A MAPPING ANALYSIS OF BLOCKCHAIN APPLICATIONS WITHIN THE FIELD OF AUDITING[***]

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ABSTRACT

Blockchain technology has a wide scope of applicability for accounting and auditing purposes, separate from Bitcoin or other cryptocurrencies. However, although blockchain technology is identified as a popular topic within the field, there currently exists a lack of consensus on how it will be realistically applied. This paper aims to map the presently existing international auditing literature and offer clarity to an otherwise heterogeneous field. The mapping analysis will aid in examining the underlying theme employed within studies. Through the use of the Bibliometrix R-Package "Biblioshiny", a sample of 112 studies were downloaded from the Web of Science Core Collection and analyzed. This study's results show that the topic has gained increased international popularity and separated into distinct research streams; Encrypted Private and Secure Information Sharing, Distributed Ledger, Smart Contracts, Continuous Audit, Audit Trail and Tokenization. However, there still exists a research gap that must be addressed to hasten the adoption of blockchain technology in auditing.

Keywords: Auditing Profession, Blockchain, Digitalization, Blockchain Applications, Mapping Analysis

JEL Classification: M40, M42, M49

DENETİM ALANINDA BLOKZİNCİR UYGULAMALARININ HARİTALAMA YÖNTEMİ İLE ANALİZİ

ÖZ

Blockchain teknolojisi, Bitcoin veya diğer kripto para birimlerinden ayrı olarak muhasebe ve denetim alanında geniş bir uygulanabilirliğe sahiptir. Ancak blokzincir teknolojisinin alanda hızlı bir şekilde yer edinmesine rağmen, günümüzde gerçekçi bir şekilde nasıl uygulanacağı konusunda fikir birliği bulunmamaktadır. Bu çalışmanın

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amacı, mevcut uluslararası denetim literatürünü haritalamak ve uygulamadaki mevcut karmaşıklığa açıklık getirmektir. Web of Science Core Collection'dan indirilen 112 çalışma Bibliometrix R-Package "Biblioshiny" yardımı ile analiz edilmiştir. Bu çalışmanın sonucunda, konunun uluslararası alanda farklı araştırma dallarına ayrıldığı tespit edilmiştir; Şifreli Özel ve Güvenli Bilgi Paylaşımı, Dijital Defter, Akıllı Sözleşmeler, Sürekli Denetim, Denetim İzi ve Tokenizasyon. Bununla birlikte, denetimde blokzincir teknolojisinin benimsenmesini hızlandırmak için ele alınması gereken araştırma boşlukları tespit edilmiştir.

Anahtar Kelimeler: Denetim Mesleği, Blokzincir, Dijitalleşme, Blokzincir Uygulamaları, Haritalama Analizi

JEL Sınıflandırması: M40, M42, M49

1. INTRODUCTION

Advances in technology have started to occur at an exponential rate within the last decade. Regardless of country boarder or industry, the new digitalization era promises to transform business practices (IAASB 2016, 1) and the economy. The growing use of technology has allowed businesses to become faster and more flexible (Vaidya, Ambad, and Bhosle 2018, 235). On the other hand, smart systems have created significant productivity gains that will reshape specific occupations, guaranteeing the efficient production (Rüßmann et al. 2015, 55) of higher-quality goods and at lower costs. This development has prompted the widespread acceptance of digitalization. The auditing profession is not immune to these technological advances. Motivated by several driving factors, the auditing field has welcomed these changes since the early 1970s to increase efficiency, withstand competition, and reduce expenses. Omoteso (2012) states that this field is one of the first areas where automated tools will be applied. Accounting firms are increasingly recognizing the potential impact of utilizing technology to perform better audits (Appelbaum et al. 2017, 2). This has been the main driver in transitioning from the traditional auditing model of "manual auditing", to a more modern framework. Governed by internationally recognized rules and regulations, independent auditing firms have consistently implemented new technological developments across each branch and are active in many countries. Moreover, the field currently faces customer demand to complete the transition to blockchain and smart systems (Alles 2015, 439). Change is inevitable; thus, the field's evolution needs to be taken into consideration before moving forward. These proposed changes promise to not only affect current auditing operations, but they will also affect the continuity of the field of auditing as a whole. Thus, with the new technological era promising to transform the profession, regardless of country borders, this creates a motivation to analyze its effect within auditing.

This study aims to identify major research streams in the field of auditing regarding blockchain applications. By collecting information from the literature listed under the Web of Science Core

Collection within the Clarivate Analytics Platform via bibliographic mapping analysis, this paper will analyze the current awareness level of the auditing field regarding changes in the profession. This study is important for researchers and the audit profession, as it highlights the gap between current and future expectations of the field. Recognized as one of the most innovative (and potentially disruptive) technological advances with business (Dai and Vasarhelyi 2017, 5; Mosteanu and Faccia 2020, 159; Smith 2018, 78; Wang and Kogan 2018, 1; Faccia et al. 2019, 31; Schmitz and Leoni 2019, 1; Tan and Low 2019, 312; Liu at al. 2019, 19; Cagle et al. 2020, 105; Yilmaz and Ozdagoglu 2020, 20), blockchain applications will be analyzed within the scope of this study via use of the software Bibliometrix R-Package "Biblioshiny". The sample consists of 112 studies downloaded from the Platform according to the search criteria. Through the R-Package program, the geographical productivity, sponsorship, collaboration network will be mapped. Moreover, the blockchain applications recognized within auditing will be analyzed by a combination of content and bibliometric analysis. This study's results show that the topic has gained increased international popularity and separated into distinct research streams. However, there still exists a research gap that must be addressed to hasten the adoption of blockchain technology in auditing. It is hoped that the results of this study will hold particular importance for researchers and regulatory agencies in promoting further improvements in this topic.

The remainder of the study is structured as follows. Section 2 addresses the currently recognized benefits of implementing blockchain technology within auditing. Section 3 presents detailed information on the methodology. The findings and discussion are summarized under Section 4, and Section 5 concludes.

2. LITERATURE REVIEW

Blockchain technology has a wide scope of applicability for accounting and auditing purposes, separate from Bitcoin or other cryptocurrencies. However, although blockchain technology is identified as a popular topic within the field, there currently exists a lack of consensus on how it will be realistically applied. This argument can be further observed in the following literature. Castka et al. (2020) analyze the potential benefit of applying blockchain technology to green audits (a.k.a. social/environmental). The authors state that green audits are a challenging endeavor that has a high cost for the auditing firm. Moreover, they argue that the information gathered often lacks reliability and timeliness (Castka et al. 2020, 1). As a result, the authors explore the role of blockchain (supported by cloud technology) within the auditing process (such as data collection, analysis, and distribution) to increase the effectiveness of green auditing practices. They determined that blockchain technology promises to improve the reliability, transparency, and timeliness of data employed within the audit. As blockchain technology becomes more prevalent within organizations, the cost of monitoring and control will be decreased.

Moreover, access to previously hard to collect data will become available (Castka et al. 2020, 3), thus improving the quality of the audit. As real-time data becomes accessible to the auditor on a continued basis, Castka et al. (2020, 4) state that firms' disposition towards non-compliance with regulatory or accounting requirements will be reduced. Finally, the authors argue that adopting blockchain technology will make falsifying information more difficult as all records will be stored within the network-rendering data unalterable (Castka et al. (2020, 5). Wang et al. (2020) address the potential role of blockchain technology in replacing 3rd party auditors. The authors design a "*fair payment smart contract for cloud storage*" framework (Wang et al. 2020, 25) that allows for the consistent sharing and receiving of data proof. Moreover, a self-executable protocol recorded within the blockchain would automatically perform any specified action once pre-determined events are met (Wang et al. 2020, 5). Once events are met, and verification is passed (or failed), the auditor would receive remuneration (pay penalties). In comparison to more traditional auditing schemes, employing blockchain within the audit would enable firms to pay for services rendered after the fact, rather than in advance. Blockchain technology would also play a role in ensuring the integrity and reliability of the information entered within the audit process. The smart processes employed would ensure that information stored on the cloud is safe and unmodified, preserving the organization's data integrity (Wang et al. 2020, 1). Mosteanu and Faccia (2020) analyzed the development of an eXtensible Business Reporting Language (XBRL) integrated blockchain system to manage the process of automatically generating the firm's financial statements from accounting-based information entered into the network. The authors argue that by including these innovative tools within the firm, the overall reliability of financial information prepared will be increased, while the risk of fraud or error decreases. This would help generate a safer business environment where time-consuming manual tasks are replaced by analytic testing and analysis (Mosteanu and Faccia 2020, 159). By integrating distributed ledger technology within the organization, they will be allowed to record their economic transactions into an interconnected system (Mosteanu and Faccia 2020, 161), which guarantees the reliability of the information and lacks an intermediary entity. By combining this technology with administrative documents (such as smart contracts), organizations would be able to delegate certain activities in a decentralized manner. The validation of transactions would be performed over the blockchain, reducing the potential for human error and fraud. Finally, cryptographic technology would aid in either blocking, linking, or safeguarding access to highly sensitive information regarding the firm's operations (Mosteanu and Faccia 2020, 163). Similarly, Faccia et al. (2019) build a framework for an integrated system that incorporates blockchain technology within each step of the financial accounting cycle. The model offered by the authors takes into account various groups of stakeholders (such as accountants, auditors, government officials, banks, and other regulatory authorities) (Faccia et al. 2019, 31) and employs the use of the XBRL. The framework suggested by the authors bars those without authorization from entering transaction history. As a result,

Faccia et al. (2019, 32) argue that maximum transparency and security are achieved, and data corruption is reduced.

Fuller and Markelevich (2019) focus on cybersecurity concerns relating to the firm's accounting and auditing operations. Contrarily to the articles addressed above, Fuller and Markelevich (2019, 1) argue that the field of accounting might not be a suitable match for the current version of blockchain technology. The authors state that, although recognition for the technology has increased dramatically over the years, it is crucial to analyze the accounting profession's view towards integrating blockchain within the field. As a result, they conduct a contents analysis on the 10K fillings us US firms listed within the exchange in 2018. Fuller and Markelevich (2019) focus on voluntary information Reported concerning the adoption of the technology within firms. The authors determine that organizations such as banks and brokers/dealers have taken steps to integrate blockchain technology (Fuller and Markelevich 2019, 4). Moreover, they argue that one of the primary motivators for facilitating the transition was managers' desire for transparent/ reliable accounting information and lower costs (Fuller and Markelevich 2019, 7). By integrating distributed letter technology within the organization, the organizations support that key data security issues could be addressed, and the misappropriation of assets could be reduced. Information entered into the blockchain would be harder to alter over time, thus further reducing the potential of fraudulent misreporting. However, the authors argue that the technology's current computational speed is incapable of sustaining this transition. Thus, although the literature supports the cost-reducing effects of blockchain integration, costs could soar before efficient performance is achieved (Fuller and Markelevich 2019, 11). Liu at al. (2019) analyzes the integration of permission(/permissionless) blockchain technology within auditing. Defining the former as a way in which accounting information can be shared freely within network users, the authors propose that this technology could offer fundamental change to the accounting profession (Liu at al. 2019, 19). Users would be permitted to either share information or transfer funds through the chain under an encrypted message containing the sender/recipient name and address. By broadcasting this encrypted message across the chain, the risk of fraud would be reduced as related parties could examine the validity of the block containing the code. In comparison to the more traditional transaction system, this technology allows for the integration of cryptographic encryption, the sharing of real-time transaction records, and, finally, embedded self-executing programs/transactions triggered when certain conditions are met (Liu at al. 2019, 19-20). Finally, the authors argue that the integration of this technology will affect the auditing processes and change the role of auditors within organizations. They state that this disruptive technology will force auditors to become a strategic partner and take steps to adapt to the new business environment (Liu et al. 2019, 26). Similarly focusing on security and privacy issues regarding blockchain applications, Naganuma et al. (2017) develops a Zerocoin protocol framework that aids in hiding the link between individual transactions and related parties (Naganuma et al. 2017, 61), without

the need for 3rd parties. The authors argue that a zerocoin protocol would allow auditors to extract information from the transaction, while simultaneously preventing data miners from doing the same. Moreover, D code also helps prevent additional information from being embedded within the chain that could harm the firm or the auditing process. The authors further support their findings by conducting a simulation analysis that proves standard blockchain could potentially be accessed and the transactions de-anonymized. The zerocoin protocol proposed by the authors addresses this issue and increases the reliability and transparency of accounting information recorded under the chain (Naganuma et al. 2017, 59). On the other hand, Ahmad et al. (2019) develop a tamper-proof system referred to as Block-trail. The authors argue that the system is tamper-proof, but it also reduces the overall storage footprint required for functioning. By dividing the chain into various levels, the block-trail introduces a multilayer network with low processing delays. Also referred to as hyper-ledger, this protocol in shores of that existing logs or audit trail entries are generated and sent to related parties to validate transactions (Ahmad et al. 2019, 5).

With the aid of blockchain technology, McCallig et al. (2019, 48) design a system aiming to increase the representational faithfulness of accounting information and share secured information concerning reporting an auditing process. Employing the use of a cryptographic protocol, the authors develop a recording technique to enhance the overall reliability of data (McCallig et al. 2019, 47). The system ensures that only valid information is entered into the network, increasing the overall completeness of data used when preparing financial statements. Data entered within the blockchain is linked together in the form of a sequence. In case of incorrectly or erroneously entered data, the sequence can be traced back to the genesis block, providing further incentive for users to provide accurate information. Not unlike McCallig et al. (2019), Tan and Low (2019) too design an accounting information system. The authors however, analyze the digitalization of the paper-based validation process. Moreover, the authors examine the changing role of auditors, as most auditing processes are moved online. They support that, regardless of the digitalization trend, the audit evidence still needs to be gathered manually to provide an audit opinion. Finally, they argue that the new technology aids in increasing the tracing, transparency of required information, while reducing the overall costs (Tan and Low 2019, 312).

If complete integration can be achieved, the accounting and auditing field stands to benefit significantly from blockchain technology. As a result, this study aims to analyze the specific applications of blockchain technology covered throughout the international auditing literature. With awareness of the topic increasing, further momentum can be facilitated through a critical review of this literature and the identification of realistically useable application themes for accounting and financial purposes.

3. METHODOLOGY

As mentioned above, the aim of the study is to identify major research streams in the field of auditing regarding blockchain applications. In order to accomplish this, the paper attempts to map the currently existing international auditing literature to offer clarity to an otherwise heterogeneous field. The mapping analysis will aid in examining the underlying theory or theme employed within studies. Moreover, it will present the current discussion on the development of blockchain auditing technology and offer implications for academic research and practice. Consequently, the methodology of the study consists of the combination of a bibliometric mapping and content analysis.

The mapping analysis employs the use of the software Bibliometrix R-Package "Biblioshiny". The Bibliometric R-Package is a widely recognized (Buccino and Mele 2019, 4) open source software that provides a wide range of functions to assist the researchers (Perannagari and Chakrabarti 2020, 3) and aids in the visualization and analysis of large sources of data via use of intuitive scientific maps, dendrograms, or collaboration networks (Aria and Cuccurullo 2017, 962). Developed using RStudio (Bariviera and Merediz-Sola 2020, 1), the Biblioshiny package is a powerful interactive tool that allows for the extraction of useful knowledge from the dataset and is supported with an online web service (Linnenluecke et al. 2020, 15). The analysis under the package also provides information on the changing structure of literature over time (Aria and Cuccurullo 2017, 960). Unlike other systematic literature reviews employed by researchers, this method is objective, transparent, and replicable (Gärtner and Rockenschaub 2018, 90; Aria and Cuccurullo 2017, 959).

The first step of employing the R-package is the compilation of a comprehensive dataset of relevant publications (Linnenluecke et al. 2020, 10). As a result, a search strategy was designed to retrieve studies that met a high standard of quality relating to Blockchain applications in auditing. Figure 1 provides summary information on the steps taken in the data collection process. The method identified by Ratajczak and Szutowski (2016) guided these steps and are divided as *preliminary study (database and keyword selection), initial search, refining the results, appraisal of exclusion criteria, and final search*. The modified Ratajczak and Szutowski (2016) model for the paper is presented below.

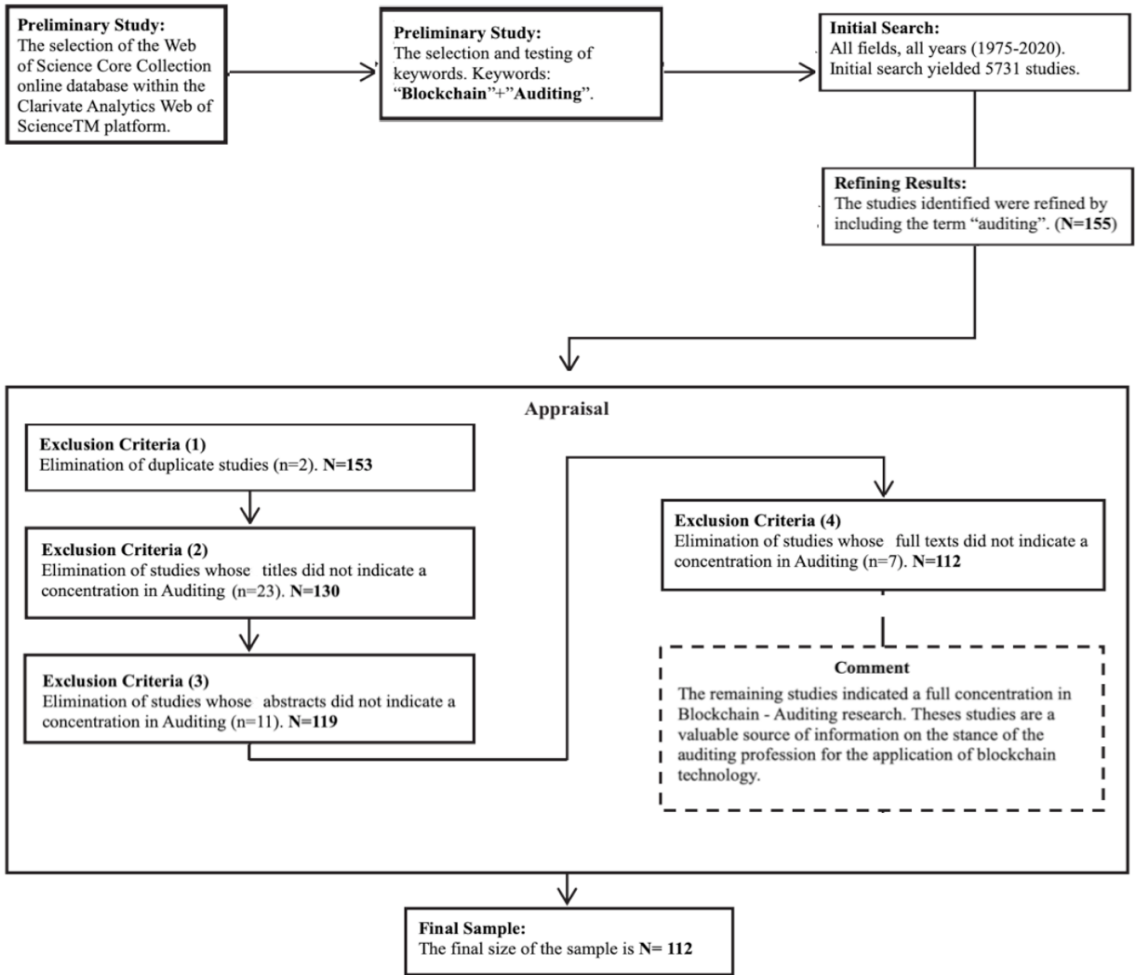

Figure 1. Sample Selection Methodology

To ensure the search encompasses a wide range (Meline 2006, 21) of accounting/auditing studies, the appropriate selection of databases is an important initial step under the review process. Moreover, the database should aid in the collection (Treadwell et al. 2011, 1) of rigorous and defensible data (Meline 2006, 23) for the review. Providing full-text access via an online delivery system (Aboelmaged 2010, 269), the Web of Science Core Collection within the Clarivate Analytics Platform was selected for the study. The works indexed under the collection are considered to be unique and contain independent/ thorough editorial processes. Moreover, studies listed within the platform are argued to be of the highest quality and reflect the current research trend within the literature (Bartol et al. 2016, 979). The database contains records of articles from the highest impact journals globally, including open-access journals with the coverage going as far back as the 1900s (Clarivate 2020a, 1). The works listed under the database are influential papers distinguished between their peers (Cheek et al. 2016, 424; Garousi and Fernandes 2016, 109). Similarly, Yan et al. (2013, 253) argue that the Core Collection is one of the most widely used databases for literature assessment and produces good results for large

quantities. Moreover, as the database classifies research according to various research areas and categories (Clarivate 2020b, 1), this aids in the detection of specific publishing trends. Stated differently, researchers can determine whether or not the related papers belong to a particular or broader scientific field (Bartol et al. 2016, 982). The Core Collection consists of "*Emerging Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI- Expanded), Sources Citation Index (ESCI), Arts & Humanities Citation Index (AHCI), Conference Proceedings Citation Index (CPCI), Science Citation Index Expanded (SCIE), Book Citation Index (BKCI) and finally, the Current Chemical Reactions and Index Chemicus Divided"* (Clarivate 2020b, 1).

After determining the database, the second stage of the preliminary study included the selection and testing of keywords relating to the research question. The keywords were selected to retrieve a complete, exhaustive dataset and initially included the word "Blockchain". A pilot test (Melbourne 2020, 1) was conducted by examining the keyword results. This pilot study aided in testing for the relevancy of identified studies. Because of the multi-discipline nature of the term, it is a challenging task to classify the literature under a single discipline. Thus, the word "Auditing" was employed in conjunction with the above terms to fine-tune the search parameters and restrict the studies to only include those in the area of accounting/auditing. As a result, the overwhelming list of unrelated cases initially identified were adjusted and/or removed. The initial sample consisted of the whole population of auditing related blockchain research within the platform. A total of 5731 studies were identified under the initial search. However, upon refining the results, the sample was reduced to include 155 studies. In order to ensure that the search provided a comprehensive overview of the available evidence, the review was originally conducted between the years 1975 to 2020. The search was restricted because the full source (title, abstract, keywords, and full text) search function on the official Web of Science website does not go further back than 1975. Thus, the collected data for the review consisted of studies published between the years 1975 to 2020. The first study relating to the field of auditing was first published in the year 2016. Finally, the usage of English keywords ensured that non-English studies were excluded from the sample.

The search was conducted in three steps and was carried out over a period of 3 weeks. Under the initial phase, all types of documents, including articles, proceeds, reviews, and books published by Clarivate Analytics, were evaluated. The full-text (title, abstract, keywords, and text) of the works covered under the engine were searched employing the use of the agreed-upon terms. Restrictions such as journal scope or year were not initially applied as the paper aimed to retrieve a complete exhaustive and representative sample (Siddaway 2014, 3) of all studies that have been conducted on the topic of interest. The initial search was conducted on the 17th of March 2020. The number of articles published on the subject matter changes quite frequently. As a result, a cut-off point for the search was determined. Works published after the cut-off point were not included in the scope of the analysis.

Following this, the remaining 155 studies were appraised according to the exclusion criteria determined. The exclusion process was completed under four steps. A summary of information on these steps can be found in Figure 1. Step 1 consisted of the elimination of duplicate works (2 studies). Next, these 153 studies were downloaded. Studies whose titles (23 studies), abstracts (11 studies), or full text (7 studies) that did not indicate a concentration in auditing were subsequently removed from the analysis. The remaining 112 studies indicate a full concentration in blockchain in auditing research. These studies are a valuable source of information on the auditing profession's stance for the application of blockchain technology. The final distribution of the identified studies according to publication year and type of document is presented below in Table 1. As mentioned above, the initial study concerning blockchain applications in the field of auditing was first published in the year 2016 within the core collection. The following period saw rapid growth in the number of articles and proceeds.

Table 1. Sample Distribution

Document Type	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
Article	0	3	8	31	4	46
Proceedings Paper	1	14	33	17	1	66
Total	**1**	**17**	**41**	**48**	**5**	**112**

Upon completion of the data selection stage, the full works were reviewed in-depth to produce the underlying theory or theme employed (Linnenluecke et al. 2020, 10) regarding blockchain applications in the field of auditing. After a detailed reading of the 112 papers in the sample, the studies were classified according to the presented blockchain applications. As several papers cover the use of more than one technology, each application was coded individually (Bariviera et al. 2020, 2). The data collected throughout this process was then mapped using the Bibliometrix R-Package Program "Biblioshiny". The 112 studies were downloaded from the Clarivate Analytics Database in the form of a BibTex. The data included the full record for all sources. This information is as follows, "title, author(s) name, publication year, journal area, type of publication and citation amount, abstract, author addresses, keywords, journal or conference name, sponsorship or Funding Agency, conference title, author contact information, publisher, publisher address and finally, research area" for each study. The package's data is uploaded in the form of a BibTex file that is automatically converted into descriptive and research-structure results (Aria and Cuccurullo 2018, 1). The analysis consisted of the geographical productivity of research concerning blockchain auditing applications, collaboration, keyword and funding mapping, and blockchain applications in auditing. The findings generated by Biblioshiny are discussed in detail in the following section.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

A total of 112 studies and 394 authors were examined within the mapping analysis. Fourteen of these studies were conducted by single authors. The remainder of the studies had a range of 2-9 authors. The country's productivity concerning blockchain research in auditing is provided below in Figure 2. The sample is distributed across 33 countries. Figure 2 depicts the most productive countries regarding blockchain applications in auditing. The map statistics are calculated under the R-package based on the authors' addresses listed in the published document. The top-most productive countries were identified as China (33% of publications) and the USA (30% of publications). Out of the 33 countries researching blockchain applications in auditing, the USA and China have contributed to a higher degree to the evolution of the current literature.

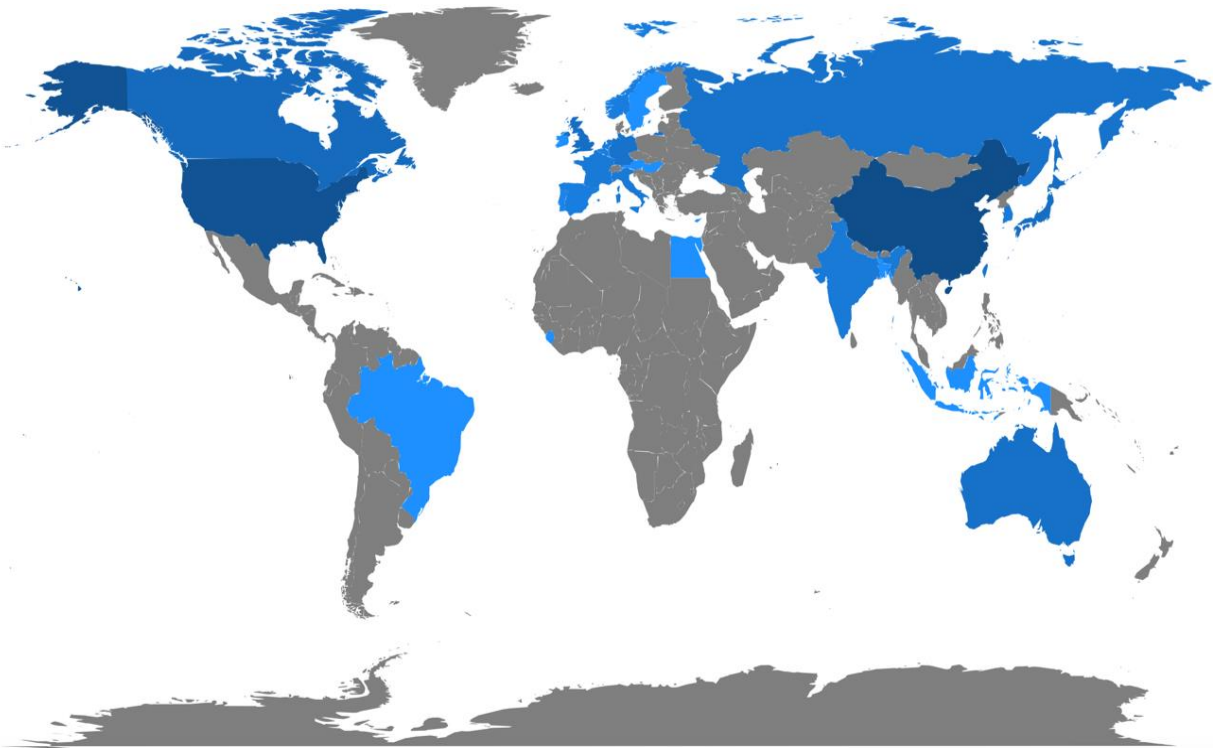

Figure 2. Country Specific Production of Blockchain Research in Auditing

It is apparent from the country-specific production analysis that both China and the USA are currently leading the high-quality research conducted regarding blockchain technology in auditing. This argument is further supported by reviewing the percentage difference (of the productivity levels) of the remaining countries. With nearly a 26% difference, Germany is the third most productive country in blockchain research in auditing (at 4%). The works published by the remainder of the countries ranges between 1-

3% [Australia, Bangladesh, Brazil, Hungary, Ireland, Malta, Sierra Leone, Singapore, Sweden, Cyprus, Dubai, Indonesia, Luxemburg, Egypt, Norway, Portugal, Wales (<1%), Canada, Italy, South Korea, Spain, Belgium, Netherlands, Taiwan (<2%), France, Australia, England, Russia (<3%), India, Japan (<4%)]. Both articles (46 items 42% of the sample) and proceeds (66 items, 58% of the sample) are distributed across a wide range of publications (32 journals) and 60 conferences meaning that a large number of groups are simultaneously driving towards increasing blockchain application research in auditing**.** Stated differently, it can be argued that researchers are currently aware of the importance of the topic and independently striving to facilitate further research in this area. The most popular top 5 sources for articles listed on the Core Collection are the IEEE Access (7 items), the *Journal of Emerging Technologies in Accounting* (4 items), the *Australian Accounting Review* (2 items), the *International Journal of Accounting Information Systems* (2 items), the *Journal of Corporate Accounting and Finance* (2 items) and the *Journal of Network and Computer Applications* (2 items). It is not surprising that these articles' scope focuses heavily on technological applications within the field of accounting. The remained or the journals (27 journals) have a publication score of 2 items within the sample. Reflecting the arguments presented above, conference publications indicate that a wide range of organizations are also striving to facilitate further auditing research in blockchain technology. The Institute of Electrical and Electronics Engineers (IEEE) publishing group seems to be at the forefront of these efforts as 41 proceed papers (36.6% of the sample and 62% of the total amount of proceeds) were published under joint conferences with the organization. Not unlike the identified articles, the remaining 25 papers were presented and published under technology-focused conferences. However, unlike the journal articles, these conferences did not have a full concentration on accounting or auditing. Instead, they focused on subjects such as business, big data, emerging trends for blockchain, technology management, machine learning, and data application security. The *13th Iberian Conference on Information Systems and Technologies (Cisti)* and the *Data Privacy Management, Cryptocurrencies, and Blockchain Technology* conference were the second and third-most-popular events, making up 16% of the remaining proceeds. After accounting for the IEEE publications, the remaining items were published by the *Association of Computing Machinery* (ACM) (10 items) and *Springer* (10 items) [with Clausius Scientific, International Business Information Management Association-IBIMA, IOP Publishing, SPIE the International Society for Optical Engineering, USENIX Association- each publishing a single proceed]. Although IEEE, Springer, and ACM seem to be in the lead for publishing auditing research in blockchain, the number of sources increases by each year- with new groups jumping on the blockchain bandwagon. When the results for articles are examined, it is apparent that, not unlike proceeds, the IEEE represents 20% of publications. Following this, the second and third highest percentage of publication is published by the *American Accounting Association*, *Elsevier* and *Wiley* (at

15%), and the *Multidisciplinary Digital Publishing Institute (MDPI)* (at 9%), respectively. Figure 3 further depicts the distribution of publishers for articles below.

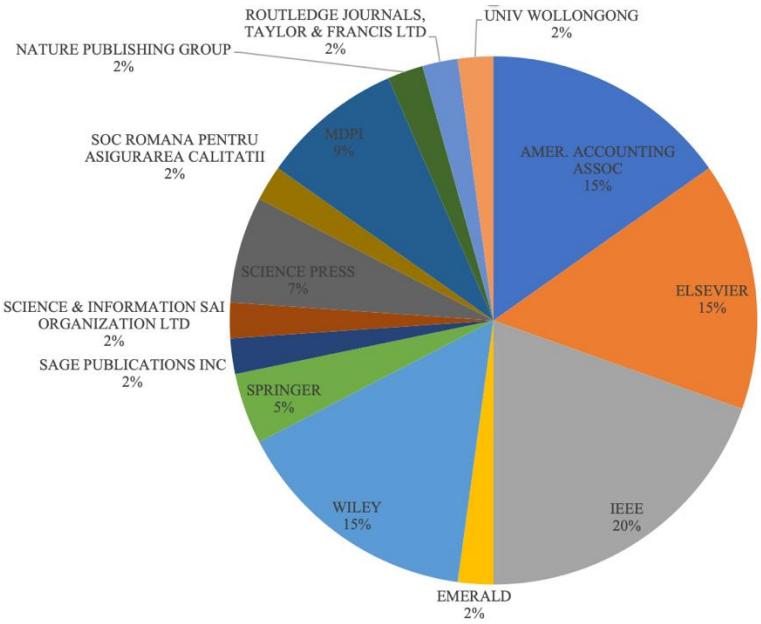

Figure 3. Distribution of Publishers for Articles

It must be noted that these publishers are international organizations that have headquarters across multiple countries. When the headquarters' geographical distribution is examined for each publisher, it is determined that an overwhelming percentage of the total sample (78 items, nearly 70%) was published by organizations in the USA. This result is surprising as the geographical distribution of the authors presented under Figure 2 indicated an accumulation within the United States and China. Stated differently, although Chinese researchers conduct 33 % of the blockchain research in auditing, only 2.6% of these items were published within China. The second and third highest rate of publication is in Switzerland (12 items, 10.7%) and England (11 items, 9.8%) [the remainder are as follows; the Netherlands, 1.7%, Australia, Canada, and Romania, <1%]. These results show that the growing merit of blockchain research is more widely recognized by publishing firms in the United States. Moreover, it could be argued that these organizations are acting as drivers and are pushing for the increased recognition of blockchain technology within the field of auditing.

Table 2. Top-10 Author Affiliations

Authors Affiliations	Articles
Rutgers State University - USA	%5
Southwestern University of Finance and Economics- China	%4
University of Electronic Science and Technology- China	%4
Hangzhou Dianzi University - China	%3

Nanjing University of Posts and Telecommunications - China	%3
Nanjing University Science and Technology- China	%3
National University of Defense Technology- China	%3
Xian University of Technology- China	%3
Zhejiang University - China	%3
Accenture Labs - USA	%2

Universities located within the USA and China were the most common author affiliations identified under the sample. It is interesting to note that author affiliations are not solely restricted to universities. For example, Accenture Laboratories, an independent organization focusing on research and development projects, constitutes %2 of the research. Finally, the total amount of citations recorded for the sample between 2016 - 2020 is presented below in Table 3. Already it is possible to argue that blockchain research and auditing have started generating discussion within the literature. With 387 citations noted on the cut-off point of 17th of March 2020, these studies have managed to create broad interest and are slowly but surely gaining in popularity.

Table 3. Total Citation Amount

Years	Total Times Cited
2016	0
2017	253
2018	93
2019	41
2020	0
Total	**387**

4.2. Collaboration Mapping Analysis

Another common bibliometric analysis consists of collaboration mapping. This type of analysis analyzes researchers' inclination to link (collaborate) with different nodes (the authors) within a network. The map allows researchers to visually identify the intellectual and conceptual structure of a given field. Depicting the collaboration network between authors' countries relating to the blockchain applications in auditing research, the map uncovers hidden study groups between scholars. It is determined that a high collaboration rate exists between nearly all countries located in the sample. This relation is made apparent in Figure 4. The publication rate and the direction of the relation are indicated by the size and linkage of the text. With the exception of Indonesia, Sweden, Spain, and Singapore, countries like Australia, Germany, the United Kingdom, and Canada have taken part in joint studies aiming to improve the research output. However, it is not surprising that an overall high rate of collaboration exists between the USA and China regarding blockchain applications in auditing. Upon comparing the multiple country publications (MCP) ratio (calculated by dividing MCP count with the total publication within country)

between the USA (MCP 3=, 10.3%) and China (MCP -10 30.3%), it is possible to argue that the later has a much higher rate of international collaboration rate than the former.

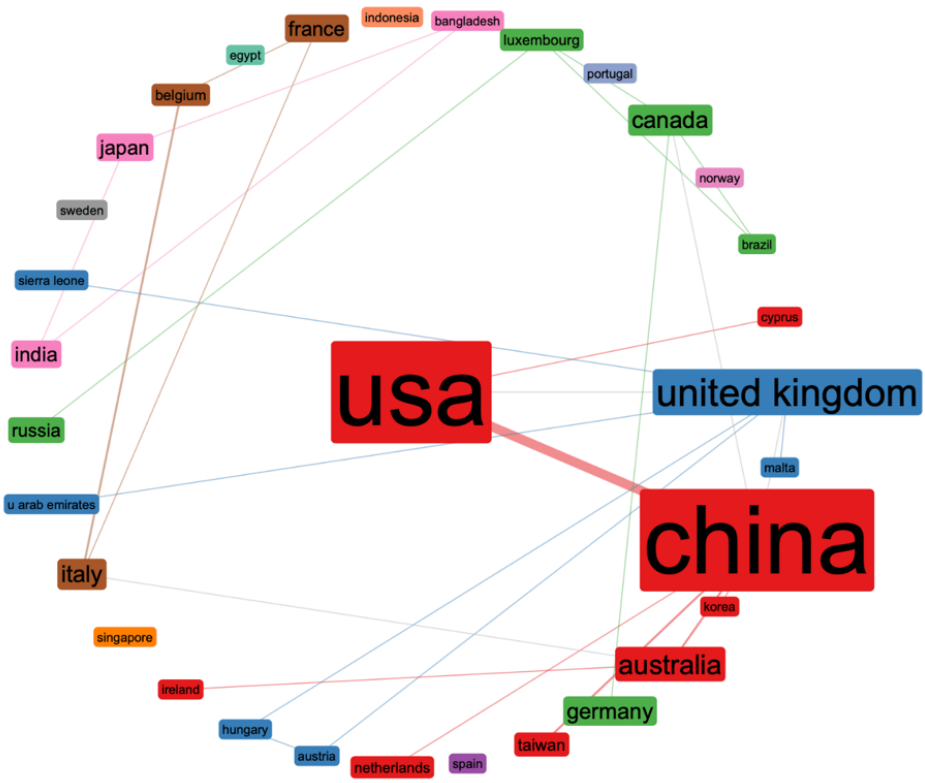

Figure 4. Collaboration Mapping Analysis

4.3. Keyword Mapping Analysis

Under this section, a keyword analysis (or a Cooccurrence Network Map) for the whole sample was conducted. The authors generate these keywords in order to represent or describe the substance of the document in question. They comprise of words that represent the essence of the study. As a result, this analysis will help draw the conceptual framework using a co-occurrence network to map and cluster terms extracted from the sample. Stated differently, this analysis aims to uncover hidden links between concepts within extracted words and to identify what is most important would then the sample. Themes identified are mapped according to their density/centrality and frequency. The thematic map presented in Figure 5 is an intuitive plot employed to analyze these themes.

Figure 5. Keyword Cluster

The words "Blockchain" and "Auditing" were removed from the cluster as they make up the main keywords employed in the search criteria. To ensure that the cluster findings are understandable and reviewable, the R-package only included the top 75 words in the co-occurrence network map. The map allows for gleaning an understanding of the areas in which researchers seem to be focusing on auditing Blockchain research. From Figure 6, it is apparent that data security (24 items), data privacy (16 items), and access control/ management (15 items) are at the forefront of research as they have scored highly within the analysis. This is indicative that research conducted within this area has a higher concentration on privacy and security issues that await the auditing field in light of the current technological shift. This is also indicative of current worries within the blockchain auditing research that need to be addressed if the field wishes to incorporate the new blockchain technology. With organizations moving away from paper too more digital information (electronic documents - 4 items) the speed and size of transfer data have increased dramatically. Thus, the current stream of research supports that it is important to ensure that individuals without proper authorization do not gain access to this information that could potentially harm the operations of the firm (cyber security- 5 items). The blockchain system would help achieve this, as access would be solely restricted to firm workers and auditors (or other stakeholders) that have been approved by management (identify management - 6 items). The managers can distribute encrypted secret-keys for other users, guaranteeing a fine-grained access control via permission-based systems (4 items). Those that should not have access to the system will be blocked

through various cryptography procedures (public key cryptography- 4 items; cryptography - 5 items). Moreover, once the relationship is terminated, permission to specific information could be automatically revoked via smart contracts (Huang et al. 2020, 574). In case of any wrongdoing, the parties with overwrite capabilities or access would be held responsible- rather than the whole chain (2 items).

The next highest scoring issue noted within studies concerns the sharing/receiving of accounting information. Blockchain technology is argued to be a solution to data integrity issues within the field of accounting and auditing. This technology ensures that the information shared is complete, accurate, consistent, and free of tampering. The hash system employed by Blockchain technology is a digital fingerprint on the documents that ensures that it cannot be changed after being entered into the sequence. In case of an erroneous entry where false information has been shared, the system will automatically correct itself via the hash sequence/chain. As a result, the blockchain systems will reduce the risk of error or manipulation (2 items), and in turn, increase data integrity (5 items) and the auditability of accounting information (public integrity auditing - 4 items). The current stream of literature identifies the internet of things (IoT) (14 items) and distributed ledger (12 items) to facilitate in the transfer of trustworthy data from parties where the authentication/verification (3 items) is conducted online systems (traceability 4 items). IoT relies heavily on cloud-based technology (7 items) and aids in the transfer and storage of data over interconnected networks (objects) (Erboz 2017, 5). By integrating this technology, firms can communicate between systems and send, receive and process data (EURDF 2019, 1), while enabling real-time responses and decision making (BCG 2019, 1) without the need for human-to-human or human-to-computer interaction (transaction processing systems- 4 items). The technology is not only defined as "digitizing all physical-systems" (Bortolini et al. 2017, 5700) but also as "advanced object interaction with existing environment" (Vaidyaet al. 2017, 233). The integration of distributed ledger technology (12 items), on the other hand, allows firms to share records (9 items) of validated real-time transactions chronologically in public or semi-open digital ledgers. The system guarantees the information reliability shared without the need for a centralized organization (4 items), increasing the transparency of the reporting environment. The shared information will not only include customer payments or fees, but it will also cover a wide range of accounting data concerning auditors, managers, creditors, and various stakeholders (Yermack 2017, 7).

Another identified benefit of blockchain applications is the usage of smart contracts (12 items) within accounting/auditing operations. Defined as a set of predefined rules, parameters, or programs (Rozario 2019; Dai and Vasarhelyi 2017), smart contract technology allows for real-time tracking and execution of operational obligations without the need for third party interference. Moreover, the smart contracts allow for the integration of IFRS and GAAP standard reporting requirements within the distributed ledger. Stated differently, once the international standards are programmed into the blockchain in the form of smart contracts, auditing, and accounting processes will self-execute without manual input

(Wang 2018; Dai 2017). Therefore, reducing the workload of both the accounting department [economic events can be automatically journalized under the distributed ledger (Dai 2017, 5; Krahel 2012, 7) and auditors [audit procedures can be preprogrammed as IF-IF rules and loaded into the blockchain framework (Rozario and Vasarhelyi 2018, 8)]. By automating routine accounting and auditing activities (that do not require the use of professional judgement), it is argued that the time necessary to complete an audit will be reduced and the auditors' efforts will be allocated to testing higher-risk areas (Rozario 2019, 1). As a result, with the implementation of smart contracts, business activities will become more transparent, and audit quality will increase (Dai 2017, 4).

Blockchain applications will reduce the need for physical documentation, thus allowing the audit to be carried out uninterruptedly throughout the accounting period. Continuous monitoring/assurance (3 items), control activities, and communication between all physical systems will be achieved through the integration of smart-shelf systems or IoT technology. The audit itself will not be left until the end of the accounting period. By conducting continuous auditing with the aid of smart systems and the distributed ledger, the disturbance to the organization's operations would be reduced to a minimum. Moreover, audited financial statements would be made available for user groups more frequently. Finally, the content and length of the auditor reports could be altered as reaching reliable information becomes easier for auditors within the blockchain technology. With the help of deep learning technology, the continuous control system will also play a role in fraud prevention (Wang 2018). Convenient data access will enable the auditor to collect and verify information efficiently. Moreover, they will be able to examine nearly 100% of audit evidence to reduce the audit risk and provide reasonable assurance (Koslowski 2016). Transitioning from manual to automated/electronic logs, detailed audit trails (10 items) generated via the blockchain technology will aid in questioning the validity and reliability of recorded transactions (Johannesen 2018, 1). Event logs will be made visible to the auditor in real-time (data provenance- 5 items), thus providing access to a more transparent audit trail (cloud auditing - 8 items).

Finally, the concept of tokenization is also addressed in blockchain auditing technology [data payment protocols - 3 items; classification of assets- 2 items]. Tokenization provides a method in which tangible or intangible assets (or liabilities) can be moved into the blockchain (Yermack 2017, 7). By monetizing participation rights for assets (or liabilities) via smart contract protocols (payments or transfer illegal rights), the economic value of the asset in question is converted into a digital token (Lansiti and Lakhani 2017, 120). These tokens can be actively stored or traded within the blockchain network. Not unlike Bitcoin technology, the value of assets (or liabilities) of any type [from stocks, bonds, real estate, cars to luxury bags, or priceless works of art (Yermack 2017, 8)] can be managed under the blockchain. The network creates a platform in which both selling and buying parties can easily connect and transact. Once a sale occurs, the blockchain updates the digital wallet of both the seller/buyer. It is argued that the incorporation of real-world assets into the network will aid in increasing

the transparency, liquidity, and the exchange potential of firm assets (Lansiti and Lakhani 2017, 121). The themes identified throughout the sample indicates the full range of applicability blockchain technology has within the auditing field. The themes identified are as follows; "*Encrypted Private and Secure Information Sharing, Distributed Ledger, Smart Contracts, Continuous Audit, Audit Trail and Tokenization*". These themes are employed within the content analysis conducted in the following section.

4.4. Blockchain Applications within Auditing

The themes identified under the 112 studies are employed as a coding framework to determine the current level of blockchain applications supported within auditing. The full text of the documents is analyzed and subsequently coded according to the 6 blockchain applications. Works addressing multiple themes were coded accordingly. The results of the content analysis are presented under Figure 6. It is apparent that privacy and security issues (Encrypted Private and Secure Information Sharing) were at the forefront of discussion and subject to 80.3% of the studies (90 studies). This is reflective of the findings of the keyword mapping analysis presented in the previous section. The second highest blockchain application incorporated into auditing research is distributed ledger technology, with 56.2% (63 studies).

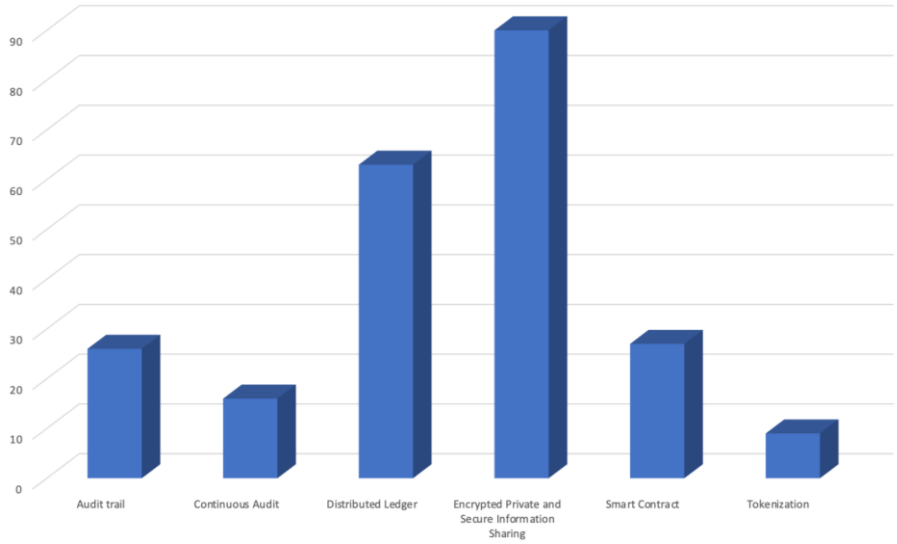

Figure 6. Blockchain Applications in Auditing

The audit trail and smart contract applications were the topics of 23.2% (26 studies) and 24% (27 studies) of works, respectively. On the other hand, continuous auditing constituted 14.2% (16 studies) of the sample. Finally, with only nine mentions, tokenization is the lowest theme covered by the current auditing literature.

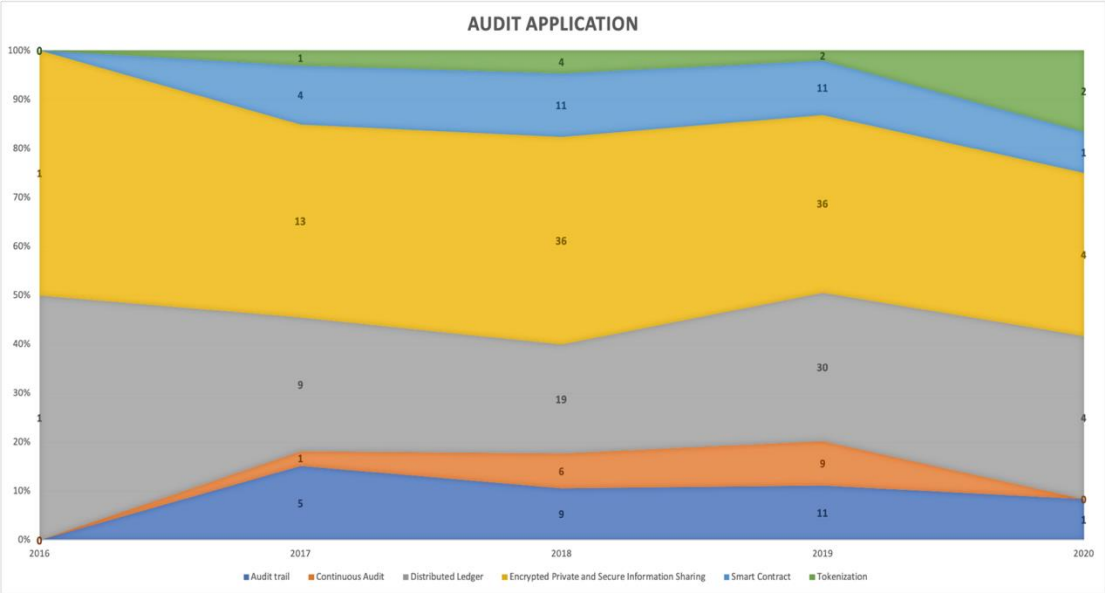

Figure 7. Chronological Development of Blockchain Applications in Auditing

The chronological development of the identified blockchain technology is presented in Figure 7. Although the range of years is limited, this figure provides valuable information as it visualizes the ease in which encrypted private and secure information sharing in distributed ledger gains support within the auditing profession. Over the next few years, audit trail, continuous audit, smart contract technology, and tokenization slowly but surely increase in volume. These results are promising as it highlights the possibility of national regulatory agencies' and organizations' integration of these applications within the practice. Following this, the amount of funding and grants offered for conducting each blockchain application is analyzed. This analysis aimed to determine whether or not certain types of applications received more funding than others. Interestingly, a significant percentage of each application is determined to be funded (tokenization 88.8%, continuous audit 75%, distributed ledger 58.7%, encrypted private and secure information sharing 67.7%, audit trail 65.3%, and smart contract 59.2%). However, although the funding set aside for each blockchain application is promising for the future development of the auditing field, it is determined that it has not positively influenced the amount of research on certain applications. Stated differently, it is not possible to argue that funding made available for authors researching certain topics has aided in increasing its outputs. Instead, it can be argued that the blockchain application in auditing, in general, is widely funded. Moreover, the funding made available continues to increase each year. Comparing these results across the 33 countries, it is determined that 44% and 29% of funding went towards Chinese and American researchers, respectively. It can be argued that the funding afforded to the two most productive countries was a driving factor in increasing the level of research by Chinese and American researchers. With nearly a 24% difference, Germany scholars were the third highest group of researchers to receive funding. Finally, the

geographical distribution of each blockchain application in auditing is analyzed in Figure 8-9. Countries with less than 1% productivity for specific blockchain applications were classified under the other category to aid in the interpretation of the findings.

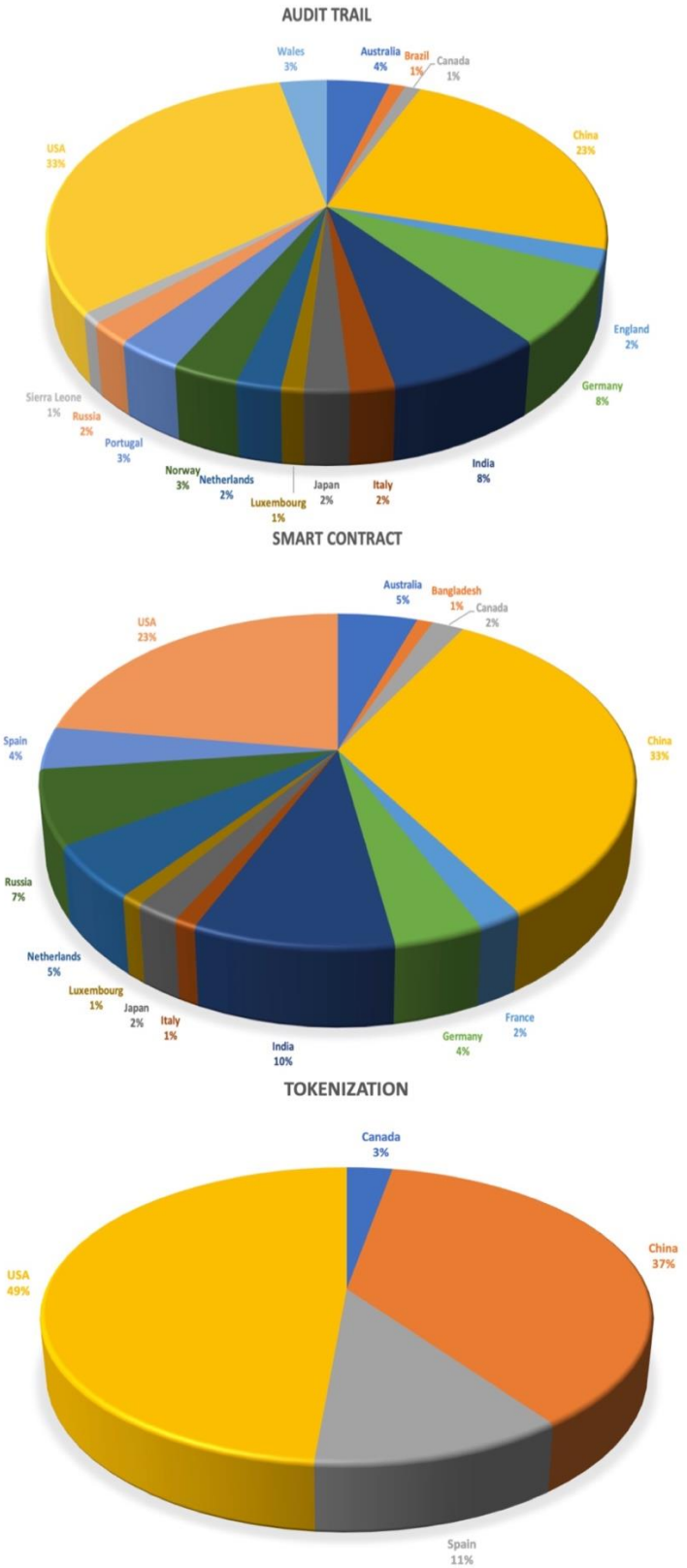

Figure 8. Geographical Distribution of Blockchain Applications in Auditing (Part 1)

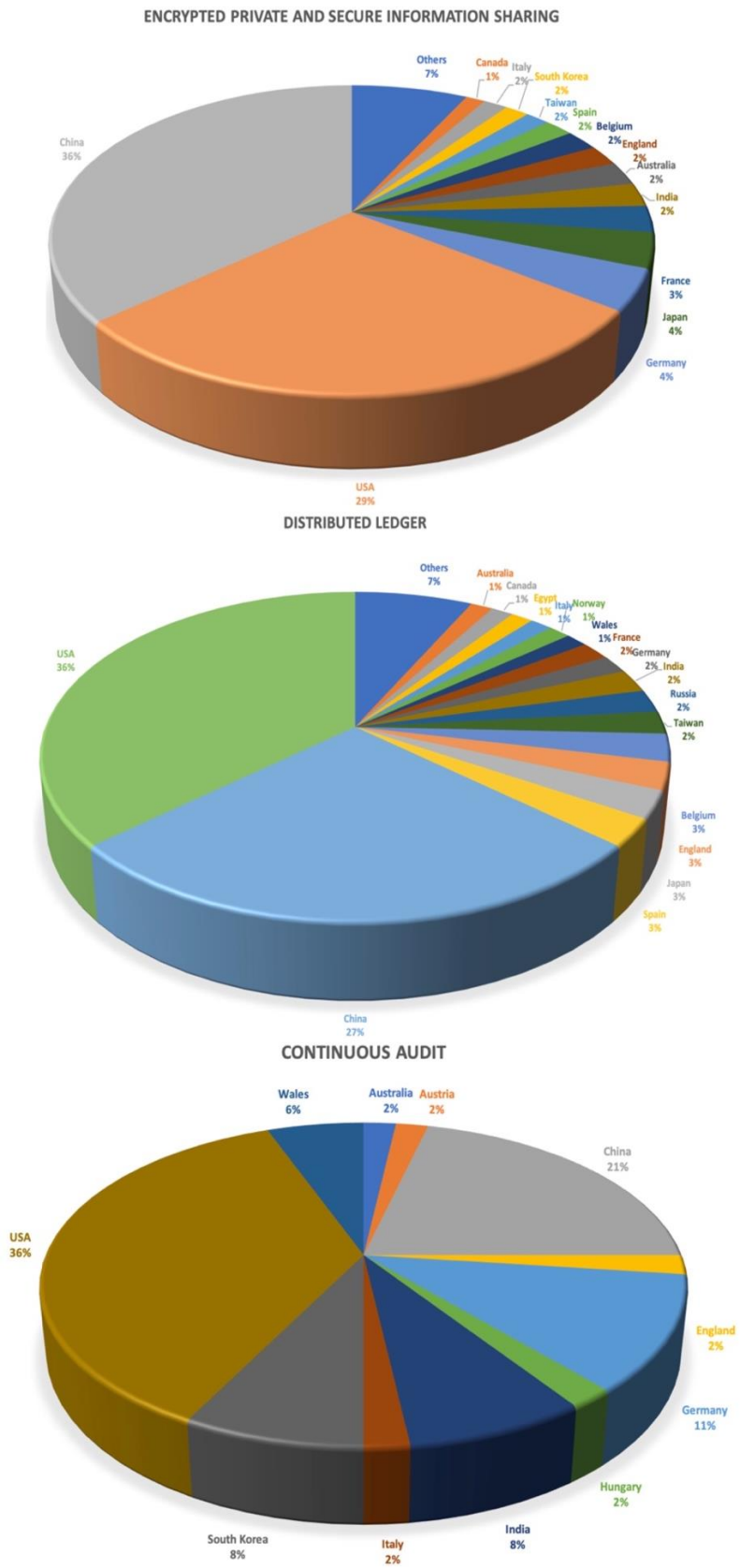

Figure 9. Geographical Distribution of Blockchain Applications in Auditing (Part 2)

Figure 8-9 presents the distribution of the geographical popularity of specific blockchain applications within the sample. Reflecting previous arguments, the USA and China are consistently leading across all types of blockchain applications. Stated differently, both countries are equally invested in analyzing the integration of each blockchain application in auditing. However, there exists a slight deviation between the ranking of these countries. Interestingly, smart contracts (33%) and encrypted private and secure information sharing (36%) research scores are higher in China than in the USA. Contrarily, audit trail (33%), tokenization (49%) and distributed ledger (36%) and continuous audit technology (36%) has gained more recognition within the USA. The USA and China aside, the distribution of blockchain applications varies dramatically for the remainder of the sample. For example, tokenization research is more prevalent in Spain (11%). Audit trail research is distributed across multiple countries, with the highest concentration is in India (8%) and Germany (8%). Similarly, smart contract research is concentrated in Russia (7%) and India (10%), while continuous audit technology is more advanced in South Korea (8%) and India (8%). Finally, the distributed ledger technology is evenly dispersed across multiple countries. Figure 8-9 is an important source of information, as it not only shows the distribution of certain blockchain applications within specific countries, but it also aids in identifying the current research gap. For example, the figure above indicates that there is currently a lack of research concerning tokenization within countries. This is surprising, as tokenization seems to be one of the most promising blockchain applications (Lansiti and Lakhani 2017, 120) in auditing. As a result, it can be stated that additional research is required to raise awareness of the potential benefits tokenization can bring to the auditing profession. The research gap identified for the remainder of the countries are listed below in Table 4. It must be noted that these countries have, to a certain degree, started researching blockchain applications within auditing. However, the applications analyzed are limited to specific topics.

Table 4 is an indicator of the area of research that needs to be filled by researchers. Any additional research in this area will contribute to the hasty adoption of blockchain technology within the auditing field. Although the topic has gained quick support within the international literature, the extent of table 4 is slightly discouraging. The swift adoption of blockchain technology within the field needs to be facilitated through a wide disbursement of countries. However, as the current population of quality blockchain research seems to be focused within the USA and China, this indicates that there is still some way to go before the technology is accepted and applied by each country. Although there is currently a high percentage of funding afforded to such studies, additional support could be offered by national regulatory agencies and independent auditing firms to promote further research. The current literature gap/ open research path provides scholars with a unique opportunity to explore the current possibilities for integrating blockchain technology within auditing. The results hold particular importance for researchers and regulatory agencies in promoting further improvements in this topic.

Table 4. Research Gap for Blockchain Applications in Auditing

Encrypted Private and Secure Information Sharing	Distributed Ledger	Smart Contracts	Continuous Audit	Audit Trail	Tokenization
Dubai Malta Norway Portugal Singapore	Brazil Luxembourg Netherlands Portugal South Korea	Austria Belgium Brazil Cyprus Dubai Egypt England Hungary Indonesia Ireland Malta Norway Portugal Sierra Leone Singapore Smart Contract South Korea Sweden Taiwan Wales	Bangladesh Belgium Brazil Canada Cyprus Dubai Egypt France Indonesia Ireland Japan Luxembourg Malta Netherlands Norway Portugal Russia Sierra Leone Singapore Spain Sweden Taiwan	Austria Bangladesh Belgium Cyprus Dubai Egypt France Hungary Indonesia Ireland Malta Singapore South Korea Spain Sweden Taiwan	Australia Austria Bangladesh Belgium Brazil Cyprus Dubai Egypt England France Germany Hungary India Indonesia Ireland Italy Japan Luxembourg Malta Netherlands Norway Portugal Russia Sierra Leone Singapore South Korea Sweden Taiwan Tokenization Wales

6. CONCLUSION

Blockchain technology integration within auditing promises to revolutionize the field with its wide-spread applicability. However, although the technology is quickly gaining traction, there currently exists a lack of consensus on how it will be realistically applied. As a result, the study aimed to identify major streams in the field of auditing regarding blockchain applications. To accomplish this, the paper attempted to map the currently existing international auditing literature to offer clarity to an otherwise heterogeneous field.

The Bibliometrix R-Package program "Biblioshiny" was employed for this purpose and aided in identifying the increased international popularity of the topic. According to the findings of this study, blockchain applications in auditing is divided across six research themes; "Encrypted Private and Secure Information Sharing, Distributed Ledger, Smart Contracts, Continuous Audit, Audit Trail and Tokenization". With 33 countries greatly contributing towards blockchain application researching in auditing, it can be argued that global awareness of the importance of the topic has increased and academics are striving to facilitate further research in this area. Moreover, a high collaboration rate exists between nearly all countries located in the sample. However, out of these countries it is apparent that both China and the USA are currently leading the high-quality research. This indicates that there is still some way to go before the technology is accepted and applied by each country.

Upon analyzing the scope of these studies, it is determined that research conducted within this area has a higher concentration on privacy and security issues that await the auditing field in light of the current technological shift. This is also indicative of the current worries within the blockchain auditing research that need to be addressed if the field wishes to incorporate the new blockchain technology. Blockchain technology is also argued to be a solution to data integrity issues within the field of accounting and auditing. As a result, it is not surprising that the second highest scoring issue noted within studies concerns the sharing/receiving of accounting information. Although the sample was limited to the Web of Science Core Collection, it would be interesting for future studies to expand and re-assess this distribution. Moreover, as the R-package program is capable of performing a citation analysis between studies, this could be analyzed to determine the citation landscape and see how it influences further research.

YAZARIN BEYANI

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AUTHOR'S DECLARATION

This paper complies with Research and Publication Ethics, has no conflict of interest to declare, and has received no financial support.

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