efficiency, reporting, disclosure, and transparency (Lombardi et al., 2021).

One disruptive concept in auditing is an online audit service (Dai & Vasarhelyi, 2017), which means auditors can provide a variety of services through the internet and create a smart contract to monitor business activities (Dai et al., 2019).

Smart contracts can improve the execution of audit processes by automating the reconciliation procedures (Rozario & Vasarhelyi, 2018). Using a smart contract as an auditing tool means that any transaction will be audited on-chain (Dabbagh et al., 2019; Du et al., 2021; Cai, 2021).

When shipped goods are equipped with special sensors or chips, these devices can self-report inventory damage and signal to smart contracts to adjust the corresponding accounting measurements (Dai & Vasarhelyi, 2017).

Finally, auditors must realize that the BCT core concept of decentralization has advantages and disadvantages. In a permission-only blockchain, there may be more collusion beyond that verifiable in the traditional world (Buterin, 2014).

*Distributed consensual accounting records*

Blockchain allows the digital consensual accounting records concept to be introduced, which brings new dimensions to accounting and has important implications for ongoing auditing and reporting. The possibility of digital consensual accounting records implies that once the nodes (e.g., the supplier, customer, auditor, regulator, and public administration) have approved a transaction it has validity (Bonsón & Bednárová, 2019).

Wang et al. (2019) constructed another data audit model that replaces single-point trust with collective trust. In this model, the public data auditing protocol comes with privacy protection, which enables audit nodes to complete the audit of the integrity of user data without entering the user's private information.

Promising areas of application to the blockchain are legal metrology, the complete automation of the legally supervised update mechanism by smart contracts, and an alternative infrastructure to public keys (Peters et al., 2018).

*Triple-entry bookkeeping in blockchain*

Triple-entry accounting is a method proposed since the 1980s but widely discussed with the advancement of BCT as an adaptation to the double-entry system with transaction processing authorization being required from an independent and reliable intermediary for each accounting record (Atik & Kelten, 2021).

Therefore, blockchain creates an interconnected system of permanent accounting records, which has implications for auditing, reducing the risk of fraud and errors by maintaining a nonbiased record (Bonsón & Bednárová, 2019).

This new framework may not prevent all types of fraud, but it can reduce internal fraud, enhance operational efficiency, and resolve fundamental trust and transparency issues (Cai, 2021).

Triple-entry accounting has address A, address B, and the third address, which is the confirmation receipt (Faccia et al., 2019). This represents a consensus that allows the auditor to establish a higher level of trust from the records.

*Permissioned access to auditors and privacy in access*

BCT allows companies to record and store all transactions in a shared book (Zhang et al., 2019), and business events can be visible to the audit client in near-real time.

The auditor can be a network node with read-only prerogatives on the blockchain and have access to timely and reliable information. The read-only access helps maintain the scalability of the private blockchain, limiting the auditor to only having access to viewing and extracting information (Rozario & Thomas, 2019).

The auditor accesses entities' private information using multiparty security (McCallig et al., 2019), which seeks to ensure that information is kept private.

Carlson (2019) shows that DLT is a low-cost, redundant, decentralized, hack-free audit trail that can use artificial intelligence components such as collaborative, self-learning, or self-programming algorithms that facilitate rapid, efficient detection of their authorized or unauthorized use.

*The auditor as a limiting factor to 51% attack on blockchain*

Considering the 51% attack rule, when a group of miners controls an absolute majority of the computer power on a blockchain, there is the possibility of defrauding the transaction records (Liu et al., 2019).

If a blockchain is kept private, then a company may have 100% control over transaction validation, but then it would be able to modify transaction history as needed. One solution to address this issue in both private and public blockchains would involve auditors in the transaction validation process, to prevent malicious actors from controlling more than 50% of network nodes (Bonyuet, 2020).

*Audited companies with cryptocurrency holdings – investment in digital assets*

In a blockchain environment, business financing can be embedded in digital assets (Zhang et al., 2019). Consequently, the financial report audits are increasingly likely to contain transactions involving cryptocurrencies (EY, 2022).

Therefore, auditors must work with specialized technicians and increase their competence on the subject. Neither the FASB, the ASB, nor the PCAOB has issued formal guidelines for cryptocurrency accounting or auditing, which implies that accounting treatment depends on unofficial concepts (Vincent & Wilkins, 2020).

Since March 2019, the International Financial Reporting Interpretations Committee has published "The Holdings of Cryptocurrencies – Agenda Paper 4" declaring that the accounting treatment for the retention of cryptocurrencies follows the International Accounting Standard IASB 38 – Intangible Assets (International Financial Reporting Standards Committee, 2019).

Deloitte (2020) discusses the blockchain applications to identity, asset tokenization, supply chain, and decentralized insurance in which the two components of payments and store of value must be considered. This directly impacts the audit.

Broby and Paul (2017) demonstrate that the audit process as it stands today is not robust enough to address the challenges of transferring and storing digital money, and the auditor should consider other challenges (Vincent & Wilkins, 2020). The major challenges to verifying existence are related to the reliability of a blockchain and the custodianship of assets, when talking about the existence of cryptoassets in the balance sheet (Pimentel et al., 2021).

*Blockchain-enabled privacy audit logs*

Sutton and Samavi (2017) propose a linked data-based model for creating tamperproof privacy audit logs and provide a mechanism for log integrity and authenticity verification that auditors can execute in conjunction with performing compliance-checking queries.

Privacy audit logs are used to identify the actions of agents in the environment in which they share data so that the auditor can verify the data's compliance with the privacy policies.

The users remain aware of their actions being recorded in an audit log, which represents that in the case of an attack or a malicious activity, the audit logs can be used to ensure that users are accountable for their actions (Ahmad et al., 2019).

If a permissioned blockchain is used, the audit log encourages the user to act correctly (Reniers et al., 2019) because the actions can leave a trail for all nodes since file hashes and locations are publicly recorded on chain.

*Tokenization and its effects on the audit*

The token represents the right to do some computing operation, such as accessing a particular platform, which can function as a digital signature. In the blockchain environment, the economic properties of tokens are divided into three types: utility, security, and asset-backed tokens (Li et al., 2019).

Tokenizing financial instruments is the most immediate current use. As technology develops, other assets can be stored and traded on blockchain systems in tokenized form (EY, 2022). Thus, tokenization represents the new types of assets registered and controlled on the blockchain (Stark, 2016).

When moved to any wallet, the business events indicated by the tokens are visible to the auditors at DLT in near-real time, enabling "real-time auditing" (Dai et al., 2019) or an "automated audit process" (Zemánková, 2019).

Li et al. (2019) proposed a blockchain-based Open Asset Protocol to convert real and virtual objects to asset-backed tokens on the blockchain.

Silva et al. (2020) proposes utilization of tokenization for governments monitoring and tracking public budget phases of forecasting and execution in DLT.

The tokenization of currencies and any assets in many companies around the world already impacts the audit ecosystem and can be considered an effective implication of BCT in this field (Roszkowska, 2020; Fuller & Markelevich, 2020; Xiao et al., 2022).

As a use case, Clean Energy Blockchain Network has announced a partnership with Silicon Valley Power to apply BCT to simplify its participation in the low carbon fuel standard program (Ashley & Johnson, 2018).

## 6. DISCUSSION AND CONCLUSION

This paper evaluated the current stage of BCT application in the auditing field, analyzing scientific publications since the emergence of BCT and identifying its implications that have already become a reality as well as its potential effects.

Through a bibliometric analysis using R-package Bibliometrix and VOSviewer, the works published on Scopus and WoS discussing implications of BCT for auditing were selected.

The most relevant papers were analyzed individually, the results of which were added to the impact verified by the Big Four audit companies that can impact the auditing ecosystem and formed the framework established in the literature in compliance with the paper's objectives.

To overcome the literature gap regarding the potential and effective impacts of BCT on the audit ecosystem, the research focused on discussions had in the selected works. The result is a table of implications with 11 clusters, each defined by the consensus of several authors.

The SLR showed that the potential implications to be implemented in the future are audit 4.0, smart contracts as auditing procedures, distributed consensual accounting records, triple-entry bookkeeping in blockchain, issues related to privacy to auditors in permissioned blockchain, auditors as a limiting factor of 51% attack, and blockchain-enabled privacy audit logs.

On the other hand, many applications of BCT and several studies in progress and applications per company are already producing effective implications, impacting areas such as governance, transparency, and trust; real-time auditing; auditors' new professional roles; auditing companies with investments in digital assets; and assets' tokenization effect.

Regarding these findings, it is reasonable to say that these points will be important research directions for researchers, companies, and governments in the coming years.

In auditing, much information requested by auditors will become unnecessary because for transactions completed on blockchain, auditors will no longer need to request many documents in the audit process. Audits will be done simply using the information from accounts, portfolios, and smart contract codes linked to the blockchain systems, which will demand audit procedures adaptable to real-time auditing.

Despite the consensus that the information recorded on the blockchain is reliable, a third party will still be needed to determine whether the physical world is properly represented in the ledger of the companies and what should remain in the auditor's role as a reality certifier.

As a limitation, it is necessary to mention the need for complementation by specialized professional literature, which refers to the production of different materials by interested investors and experts in the blockchain ecosystem, given the lack of regulation by governments and professional supervisory boards.

Finally, as a direction for future research, we think it is relevant to carry out studies on automation caused by mapping asset products and components such as vehicles, machines, and equipment given the recent rush to the IoT, the adoption of the central bank digital currencies, and the holding of digital assets such as cryptocurrencies and nonfungible tokens by companies and governments.

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