ARTICLE IN PRESS

Technovation xxx (xxxx) xxx

Contents lists available at ScienceDirect

Technovation

journal homepage: www.elsevier.com/locate/technovation

Digital transformation in the healthcare sector through blockchain technology. Insights from academic research and business developments

Maurizio Massaro [1]

Department of Management, Ca' Foscari University of Venice, Venice, Italy

ARTICLE INFO

Keywords:
Digital transformation
Blockchain
Healthcare
Research-practice gap
Content analysis

ABSTRACT

Healthcare research is a multidisciplinary field that looks at the entire stakeholder ecosystem. Digital transformation could assist in the resolution of problems in medical practice by introducing new value creation trends. Blockchain technology has the potential to help speed up this digital transformation process by reducing certain elements, such as data management issues. As with any new technology, its actual value must be shown because it is based on expectations rather than solid facts. This study compares the findings of a content analysis focused on papers and patents with the aim of presenting data on the expectations for blockchain implementation in the healthcare sector. While the papers provide the perspective of researchers, patents should depict the expectation of the companies and investors patenting their inventions. Comparing data from papers and patents, this paper aims to help close the research-practice gap by showing how the two expectations for blockchain application in the healthcare sector are evolving.

1. Introduction

While the existing literature has improved our understanding of specific aspects of digital transformation (Gong and Ribiere, 2021), in several contexts we still lack a detailed picture of its existence and consequences (Sebastian et al., 2017). Previous studies have focused on the role of digital technologies to trigger strategic changes (Urbinati et al., 2019), disrupt the way organizations create and transfer value (Chirumalla, 2021; Tian et al., 2021), and manage the social and organizational structural modifications required (Vial, 2019). However, according to Sebastian et al. (2017, p. 198), "Most big old companies' digital transformations are at an early stage—in most industries, the vast majority of established companies' revenues still come from traditional products and services." Similarly, digital transformation can have multiple positive effects within the healthcare sector in supporting current challenges, such as empowering a patient-centric approach, increasing operational efficiency, and supporting workflow practices (Kraus et al., 2021). However, although digital transformation has been widely analyzed and has become a trendy topic for many streams of business research, it still lacks appropriate attention to the various managerial applications (Kraus et al., 2021). While there is growing attention to digital transformation in many sectors, research and practical applications in the healthcare sector still seem fragmented and at the beginning of the journey.

Trust in data handling and security are considered among the most important reasons the healthcare sector lags behind in the implementation of digital transformation (Kraus et al., 2021). Interestingly, blockchain technology could be helpful in handling, sharing, and processing personal health records, reducing data security issues and supporting the digital transformation of the healthcare sector (Tandon et al., 2020). However, while organizations are making significant investments in blockchain-based technology, they are also taking a conservative approach due to a widespread view that the benefits might be exaggerated (Iansiti and Lakhani, 2017). Thus, while digital transformation potentially affects healthcare, the lack of trust and the fear of data security combine to limit its development. Blockchain technology can reduce the problem, but further studies are required to test its validity.

This paper contributes to the special issue on digital transformation in healthcare, understanding "the potential applications of novel digital technologies … for innovating the healthcare ecosystem." More precisely, following the call for the special issue, this study investigates "technological trends and breakthroughs for disruptive innovation in healthcare," with a focus on blockchain technology. As a young research field, most of the studies focused on this topic employ qualitative approaches based on case studies that allow in-depth analysis but limit the

E-mail address: maurizio.massaro@unive.it.

[1] https://www.unive.it/data/persone/18972961

https://doi.org/10.1016/j.technovation.2021.102386
Received 10 May 2021; Received in revised form 17 August 2021; Accepted 3 September 2021

generalizability of the findings (Kraus et al., 2021). Previous studies have also highlighted that the potential benefits derived from academic research are not applied due to a gap between research and practice (Makin, 2021). In further analyzing the theoretical benefits of blockchain solutions, there is therefore also a need to understand how business entities are implementing blockchain solutions to support further practical applications of this technology.

This study seeks to answer this call by analyzing how blockchain has been studied in published papers and implemented in patented inventions through content analysis. Content analysis is an umbrella term used to extract information from a broad set of documents (Krippendorff, 2013). When employed with patents, it is used for handling technology analysis, forecasting technological developments, and providing highlights on future competitions based on emerging technology. When applied to research papers, it is used for reviewing a corpus of scholarly literature to generate new ideas, engage in critical reflections, identify future research directions, and create research questions (Massaro et al., 2016). Patent and publication sources are commonly used to chart the evolution of technologies, and the use of multiple data sources allows comparison of different outcomes of research and inventions (Goeldner et al., 2015). Indeed, patent databases provide information on technical innovations and patterns of technological advancement, while publication databases provide information on scientific advances (Kumari et al., 2019).

This paper is novel in several ways. First, to the best of our knowledge, this is the first attempt that combines scientific papers and patent inventions in the field of blockchain in the healthcare sector, and therefore enlarges previous studies that mainly focused on scientific sources (Abu-elezz et al., 2020; Attaran, 2020; Hasselgren et al., 2020). Previous studies have used this approach to study several other technologies, such as care robotics (Goeldner et al., 2015) and emerging technologies in general (Daim et al., 2006). Second, this study enlarges previous literature reviews using broader keyword search terms that includes smart contracts and distributed ledgers (Tandon et al., 2020). Third, an analysis of word co-occurrences was used for theme extraction. This approach makes “the analyst aware of the global context and significance of concepts and … help avoid fixation on particular anecdotal evidence, which may be atypical or erroneous” (Smith and Humphreys, 2006, p. 262).

The rest of the paper is organized as follows. The next section describes the background of the study, beginning with the current challenges of digital transformation in healthcare, followed by a presentation of blockchain technology, and a discussion of how blockchain technology is a controversial topic, as well as presenting the research questions. The following section illustrates the methodology used. The findings and discussion sections depict the main results. The conclusion section ends the paper.

2. Theoretical background

2.1. Digital transformation in the healthcare sector

The implementation and use of information and emerging technologies to alter various facets of an organization—ranging from the development of new business models to changes in current organizational processes and customer service—is usually referred to as digital transformation (Bunduchi et al., 2019; Gong and Ribiere, 2021). Indeed, new digital technologies are game-changing chances for the public sector, as well as for businesses of all sizes. Additionally, at a higher level, information and communication technologies have also been used to address a wide range of significant societal issues, including housing, climate change, health, and human migration (Majchrzak et al., 2016). Due to its potential, digital transformation has also been widely analyzed in the healthcare sector (Burton-Jones et al., 2020).

Healthcare can be thought of as a system with two main components: (a) key providers of medical care services, such as medical doctors, nurses, hospital administrations, and technicians; and (b) essential services connected with medical care, such as medical testing and health insurance (Campbell et al., 2000). Additionally, there is growing attention to global health issues that might have a “political and economical impact across national borders” (Wallberg-Henriksson, 2013, p. 106). The digital revolution in healthcare opens up new market opportunities and yields new business models to improve medical care services and health insurance problems, solving issues such as medical practice, value development, and general issues related to the ageing population (Kraus et al., 2021). According to Agarwal et al. (2010, pp. 796–797), “there is substantial consensus that the digital transformation of healthcare through broad and deep use of health information technology … across the healthcare ecosystem, in conjunction with other complementary changes, can reduce costs and improve quality.” However, digital transformation projects are complex, time-consuming, and challenging to execute, and they often struggle to achieve their goals (Bunduchi et al., 2019). Additionally, healthcare organizations’ adoption of health information technologies is slow, thus limiting the potential benefits promised by the research papers (Hermes et al., 2020). While digital transformation has the potential to improve the healthcare sector both in terms of medical care services and the overall ecosystem, its implementation might be difficult.

Several causes have been investigated to explain the slow pace of the adoption of information technology. The healthcare landscape is a multi-stakeholder ecosystem in which patients, physicians, nurses, public bodies, and private organizations interact (al Abdullah and al Bakri, 2016; Secundo et al., 2019). As a result, health information silos have emerged as a consequence of the complexities and regulation of healthcare. Additionally, the interoperability of health information technologies between critical stakeholders is still lacking, which impedes efficiency, undermines care management, and raises costs (Hermes et al., 2020). Privacy issues related to very sensitive patient health information data have often reduced digital innovation processes. A clear example comes from the discussion of contact-tracing apps during the COVID-19 pandemic. Perrigo (2020, p. 2), in a column from the newspaper *The Times* wrote: “Contact tracing—either via an app or the old-fashioned method of interviewing people—is crucial to notify people who don’t know they’ve been exposed to the virus, so they can isolate. But it always involves a tradeoff between privacy and public health.” Indeed, any disclosure of personal information carries the risk of being used for reasons not revealed at the time of collection. Regardless of how complicated the data encryption method is, a fundamental solution to sensitive data security is needed (Zhao et al., 2021). In the period 2010–2017, the US Health and Human Services Office for Civil Rights reported 2149 security breaches involving data from 174.4 million records (McCoy and Perlis, 2015). The lack of incentives and trust in public and private organizations has been recognized as the main problem for overcoming the previously raised concerns (Hermes et al., 2020; Li et al., 2016).

2.2. Blockchain technology

Blockchain has been proposed as a solution to healthcare’s crucial problems, such as safe medical record sharing and compliance with data privacy laws (Anushree Tandon et al., 2020). Blockchain is essentially a method for storing data in a transparent, distributed, and immutable manner (Tapscott and Tapscott, 2016). Being essentially a general ledger, there are two ways of developing blockchain that share several characteristics but differ in terms of validation and recording processes: permissionless (also known as public blockchain) and permissioned (also known as private or consortium blockchain). Both private and public blockchain could be used to tackle privacy concerns with several organizations, starting with private blockchain and then continuing to a public one (Toufaily et al., 2021). Due to its double key authentication approach in permissionless systems, blockchain allows untrusted actors to exchange and preserve data in a trusted way. The overall chain of data recorded is transparently observable but anonymized (Schmitz and Leoni, 2019). Interestingly, the entire process is built without the need for a middleman (Tapscott and Tapscott, 2016). Thus, thanks to blockchain's stable and immutable characteristics, there might be a significant impact on data transaction cost and safety (Andreassen et al., 2018).

Additionally, because the data stored are immutable, they become rare, and when data are useful, they might gain value, becoming a digital asset (Newbert, 2008). Digital assets recorded in the blockchain are defined tokens, and their implementation goes beyond the simple applications such as cryptocurrencies (Massaro et al., 2020). Some blockchain tokens serve as preorders for crowdfunding ventures, whereas others serve as equity stakes in profit-sharing campaigns (Chen, 2018). Several companies have started tokenizing their R&D processes, thus supporting the development of critical cures in the healthcare sector (Southey, 2018).

Finally, because blockchain is a distributed system, all members must agree on the rules for data registration and exchange in what is known as a "consensus protocol." The consensus protocol, in technical terms, provides the specifications by which computers in a distributed system share and record data. Because data would not be stored in the system if the protocol is modified without the consent of the majority of network members, it cannot be changed. As a result, the protocol ensures that all members are aligned, and it must be established with a long-term perspective (Kouhizadeh et al., 2021). Blockchain might thus help to establish more trust in the system because no one can change it after it has been approved.

Interestingly, while blockchain technology can support digital transformation in the healthcare sector, several concerns have been raised about its real applicability. Regulatory barriers, the unfamiliarity of users with the real advantages of the technology, and the time and cost required to implement blockchain projects are some of the main elements that can slow down blockchain implementation (Deloitte, 2020).

2.3. Developing the research questions

Blockchain technology is still in its infancy, and more research is required to understand its real potential, especially when applied to the healthcare sector. Interestingly, blockchain technology has its roots in a seminal paper by the scientists Steward Haber and Scott W. Stornetta, which was published in 1991 (Haber and Stornetta, 1991), but only in 2008 with the development of the bitcoin whitepaper blockchain became widely known (Skwarek, 2019). While the practical translation of scientific papers requires time, a growing literature draws attention to a research-practice gap (also known as the academic-practitioner divide) that limits the application of academic research (Makin, 2021). Defined as a communication gap where two communities are not in dialogue, the research-practice gap makes it difficult to translate academic research into practical solutions in many research fields (Neal et al., 2015). Concerning the topic of blockchain, there is a growing call for a more holistic approach (Tandon et al., 2020) able to bridge the research-practice gap (Böckel et al., 2021). Emerging new technologies lack a track record of effective implementation, and actors shape value standards based on their potential rather than proof of implementation (Borup et al., 2006). Assessing results from both practitioner and research sources could help research stakeholders better understand blockchain value in the healthcare sector (Palas and Bunduchi, 2020). Starting from this point, this paper has been developed to address the following research question:

RQ1: How is blockchain studied and applied in the healthcare sector?

3. Methodology

To answer the research question, the content analysis methodology was applied considering two different sources. First, published papers were used as a source of scientific research. Second, patents were used as examples of applied innovation. Indeed, "Publication data provide useful insights on scientific advances, whereas patent DBs [databases] provide information regarding technical inventions and patterns of technological growth" (Kumari et al., 2019, p. 2). Content analysis is a broad umbrella term that refers to the systematic analysis of text to extract meaningful information, and its roots can be traced back to the 17th century (Krippendorff, 2013). The development of text sources and the increased capacity of computers to support human analysis has led to the development of multiple branches and techniques able to support content extraction of useful information from a wide range and large quantity of data sources. Due to the large amount of data to be analyzed to develop research, several techniques such as manual coding and topic modeling were employed. To compare the results from the two sources, the statistical Kruskal–Wallis test was used. The overall methodology was developed as explained below.

3.1. Data collection

Data were collected from two sources. The Scopus database, one of the most comprehensive sources for scientific papers, was used with the following keyword search: "blockchain" or "smart contract" or "distributed ledger" and "healthcare" OR "health" OR "hospital" OR "medicine." We decided to limit our research to scientific published papers, excluding conference proceedings and book chapters as qualitative criteria, assuming that papers published in peer-reviewed journals would offer better quality assurance (Massaro et al., 2016). This research returned an initial set of 361 papers, but only 287 papers were selected after abstract reading.

The same keyword search was employed to select patents. The European Patent Office (EPO) Database was selected as the database source. The initial search showed that 80% of the applications related to blockchain in healthcare are still under evaluation by the EPO authority. All patent applications were included to make the research more comprehensive, without limiting the data to only granted applications. According to Goeldner et al. (2015, p. 116) "Patent and publication data are widely used to map the emergence of technologies." Several studies have previously compared the findings in two different sources to better evaluate technological evolution and research and invention opportunities (Daim et al., 2006; Goeldner et al., 2015; Järvenpää et al., 2011).

3.2. Data analysis

The data analysis started with the descriptive analysis of patents and papers. Information extracted from the specific sources were categorized in an Excel spreadsheet and then analyzed. The aim of this step was to understand the evolution of the topic over time and the key contributors in terms of organizations and countries. Network analysis was used to understand key collaborations via the software R (version 4.04) and RStudio IDE (RStudio Team, 2015). Subject area analysis was used to understand the main research domain within the two sources.

The second step of the analysis focused on topic and theme extraction from the paper and patent abstracts. Abstract texts were used as the best possible refinement of document key points (Delgosha et al., 2021). Leximancer was used to classify concepts automatically (Smith and Humphreys, 2006). According to Dumay (2014, p. 1261), "Leximancer allows us to analyze qualitative data, thus avoiding the subjective and labour intensive aspects of manual data coding." Additionally, as highlighted by Massaro et al. (2018, p. 371), "Leximancer offers an automated text mining process that determines the concepts resident in the text using internal dictionaries and provides a word count for each concept." The automatic initial proposal of concepts was reviewed by the author, and similar concepts were manually grouped using features within Leximancer. Finally, concepts were grouped into themes by Leximancer using word co-occurrences (Biroscak et al., 2017). The proximity of two concepts indicates their frequent occurrence in similar contexts. Themes are shown as colored circles around the concept clusters provided by the conceptual map produced by Leximancer. The arrows show the most likely path between concepts. The overall approach used by Leximancer allows the analyst to identify the global context and gain the meaning of the concepts discussed in the text analyzed (Smith and Humphreys, 2006).

The last step of the data analysis allowed, using word count, measurement of theme evolution over time, as well as indicating the main differences between the two data sources used: patents and papers. The Kruskal–Wallis test was employed as a non-parametric test to evaluate categorical variable variances and compare variations between two or more classes (Tufféry, 2011). The null hypothesis tested was that there is no substantial difference between groups in various topics. When the value of the p-value for the Kruskal–Wallis chi-square test is less than 0.05, the null hypothesis can be rejected, and one can assume that the word count per topic is substantially different between groups. A similar approach was developed in similar previous studies (Chang et al., 2019; Massaro et al., 2018).

4. Findings

Three sub-sections are used to present the results. A descriptive analysis of both datasets is discussed first, with comparisons of the numbers of scientific publications and priority patent applications at the country, organizational, and collaboration levels. Second, topic and thematic analysis is performed to better understand the content of patents and papers. Finally, topics and themes are analyzed in terms of time evolution and the difference between sources (patents vs papers).

4.1. Evolution of papers and patents, structure among institutions and countries, permissioned and permissionless

The results of the analysis revealed that blockchain application in the healthcare sector is a relatively recent research field. The first papers appeared on Scopus in 2016, and since then, publications have been continuously growing. The overall production is the effort of 498 institutions spread across 36 countries, with 4 countries (the USA, China, India, and South Korea) leading research on the topic. Focusing on patents, we can see that the first patent appeared in 2013 with a growing trend. Some universities, such as the Taipei Medical University, are strongly investing in the technology. IBM, Nant Holdings IP, and Janssen Pharmaceuticals are among the most prolific companies that are investing in the field. However, the vast majority of applications have been generated by individuals, with universities and companies representing only 30% of all applicants (63 out of 208 applicants). Table 1 depicts the main descriptive values for the overall production of papers and patents in the period 2013–2020.

Focusing on country collaboration, the results indicate that there are strong international collaborations between the leading countries in terms of overall paper production. Those countries (China, the USA, and the UK) are in the middle of a robust global network. However, patent production shows a much more scattered situation, with fewer international collaborations focused around a strong connection between the USA and UK, with some extensions into Finland and Switzerland. Interestingly, South Korea is among the most important contributors, but it is not among the most interconnected countries. Several emerging countries, especially from Africa and South America, are almost absent in the overall production of papers and patents. Fig. 1 provides a graphical representation of the data.

Using the Scopus journal classification, the results indicate that this domain of research is led by papers published in computer science and engineering journals (145 and 114, respectively). Medicine is the third most relevant subject area (107 papers). All of the other areas are less relevant, with only 19 papers published in journals focused on business, management and accounting. Interestingly, almost all of the patents have been classified as healthcare informatics or healthcare data (155) according to the International Patent Classification. Other important areas are data processing and digital data processing (108 and 106, respectively). Results are reported in Table 2.

Focusing on the difference between permissioned and permissionless blockchain, the analysis revealed that while all of the patents provide a detailed explanation about the use of blockchain, even declaring the blockchain provider to be used, such as Ethereum or hyper ledger, papers have a more general approach. Indeed only 29 papers specifically

Table 1
Papers and patent evolution over time.

Variables	2013	2015	2016	2017	2018	2019	2020
Papers	0	0	2	9	33	91	152
Number of institutions			4	17	64	172	295
Top contributors with more than one paper			Zhongnan University of Economics and Law (2)	University of California San Diego School of Medicine (2)	La Paz University Hospital (2) Lovely Professional University (2) Sungkyunkwan University School of Medicine (2)	Imperial College London (5) University of Oxford (5) Aalborg University Hospital (3)	King Saud University (6) Asia University (5) Beijing University of Posts and Telecommunications (5)
Top contributors per country			China (2)	USA (5)	USA (7) China (5) Korea (3)	USA (10) India (8) China (7)	China (19) USA (19) Korea (13)
Patents	1	2	5	17	73	70	8
Number. of applicants	1	3	16	29	57	85	17
Top applicants	Individual (1)	Nant Holdings IP (2)	Individual (2)	IBM (1)	Taipei Medical University (2)	Patientory (3) Janssen Pharmaceutical (2) Taipei Medical University (2) IBM (2) Nant Holdings IP (2)	Janssen Pharmaceuticals (1)
Top contributors per country	Korea (1)	USA (4)	USA(9)	USA (13) UK (10)	USA (36) Taiwan (11)	USA (78) Taiwan (11)	USA (18)

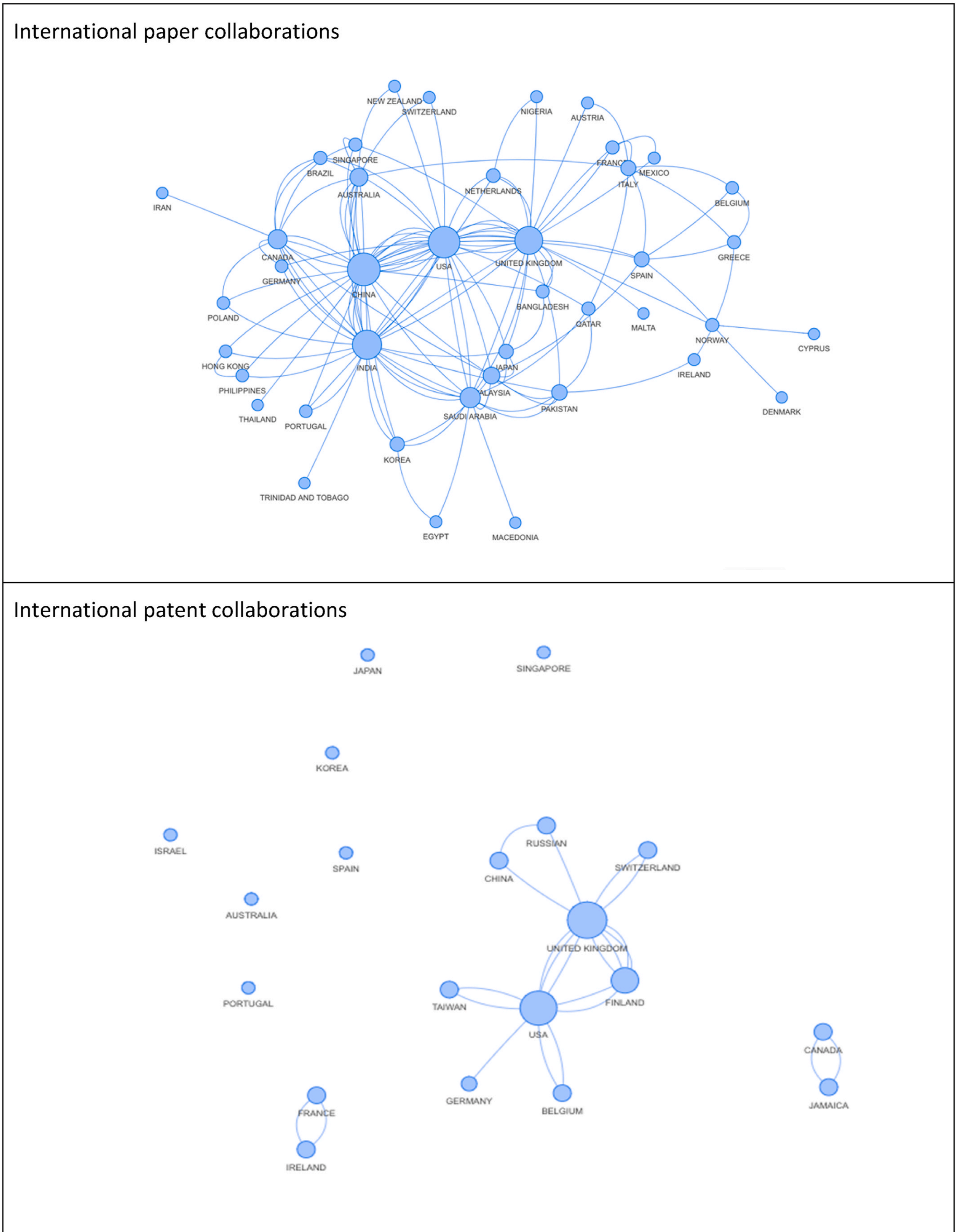

Fig. 1. International collaborations for papers and patents.

Table 2
Subject areas for papers and patents.

Papers	No.	Patents	No.
Computer Science	145	Healthcare informatics or healthcare data	155
Engineering	114	Data processing systems or methods	108
Medicine	107	Electric digital data processing	106
Materials Science	35	Electric communication technique	104
Biochemistry, Genetics and Molecular Biology	23	Recognition of data; presentation of data; record carriers; handling record carriers	11
Health Professions	21		
Social Sciences	21		
Physics and Astronomy	20		
Business, Management and Accounting	19		
Chemistry	14		
Mathematics	13		

Note: Papers and patents might belong to more than one category, so the total is higher than the number of papers and patents considered; Cut-off≥10 papers/patents.

addressed the type of blockchain analyzed in the abstract.

4.2. Topic and thematic analysis

The topic and thematic analysis revealed the existence of six main themes in the patents and papers. The following subsections interpret each topic based on an exploration of the concept map and in-depth readings of text samples and related papers and patents.

4.2.1. Applications

This theme describes the overall application of blockchain to the healthcare sector and depicts challenges and opportunities arising from the adoption of blockchain technology in this sector. Contributions to the theme come mainly from scientific papers rather than patents (e.g., Dimitrov, 2019; Mackey et al., 2019; Siyal et al., 2019). For example, Kuo et al. (2017, p. 1211) stated that the aim of their study was to "Introduce blockchain technologies, including their benefits, pitfalls, and the latest applications, to the biomedical and health care domains." These studies represent research efforts to define the boundaries of the field.

Blockchain was first developed as a tool to create timestamps and digital fingerprints (Haber and Stornetta, 1991). The technology then evolved as a means to power Bitcoin; however, it is now recognized as a foundational technology made up of different layers (e.g., smart contracts and utility tokens are usually built on blockchain technology developments) for a wide range of decentralized applications (Iansiti and Lakhani, 2017). Two different research areas are recognized. The first group of studies focused on the possibility of using blockchain technology to improve existing processes. The second group focused on the foundational capabilities of blockchain to improve our social system. These studies concentrate on designing "a smart healthcare system … through integration and interoperability of Blockchain 3.0 and Healthcare 4.0 in consideration with healthcare ground-realities" (Kumar et al., 2020, p. 1).

4.2.2. Models and frameworks

This theme focused on the need to develop models and frameworks that could capture the potential benefits of blockchain. Two main approaches emerged. First, several studies focused on the need to create an interaction framework that could capture IoT data (e.g., Biswas et al., 2020; Rahman et al., 2020). Second, the performance and benefits of blockchain were measured and analyzed. For example, Zarour et al. (2020, p. 1) stated, "selecting the most effective blockchain model for secure and trustworthy EHRs in the healthcare sector requires an accurate mechanism for evaluating the impact of different available blockchain models for its features." Indeed, studies have implied that certain aspects of the architectural frameworks developed for the adoption of blockchain in healthcare could affect performance efficiency and exacerbate possible problems such as scalability and the computational load of sensor data (Su et al., 2020; Zhang et al., 2016). As in the previous case, this topic has mainly been developed by scientific papers due to its specificity.

4.2.3. Technology

The theme of technology presents the key differences as well as the implementation opportunities with other technologies. For example, Chenthara et al. (2020, p. 1) stated, "Blockchain technology will be the unifying platform for sharing patient data currently inaccessible due to the siloed architecture of legacy software systems, and as a result potentially be the basis for precision or individualized patient treatment." Interaction with other technologies such as IoT and cloud computing are also discussed (e.g., Benil and Jasper, 2020; Mohanta et al., 2019; Ullah et al., 2020).

One of the key topics discussed within the technology theme is privacy. Privacy has always been a big problem in the healthcare industry, especially due to the growing digitalization of information. As suggested by Griggs et al. (2018, p. 130), "healthcare data is a lucrative target for hackers, and there is a strong motivation in government regulation to secure protected health information (PHI) transmission." At the time of writing, a cyberattack in Rome (Italy) blocked the COVID-19 vaccination of almost six million people and caused a massive data leak.[2] In Europe, the General Data Protection Rules (GDPR) protect all personal data, while the Department of Health and Human Services protects personal health information (PHI) in the USA. However, if privacy has to be protected, health data must be safely manageable and transferable (Griggs et al., 2018; Liang et al., 2018).

There are no electronic systems that are riskless. Blockchain is no exception (Aggarwal and Kumar, 2021). However, studies developed within the specific healthcare sector have provided enough evidence to support not only the validity of the system compared to traditional data storage approached but also its compliance with GDPR and PHI rules (Chukwu and Garg, 2020). Interestingly, the topic of privacy is rigorously considered by several inventions. For example, one of the patents granted by the EU on gene detection and sharing states: "on the basis of a public-key encryption scheme, privacy data of an individual user is protected, so the individual has complete control power and ownership over own gene data" (University of Jinan, 2017, p. 1). Privacy has also been investigated by some giant tech companies. For example, IBM is working on a patent for a "Secure Distributed Patient Consent and Information Management" that, at the time of this writing, is still under evaluation by the EPO (IBM, 2017, p. 1).

4.2.4. Data

Data handling is one of the most analyzed topics in both papers and patents. Several papers have focused on the overall recording system for health data. For example, Mayer et al. (2020, p. 1273) stated, "Blockchain could reinvent the way patient's electronic health records are shared and stored by providing safer mechanisms for health information exchange of medical data in the healthcare industry, by securing it over a decentralized peer-to-peer network." Data access, use, protection, and control are key elements studied by various scholars, as well as in several patents. For example, an invention by Sinochain Technology (2018, p. 1) "discloses a blockchain-based medical resource data processing method." Performance is an important drawback of blockchain, which has often been analyzed in terms of the time required to register data. New studies are, however, bringing new hope. For example, Ismail and

[2] See https://www.reuters.com/world/europe/hackers-shut-down-system-booking-covid-19-shots-italys-lazio-region-2021-08-01/, accessed August 1, 2021.

Materwala (2020, p. 1) stated, "The results reveal that notable performance can be achieved using blockchain in a patient-centric approach. In addition, the immutable and valid patients' data in the blockchain can aid allied health professionals in better prognosis and diagnosis support through machine learning and artificial intelligence." The topic is also supported by a variety of innovations. For example, Hebei North University (2019, p. 1) proposed an invention to disclose a medical data–sharing method and system based on a blockchain able to improve "data security of medical data sharing … [and where] … the sharing performance is good."

4.2.5. Health and electronic monitoring

The theme of health, healthcare, and electronic data has emerged as a central topic, especially due to the COVID-19 crisis. The pandemic emergency has shown the dialogic approach between individual health and public health (Cobianchi et al., 2020, 2021a, 2021b). Electronic data provided by wearables have been widely used to track COVID-19 patients in different countries, which has changed the overall health industry (Nayak and Bhattacharyya, 2020). For example, Fusco et al. (2020, p. 1) stated, "The use of blockchain in combination with artificial intelligence systems allows the creation of a generalizable predictive system that could contribute to the containment of pandemic risk on national territory." However, the potential for using health data from a broad perspective was not brought about by the pandemic. In 2015, one of the first patents registered by the EPO was specifically oriented to create a validation system for healthcare data useful to various stakeholders (Nant Holding, 2015).

4.2.6. Invention

The last theme appears mainly among patents, as visually described in Fig. 2, and focuses on the key distinctive elements of each invention. Topics in this theme describe how blockchain makes it possible to store and share data in the overall healthcare system. For example, Canon (2017, p. 1) developed an innovative system and method for providing medical information based on blockchain. Similarly, specific solutions for hospitals are provided. For example, Irise (2018) defined a patent in which "drug delivery information and payment information exchanged between a medical institution terminal/a medical institution server and a pharmaceutical company terminal/a pharmaceutical company server are recorded."

4.3. Theme evolution and source differences

Focusing on theme evolution, Fig. 3 clearly illustrates how the topics of health, data, and technology show growing importance in the period observed. Several elements justify this trend. First, at the time of this writing, the development of the COVID-19 pandemic has pushed the need to develop contact-tracing applications (Kalla et al., 2020). However, to fight the new challenges, an overall approach that includes interaction with other technologies for data management such as IoT, cloud computing, and all of the other industry 4.0 technology is required (Abdel-Basset et al., 2021), which might explain the growing attention paid to these topics.

A word count analysis was performed to search for the topic differences between patents and papers, and a Kruskal–Wallis analysis was performed to search for the main differences between the two sources used. Table 3 depicts the results for topics with more than an average 50% difference in word appearance for papers and patents. The results indicate that some topics are mainly discussed in patents, while papers mainly discuss other topics. Patents are more focused on developing inventions to provide hospitals with methods to store transactions. Papers, meanwhile, focus more on challenges and application of blockchain technology, as well as on specific aspects of the technology such as interaction with other technologies (mainly could and IoT).

5. Discussion

There is growing attention to the notion that blockchain research has been undertheorized and has provided more of a descriptive approach rather than focusing on causes and implications (Gligor et al., 2021). To overcome this critique, this section discusses the results defining some of the theoretical implications that, in my opinion, could deserve future research attention.

5.1. Implication #1. The dark side of blockchain technology. A social dominance perspective

The results confirm that attention to blockchain technology in the healthcare sector is growing both for practitioners and scholars. However, while a global approach to healthcare problems has emerged (Wallberg-Henriksson, 2013), the results indicate that research collaboration is highly developed within academia. The international collaboration for patent development focused on finding global solutions is much more limited. Additionally, collaborations in emerging countries (e.g., in Africa and South America) are very limited in terms of research and inventions. As highlighted by Yadav (2015, p. 150), in developing countries, "One of the main sources of underperformance in public sector supply chains stems from the lack of information capture and information sharing." Blockchain can support information sharing (Mayer et al., 2020); however, emerging countries represent a specific research context, and the theories and solutions developed for most advanced economies cannot be applied indiscriminately (Massaro et al., 2015).

Our results contribute to illustrating the development of the dark side of blockchain technology (Umeh, 2019). While most of the hopes for blockchain depict its role in reducing inequalities (Toufaily et al., 2021), the results of this analysis show how its implementation is strongly focused on developed economies. Social dominance theory has been previously applied to understand why and how some groups of people act to maintain their power, and the theory has been applied in different research fields such as economics, management, accounting, and finance (Sidanius et al., 2004). When applied to blockchain, this theory depicts the potential dark side of blockchain in several ways, particularly in propagating myths and creating lock-in effects that limit choices for non-dominant groups(Gligor et al., 2021). Thus, there is a call for a better definition of the dominant logic of technology development and more effort into studying and involving non-dominant countries to reduce the digital divide between advanced and emerging economies.

At the same time, the results show how blockchain could affect social dominance at a micro-level. Previous studies have shown how digital transformation could have essential impacts on organizational procedures and workforce practices and could shift power among all stakeholders (Kraus et al., 2021). Blockchain is no exception, and further studies are needed on this topic. For example, transparency could change the balance of power between good physicians (e.g., surgeons) and organizations, with rising salary demands creating new forms of competition between healthcare organizations. New forms of co-production could be provided by the implementation of IoT and blockchain technology (Dal Mas et al., 2020a,b). At the same time, dominant social groups could force the adoption of specific protocols to develop smart contracts. Further studies are needed to understand the actual and potential implications of blockchain in terms of social dominance.

5.2. Implication #2. Going beyond the hype. A call to investigate technology acceptance

The results indicate that research developed on blockchain in healthcare belongs to the domains of computer science, engineering, and medicine. Similarly, patent applications have been registered in the

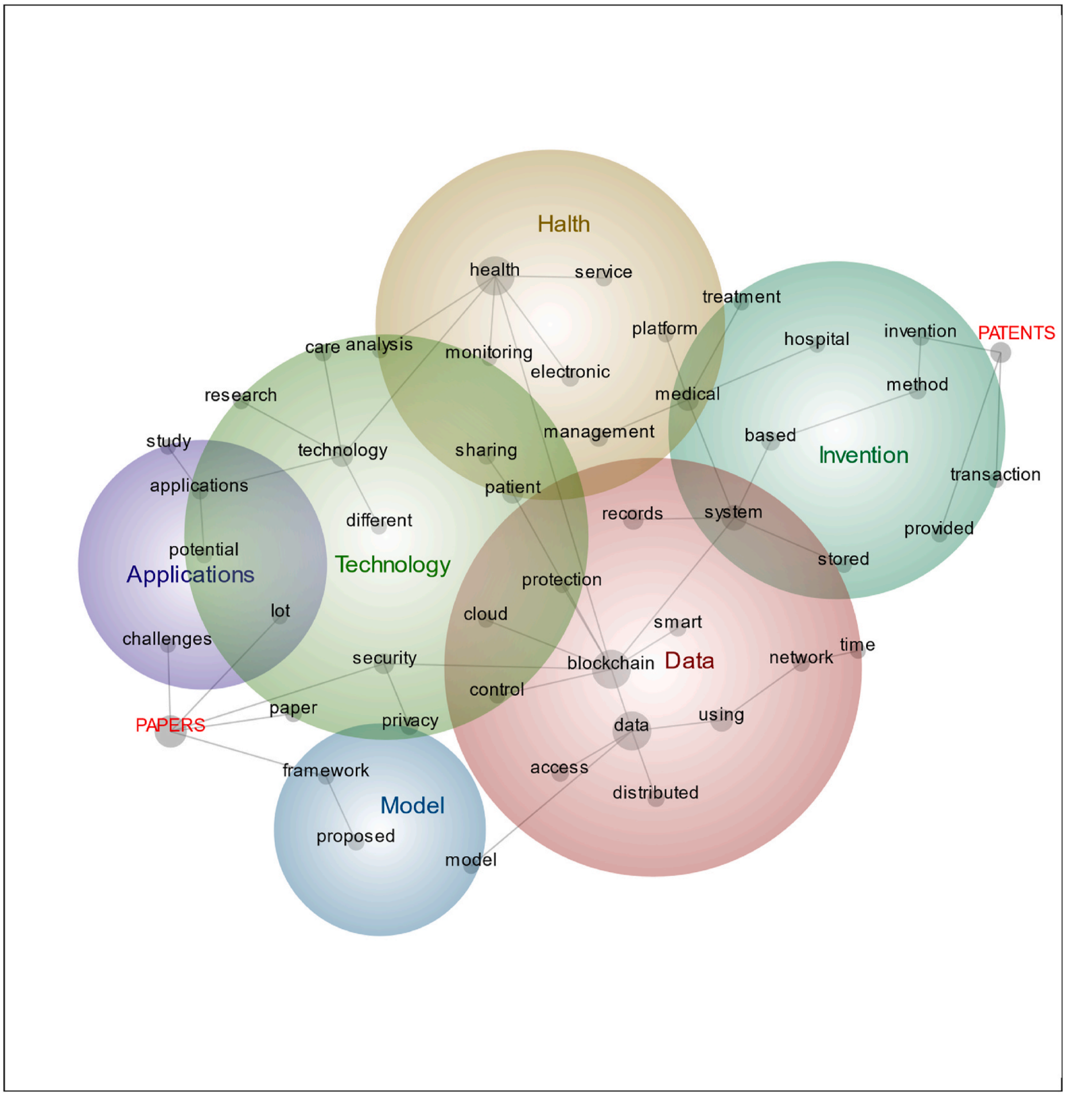

Fig. 2. Topic and thematic analysis.

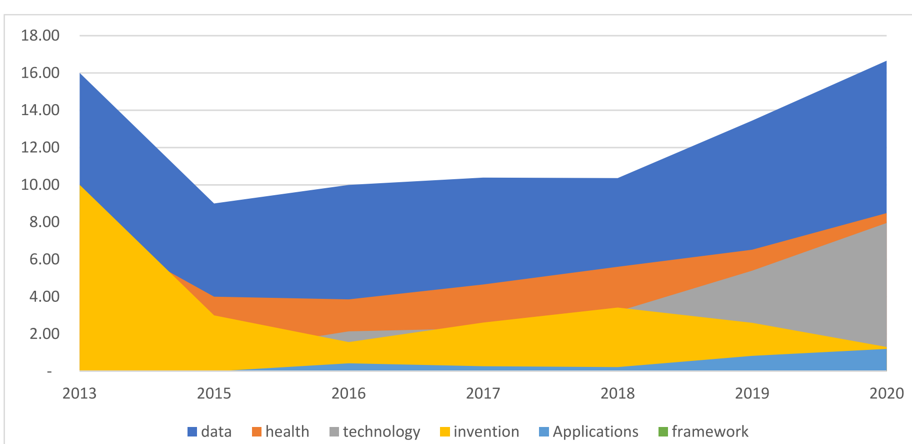

Fig. 3. Theme development.

categories of healthcare informatics and data processing. In all, efforts focused on blockchain application in healthcare belong to the hard sciences, while the focus on the managerial implications remains limited. Not surprisingly, most of the results show how enhancing privacy and security (Griggs et al., 2018) and improving data management (Abdel-Basset et al., 2021) are seen as the main advantages of blockchain implementation. However, despite the advantages claimed and although some big companies such as IBM and Janssen

Table 3
Topic differences, appearance by source document.

Theme	Topic	Chi-square	Degree of Freedom	P-value	Difference in topic word appearance
Invention					
	based	29.81	1	>0.001	-77%
	method	185.709	1	>0.001	-1155%
	provided	34.892	1	>0.001	-247%
	hospital	16.534	1	>0.001	-157%
	transaction	25.027	1	>0.001	-308%
Applications					
	challenges	53.103	1	>0.001	100%
	study	40.798	1	>0.001	100%
	potential	37.526	1	>0.001	94%
	applications	34.913	1	>0.001	85%
Technology					
	technology	121.844	1	>0.001	78%
	patient	39.392	1	>0.001	62%
	security	100.026	1	>0.001	83%
	privacy	62.536	1	>0.001	88%
	sharing	12.456	1	>0.001	56%
	care	29.39	1	>0.001	80%
	paper	94.027	1	>0.001	98%
	research	56.823	1	>0.001	94%
	different	22.083	1	>0.001	73%
	cloud	7.597	1	0.006	57%
	IoT	25.384	1	>0.001	98%

Note: topics with an average difference of less than 50% appearance (minor differences) or those that were not statistically significant are not reported for clarity. Differences were calculated as papers minus patents. Differences with negative numbers thus indicate that the word is used more often in patents. Differences with positive numbers indicate that papers use these terms more.

Pharmaceuticals have started investing in blockchain, most patents are still under evaluation and mainly registered to individuals. Further efforts in business and management research using the technology acceptance model (Rahimi et al., 2018) to investigate why organizations are reluctant to apply the claimed advantages of this technology could help fill an important research gap.

5.3. Implication #3. The valley of death and the risk of grand theories

The present results contribute to deepening the findings of the study by Palas and Bunduchi (2020), suggest convergence in the practitioners' perception of blockchain's potential. the findings show that while papers have a broader approach, patents seem more focused on specific organizational problems such as how to record and manage data within hospitals. Thus, while digital transformation in healthcare is lagging (Kraus et al., 2021), both patents and papers show how blockchain could reduce some of the main problems that limit its application, such as data protection and exchange, privacy, and collaboration with other industries 4.0 technologies. However, inventions seem more focused on single organizational problems, while papers have a broader ecosystemic approach.

Academics have barely considered the difference between public and private blockchain. The broader approach used by academics might increase the research-practice gap and nurture the so-called "valley of death" (Butler, 2008), where insights coming from research are never applied by practitioners (Makin, 2021; Tucker and Lowe, 2014). For example, Toufaily et al. (2021) used the Diffusion of Innovation theory to discuss how different aspects (e.g., perceived attributes, norms, and degree of network interconnectedness) might lead to different implementation and design for the technology. Too general an approach might lead to interesting insights that would not be implemented by practitioners looking for solutions to specific problems.

The formulation of ideas at a high level of generality derived from abstract thinking has been called "grand theories" development (Llewelyn, 2003). Grand theories have been critiqued as a "grand narrative" that makes it easy for people to understand problems and at the same time avoid the need to offer conclusive proof of possible solutions (Dumay, 2012). This approach might be common, especially given the hype about new technologies, and blockchain is no exception. Indeed, most of the research is "mainly conceptual, argumentative and design-oriented, based on prototypes and case studies [and] the number of business-related qualitative or quantitative research is limited" (Toufaily et al., 2021, p. 2). Thus, scholars are calling to develop pragmatic research (Makin, 2021) that merges sound theories, methodological rigor, and practical relevance, while avoiding filling the valley of death with grand theories that will never be used by practitioners.

5.4. Implication #4. Focusing on transformative outcomes and the value creation and appropriation process

Focusing on a national perspective, the healthcare sector requires the interoperability of multiple stakeholders: patients, healthcare providers, and insurance companies, among others (Hermes et al., 2020). Previous studies have found that the digital transformation of the health insurance system remains unexplored (Kraus et al., 2021). The results indicate that blockchain can support the health insurance system by reducing fraud (Lakshma Reddy et al., 2019). However, although insure-tech is a growing business (Cao et al., 2020), and blockchain has proved capable of creating new business models (Dal Mas et al., 2020a, b), a comprehensive investigation of the disruptive adoption is still lacking, as only one paper specifically addresses this issue (Nayak and Bhattacharyya, 2020).

The results show how current research has focused on incremental benefits rather than on transformative outcomes. Blockchain has been described as a foundational technology (Iansiti and Lakhani, 2017). For example, Dal Mas et al. (2020) have shown how smart contracts push social proof behaviors, helping the development of more sustainable business models. Many different actors work together in the healthcare sector to provide the required care to the patient—public entities work with private and nonprofit organizations. However, while the results show how blockchain can contribute to public health improvement, the value creation and appropriation problem appears to be undefined. For example, fraud reduction can increase profitability for private insurance companies, but at the same time, reduce the insurance cost for the collectivity. Lord (2018, p. 1) has stated, for example, "Beyond security and privacy, there are numerous important challenges related to blockchain that we must discuss as an industry, such as the financial and environmental costs of implementing these systems, the need for a single blockchain standard or the challenges of compounding is diagnoses and low-quality care over time, exacerbating disparities in underserved populations." Thus, there is a call for further developments related to the problem of value creation and appropriation for the benefits generated by the blockchain.

6. Conclusion

In concluding our study, recalling the initial premise could help the reader understand its value. Healthcare studies is a multidisciplinary area of research that examines an overall ecosystem of stakeholders (Campbell et al., 2000; Wallberg-Henriksson, 2013). Digital transformation could help to solve challenges in medical practice by offering new value development patterns (Kraus et al., 2021). Blockchain technology, besides being an important digital technology, could generally help speed up the digital transformation process and reduce some difficulties such as data management problems (Anushree Tandon et al., 2020). Like any new technology, its real value has yet to be confirmed and is currently strongly related to expectations rather than solid evidence (Borup et al., 2006). Comparing results from a content analysis based on papers and patents, this research sought to provide evidence of the relevant expectations for blockchain technology and contribute to closing to the research-practice gap (Makin, 2021). The following subsections highlight the research, practice, and policy implications of our study.

6.1. Research implications

The results confirm that blockchain is still in its infancy, with most of the inventions provided by individuals and few big companies actually investing in providing patented solutions. Advanced economies are leading in the domain of research and practice, limiting the benefit of blockchain in reducing the digital divide between the rich and poor.

These results suggest the development of four main research streams to further advance the topic and overcome the critique of its under-theorization. First, more studies on the dark side of the technology should be developed. Second, a social dominance approach is proposed to explain how the technology is developing at both a macro and micro level, preventing the risk that a few people set the rules, propagate myths, and create lock-in effects. Third, the limited number of companies with patented solutions calls for further studies investigating the technology acceptance model. Finally, while there is a call to understand the value creation and appropriation process in healthcare technology, there is also a need to avoid grand theories that nurture "valley of death" research.

6.2. Practical implications

At a more practical level, the results show how blockchain technology could effectively contribute to digital transformation in the healthcare sector because it offers the possibility to reduce information asymmetry and transaction costs and to create value from unique pieces of data, providing the premise for a new sustainable "crypto-economy" (Massaro et al., 2020). Previous studies have shown how these elements could foster more responsible behaviors based on a social proof base (Dal Mas et al., 2020a,b). While the technical benefits of blockchain have been widely analyzed, a sociological approach is required to understand how transparency and transaction cost reduction could affect people's behavior. At the same time, more effort is needed to understand the impact of this new approach on people working in the healthcare sector. While the technology itself might increase co-production to meet the challenges of healthcare 4.0 (Dal Mas et al., 2020a,b), the opportunity might be wasted if it is not grounded on people's needs and behaviors. Most of the efforts are still grounded in hard science with minimal contributions in business and management sciences. Not surprisingly, most of the contributions highlight the incremental benefits of the technology without considering its potential foundational contribution to creating new economic and social systems (Iansiti and Lakhani, 2017). There are thus opportunities to develop patents focused on human necessities[3] rather than on specific technical improvements.

6.3. Policy implications

At a more general level, the results have some policy implications. The healthcare sector requires the interconnection among public, private, and non-profit organizations. According to the OECD (2019), there is a need to develop a supranational technological standard to allow effective data exchange. Some of the limitations found in this study, such as the focus of inventions on a single organization problem and the reluctance of big companies to invest in the sector, might stem from this policy problem. Policymakers need to understand the technology and work at a supranational level to embrace the digital disruption provided by blockchain technology.

[3] "Human necessities" is a specific category of patents according to the International Patent classification.

6.4. Limitations of the study

As with any research, this study has some limitations. The first is based on the sources used: Scopus and the EPO. Essential contributions such as books or inventions not under a patenting process, might have been missed and thus might bias the results of our analysis. This is more relevant because the research field is relatively new. The second limitation stems from the type of analysis developed. While computer-aided content analysis is a powerful tool for extracting information from a large amount of text, it is still limited to the computer's capabilities for measuring and analyzing data. Finally, as in all qualitative studies, data interpretation is limited by the investigator's abilities. Further studies might try to replicate our results in the future or in different contexts.

References

Abdel-Basset, M., Chang, V., Nabeeh, N.A., 2021. An intelligent framework using disruptive technologies for COVID-19 analysis. Technol. Forecast. Soc. Change 163. https://doi.org/10.1016/j.techfore.2020.120431.

Abu-elezz, I., Hassan, A., Nazeemudeen, A., Househ, M., Abd-alrazaq, A., 2020. The benefits and threats of blockchain technology in healthcare: a scoping review. Int. J. Med. Inf. 142 https://doi.org/10.1016/j.ijmedinf.2020.104246.

Agarwal, R., Gao, G.G., DesRoches, C., Jha, A.K., 2010. The digital transformation of healthcare: current status and the road ahead. Inf. Syst. Res. https://doi.org/10.1287/isre.1100.0327.

Aggarwal, S., Kumar, N., 2021. Attacks on blockchain. Adv. Comput. https://doi.org/10.1016/bs.adcom.2020.08.020.

al Abdullah, M., al Bakri, A.A., 2016. Electronic health record system: adoption and influencing factors. Int. J. Enterpren. Innovat. Manag. 20, 200–213. https://doi.org/10.1504/IJEIM.2016.077961.

Andreassen, T.W., Lervik-Olsen, L., Snyder, H., Van Riel, A.C.R., Sweeney, J.C., Van Vaerenbergh, Y., 2018. Business model innovation and value-creation: the triadic way. J. Serv. Manag. 29 (5), 883–906. https://doi.org/10.1108/JOSM-05-2018-0125.

Attaran, M., 2020. Blockchain technology in healthcare: challenges and opportunities. Int. J. Healthc. Manag. https://doi.org/10.1080/20479700.2020.1843887.

Benil, T., Jasper, J., 2020. Cloud based security on outsourcing using blockchain in E-health systems. Comput. Network. 178 https://doi.org/10.1016/j.comnet.2020.107344.

Biroscak, B.J., Scott, J.E., Lindenberger, J.H., Bryant, C.A., 2017. Leximancer software as a research tool for social marketers: application to a content analysis. Soc. Market. Q. 23, 223–231. https://doi.org/10.1177/1524500417700826.

Biswas, S., Sharif, K., Li, F., Alam, I., Mohanty, S., 2020. DAAC: digital asset access control in a unified blockchain based E-health system. IEEE Transactions on Big Data. https://doi.org/10.1109/TBDATA.2020.3037914.

Böckel, A., Nuzum, A.K., Weissbrod, I., 2021. Blockchain for the circular economy: analysis of the research-practice gap. Sustainable Production and Consumption. https://doi.org/10.1016/j.spc.2020.12.006.

Borup, M., Brown, N., Konrad, K., van Lente, H., 2006. The sociology of expectations in science and technology. Technol. Anal. Strat. Manag. 18, 285–298. https://doi.org/10.1080/09537320600777002.

Bunduchi, R., Tursunbayeva, A., Pagliari, C., 2019. Coping with institutional complexity: intersecting logics and dissonant visions in a nation-wide healthcare IT implementation project. Inf. Technol. People 33, 311–339. https://doi.org/10.1108/ITP-08-2018-0373.

Burton-Jones, A., Akhlaghpour, S., Ayre, S., Barde, P., Staib, A., Sullivan, C., 2020. Changing the conversation on evaluating digital transformation in healthcare: insights from an institutional analysis. Inf. Organ. 30 https://doi.org/10.1016/j.infoandorg.2019.100255.

Butler, D., 2008. Crossing the valley of death. Nature 453, 840–842.

Campbell, S.M., Roland, M.O., Buetow, S.A., 2000. Defining quality of care. Soc. Sci. Med. 51, 1611–1625. https://doi.org/10.1016/S0277-9536(00)00057-5.

Canon, 2017. System and Method for Providing Medical Information Based on Block Chain. Application ID:498367255.

Cao, S., Lyu, H., Xu, X., 2020. InsurTech development: evidence from Chinese media reports. Technol. Forecast. Soc. Change 161. https://doi.org/10.1016/j.techfore.2020.120277.

Chang, H.C., Wang, C.Y., Hawamdeh, S., 2019. Emerging trends in data analytics and knowledge management job market: extending KSA framework. J. Knowl. Manag. 23, 664–686. https://doi.org/10.1108/JKM-02-2018-0088.

Chen, Y., 2018. Blockchain tokens and the potential democratization of entrepreneurship and innovation. Bus. Horiz. 61, 567–575. https://doi.org/10.1016/j.bushor.2018.03.006.

Chenthara, S., Ahmed, K., Wang, H., Whittaker, F., Chen, Z., 2020. Healthchain: a novel framework on privacy preservation of electronic health records using blockchain technology. PloS One 15. https://doi.org/10.1371/journal.pone.0243043.

Chirumalla, K., 2021. Building digitally-enabled process innovation in the process Industries: a dynamic capabilities approach. Technovation 102256. https://doi.org/10.1016/j.technovation.2021.102256.

Chukwu, E., Garg, L., 2020. A systematic review of blockchain in healthcare: frameworks, prototypes, and implementations. IEEE Access 8, 21196–21214. https://doi.org/10.1109/ACCESS.2020.2969881.
Cobianchi, L., Dal Mas, F., Peloso, A., Pugliese, L., Massaro, M., Bagnoli, C., Angelos, P., 2020. Planning the full recovery phase: an antifragile perspective on surgery after COVID-19. Ann. Surg. 272, E296–E299. https://doi.org/10.1097/SLA.0000000000004489.
Cobianchi, L., Dal Mas, F., Angelos, P., 2021a. One size does not fit all - translating knowledge to bridge the gaps to diversity and inclusion of surgical teams. Ann. Surg. https://doi.org/10.1097/SLA.0000000000004604.
Cobianchi, L., Dal Mas, F., Massaro, M., Bednarova, R., Biancuzzi, H., Filisetti, C., Barcellini, A., Orlandi, E., Miceli, L., Angelos, P., 2021b. Hand in hand: a multistakeholder approach for co-production of surgical care. Am. J. Surg. https://doi.org/10.1016/j.amjsurg.2021.07.053.
Daim, T.U., Rueda, G., Martin, H., Gerdsri, P., 2006. Forecasting emerging technologies: use of bibliometrics and patent analysis. Technol. Forecast. Soc. Change 73, 981–1012. https://doi.org/10.1016/j.techfore.2006.04.004.
Dal Mas, F., Biancuzzi, H., Massaro, M., Miceli, L., 2020a. Adopting a knowledge translation approach in healthcare co-production. A case study. Manag. Decis. 58, 1841–1862. https://doi.org/10.1108/MD-10-2019-1444.
Dal Mas, F., Dicuonzo, G., Massaro, M., Dell'Atti, V., 2020b. Smart contracts to enable sustainable business models. A case study. Manag. Decis. 58, 1601–1619. https://doi.org/10.1108/MD-09-2019-1266.
Delgosha, M.S., Hajiheydari, N., Talafidaryani, M., 2021. Discovering IoT implications in business and management: a computational thematic analysis. Technovation. https://doi.org/10.1016/j.technovation.2021.102236.
Deloitte, 2020. Deloitte's 2020 Global Blockchain Survey.
Dimitrov, D.V., 2019. Blockchain applications for healthcare data management. Healthcare Informatics Research 25, 51–56. https://doi.org/10.4258/hir.2019.25.1.51.
Dumay, J.C., 2012. Grand theories as barriers to using IC concepts. J. Intellect. Cap. 13, 4–15. https://doi.org/10.1108/14691931211196187.
Dumay, J., 2014. Reflections on interdisciplinary accounting research: the state of the art of intellectual capital. Account Audit. Account. J. 27, 1257–1264. https://doi.org/10.1108/AAAJ-05-2014-1714.
Fusco, A., Dicuonzo, G., Dell'atti, V., Tatullo, M., 2020. Blockchain in healthcare: insights on COVID-19. Int. J. Environ. Res. Publ. Health 17, 1–12. https://doi.org/10.3390/ijerph17197167.
Gligor, D.M., Pillai, K.G., Golgeci, I., 2021. Theorizing the dark side of business-to-business relationships in the era of AI, big data, and blockchain. J. Bus. Res. 133, 79–88. https://doi.org/10.1016/j.jbusres.2021.04.043.
Goeldner, M., Herstatt, C., Tietze, F., 2015. The emergence of care robotics - a patent and publication analysis. Technol. Forecast. Soc. Change 92, 115–131. https://doi.org/10.1016/j.techfore.2014.09.005.
Gong, C., Ribiere, V., 2021. Developing a unified definition of digital transformation. Technovation 102. https://doi.org/10.1016/j.technovation.2020.102217.
Griggs, K.N., Ossipova, O., Kohlios, C.P., Baccarini, A.N., Howson, E.A., Hayajneh, T., 2018. Healthcare blockchain system using smart contracts for secure automated remote patient monitoring. J. Med. Syst. 42 https://doi.org/10.1007/s10916-018-0982-x.
Haber, S., Stornetta, W.S., 1991. How to time-stamp a digital document. J. Cryptol. 3, 99–111. https://doi.org/10.1007/BF00196791.
Hasselgren, A., Kralevska, K., Gligoroski, D., Pedersen, S.A., Faxvaag, A., 2020. Blockchain in healthcare and health sciences—a scoping review. Int. J. Med. Inf. 134 https://doi.org/10.1016/j.ijmedinf.2019.104040.
Hermes, S., Riasanow, T., Clemons, E.K., Böhm, M., Krcmar, H., 2020. The digital transformation of the healthcare industry: exploring the rise of emerging platform ecosystems and their influence on the role of patients. Business Research 13, 1033–1069. https://doi.org/10.1007/s40685-020-00125-x.
Iansiti, M., Lakhani, R.K., 2017. The truth about blockchain. Harv. Bus. Rev. 1–17. https://doi.org/10.1016/j.annals.2005.11.001.
IBM, 2017. Secure Distributed Patient Consent and Information Management. Application ID: 492084887.
Irise, 2018. HOSPITAL SECURITY SYSTEM THAT STORES PATIENT INFORMATION ON A BLOCKCHAIN BASIS. Application ID: 498205819.
Ismail, L., Materwala, H., 2020. Blockchain paradigm for healthcare: performance evaluation. Symmetry 12. https://doi.org/10.3390/SYM12081200.
Järvenpää, H.M., Mäkinen, S.J., Seppänen, M., 2011. Patent and publishing activity sequence over a technology's life cycle. Technol. Forecast. Soc. Change 78, 283–293. https://doi.org/10.1016/j.techfore.2010.06.020.
Kalla, A., Hewa, T., Mishra, R.A., Ylianttila, M., Liyanage, M., 2020. The role of blockchain to fight against COVID-19. IEEE Eng. Manag. Rev. 48, 85–96. https://doi.org/10.1109/EMR.2020.3014052.
Kouhizadeh, M., Saberi, S., Sarkis, J., 2021. Blockchain technology and the sustainable supply chain: theoretically exploring adoption barriers. Int. J. Prod. Econ. 231 https://doi.org/10.1016/j.ijpe.2020.107831.
Kraus, S., Schiavone, F., Pluzhnikova, A., Invernizzi, A.C., 2021. Digital transformation in healthcare: analyzing the current state-of-research. J. Bus. Res. 123, 557–567. https://doi.org/10.1016/j.jbusres.2020.10.030.
Krippendorff, K., 2013. Content Analysis. An Introduction to its Methodology. Sage Publications, Thousand Oaks, CA.
Kumar, A., Krishnamurthi, R., Nayyar, A., Sharma, K., Grover, V., Hossain, E., 2020. A novel smart healthcare design, simulation, and implementation using healthcare 4.0 processes. IEEE Access 8, 118433–118471. https://doi.org/10.1109/ACCESS.2020.3004790.
Kumari, R., Jeong, J.Y., Lee, B.H., Choi, K.N., Choi, K., 2019. Topic modelling and social network analysis of publications and patents in humanoid robot technology. J. Inf. Sci. https://doi.org/10.1177/0165551519887878.
Kuo, T.-T., Kim, H.-E., Ohno-Machado, L., 2017. Blockchain distributed ledger technologies for biomedical and health care applications. J. Am. Med. Inf. Assoc. 24, 1211–1220. https://doi.org/10.1093/jamia/ocx068.
Lakshma Reddy, B., Karthik, A., Prayla Shyry, S., 2019. A blockchain framework for insurance processes in hospitals. Int. J. Recent Technol. Eng. 7, 116–119.
Li, H., Wu, J., Gao, Y., Shi, Y., 2016. Examining individuals' adoption of healthcare wearable devices: an empirical study from privacy calculus perspective. Int. J. Med. Inf. 88, 8–17. https://doi.org/10.1016/j.ijmedinf.2015.12.010.
Liang, X., Shetty, S., Tosh, D., Bowden, D., Njilla, L., Kamhoua, C., 2018. Towards blockchain empowered trusted and accountable data sharing and collaboration in mobile healthcare applications. EAI Endorsed Transactions on Pervasive Health and Technology 4. https://doi.org/10.4108/eai.24-7-2018.159338.
Llewelyn, S., 2003. What counts as "theory" in qualitative management and accounting research? Introducing five levels of theorizing. Account Audit. Account. J. 16, 662–708. https://doi.org/10.1108/09513570310492344.
Lord, R., 2018. Blockchain in Health Care: the Good, the Bad and the Ugly. Forbes.
Mackey, T.K., Kuo, T.-T., Gummadi, B., Clauson, K.A., Church, G., Grishin, D., Obbad, K., Barkovich, R., Palombini, M., 2019. "Fit-for-purpose?" - challenges and opportunities for applications of blockchain technology in the future of healthcare. BMC Med. 17 https://doi.org/10.1186/s12916-019-1296-7.
Majchrzak, A., Markus, M.L., Wareham, J., 2016. ICT and societal challenges designing for digital transformation: lessons for information systems research from the study of ICT and societal challenges. MIS Q. 40, 267–277. https://doi.org/10.25300/MISQ/2016/40.
Makin, S., 2021. The Research-Practice Gap as a Pragmatic Knowledge Boundary. Information and Organization. https://doi.org/10.1016/j.infoandorg.2020.100334.
Massaro, M., Dumay, J., Garlatti, A., 2015. Public sector knowledge management : a structured literature review. J. Knowl. Manag. 19, 530–558. https://doi.org/10.1108/JKM-11-2014-0466.
Massaro, M., Dumay, J., Guthrie, J., 2016. On the shoulders of giants: undertaking a structured literature review in accounting. Account Audit. Account. J. 29, 767–801. https://doi.org/10.1108/AAAJ-01-2015-1939.
Massaro, M., Dumay, J., Garlatti, A., Dal Mas, F., 2018. Practitioners' views on intellectual capital and sustainability: from a performance-based to a worth-based perspective. J. Intellect. Cap. 19, 367–386. https://doi.org/10.1108/JIC-02-2017-0033.
Massaro, M., Dal Mas, F., Chiappetta Jabbour, C.J., Bagnoli, C., 2020. Crypto-economy and new sustainable business models: Reflections and projections using a case study analysis. Corporate Social Responsibility and Environmental Management 27 (5), 2150–2160. https://doi.org/10.1002/csr.1954.
Mayer, A.H., da Costa, C.A., Righi, R.D.R., 2020. Electronic health records in a Blockchain: a systematic review. Health Inf. J. 26, 1273–1288. https://doi.org/10.1177/1460458219866350.
McCoy, T.H.J., Perlis, R.H., 2015. Data breaches of protected health information in the United States. JAMA - Journal of the American Medical Association 313, 1471–1473. https://doi.org/10.1001/jama.2015.2252.
Mohanta, B.K., Jena, D., Satapathy, U., 2019. Trust management in IOT enable healthcare system using ethereum based smart contract. International Journal of Scientific and Technology Research 8, 758–763.
Nant Holding, I.P., 2015. Healthcare Transaction Validation via Blockchain, Systems and Methods. Application ID: 446436483.
Nayak, B., Bhattacharyya, S.S., 2020. The changing narrative in the health insurance industry: wearables technology in health insurance products and services for the COVID-19 world. J. Health Manag. 22, 550–558. https://doi.org/10.1177/0972063420983112.
Neal, J.W., Neal, Z.P., Kornbluh, M., Mills, K.J., Lawlor, J.A., 2015. Brokering the research–practice gap: a typology. Am. J. Community Psychol. 56, 422–435. https://doi.org/10.1007/s10464-015-9745-8.
Newbert, S.L., 2008. Value, rareness, competitive advantage and performance: a conceptual-level empirical investigation of the resource-based view of the firm. Strat. Manag. J. 29, 745–768. https://doi.org/10.1002/smj.686.
North University, Hebei, 2019. Medical Data Sharing Method and System Based on Block Chain. Application ID: 526312879.
OECD, 2019. The Policy Environment for Blockchain Innovation and Adoption 2019 OECD Global Blockchain Policy Forum Summary Report OECD BLOCKCHAIN POLICY SERIES.
Palas, Md Jahir Uddin, Bunduchi, R., 2020. Exploring interpretations of blockchain's value in healthcare: a multi-stakeholder approach. Inf. Technol. People 34, 453–495. https://doi.org/10.1108/ITP-01-2019-0008.
Palas, M.J.U., Bunduchi, R., 2020. Exploring interpretations of blockchain's value in healthcare: a multi-stakeholder approach. Inf. Technol. People 34, 453–495. https://doi.org/10.1108/ITP-01-2019-0008.
Perrigo, B., 2020. U.S. States Are Rolling Out COVID-19 Contact Tracing Apps.Months of Evidence from Europe Shows They're No Silver Bullet. Times.
Rahimi, B., Nadri, H., Afshar, H.L., Timpka, T., 2018. A systematic review of the technology acceptance model in health informatics. Appl. Clin. Inf. 9, 604–634. https://doi.org/10.1055/s-0038-1668091.
Rahman, M.A., Shamim Hossain, M., Islam, M.S., Alrajeh, N.A., Muhammad, G., 2020. Secure and provenance enhanced internet of health things framework: a blockchain managed federated learning approach. IEEE Access 8, 205071–205087. https://doi.org/10.1109/ACCESS.2020.3037474.
RStudio Team, 2015. RStudio: Integrated Development for R. RStudio. RStudio, Inc., Boston, MA [WWW Document].

Schmitz, J., Leoni, G., 2019. Accounting and auditing at the time of blockchain technology: a research agenda. Aust. Account. Rev. 29, 331–342. https://doi.org/10.1111/auar.12286.

Sebastian, I.M., Moloney, K.G., Ross, J.W., Fonstad, N.O., Beath, C., Mocker, M., 2017. How big old companies navigate digital transformation. MIS Q. Exec. 16, 197–213.

Secundo, G., Toma, A., Schiuma, G., Passiante, G., 2019. Knowledge transfer in open innovation: a classification framework for healthcare ecosystems. Bus. Process Manag. J. 25, 144–163. https://doi.org/10.1108/BPMJ-06-2017-0173.

Sidanius, J., Pratto, F., van Laar, C., Levin, S., 2004. Social Dominance Theory: its Agenda and Method.

SINOCHAIN TECHNOLOGY CO, 2018. Blockchain-based Medical Resource Data Processing Method and Device. Application ID: 506715624.

Siyal, A.A., Junejo, A.Z., Zawish, M., Ahmed, K., Khalil, A., Soursou, G., 2019. Applications of blockchain technology in medicine and healthcare: challenges and future perspectives. Cryptography 3, 1–16. https://doi.org/10.3390/cryptography3010003.

Skwarek, V., 2019. A short history of blockchain: origins, concepts and current developments | Eine kurze Geschichte der Blockchain: Ursprünge, Begriffe und aktuelle Entwicklungen. Informatik-Spektrum 42, 161–165. https://doi.org/10.1007/s00287-019-01175-0.

Smith, A.E., Humphreys, M.S., 2006. Evaluation of unsupervised semantic mapping of natural language with Leximancer concept mapping. Behav. Res. Methods 38, 262–279. https://doi.org/10.3758/BF03192778.

Southey, S., 2018. Tokenizing Healthcare Assets. Forbes.

Su, Q., Zhang, R., Xue, R., Li, P., 2020. Revocable attribute-based signature for blockchain-based healthcare system. IEEE Access 8, 127884–127896. https://doi.org/10.1109/ACCESS.2020.3007691.

Tandon, Anushree, Dhir, A., Islam, N., Mäntymäki, M., 2020. Blockchain in healthcare: a systematic literature review, synthesizing framework and future research agenda. Comput. Ind. 122 https://doi.org/10.1016/j.compind.2020.103290.

Tandon, A., Dhir, A., Islam, N., Mäntymäki, M., 2020. Blockchain in healthcare: a systematic literature review, synthesizing framework and future research agenda. Comput. Ind. 122 https://doi.org/10.1016/j.compind.2020.103290.

Tapscott, D., Tapscott, A., 2016. Blockchain Revolution: How the Technology behind Bitcoin Is Changing Money, Business, and the World. Portfolio, New York.

Tian, J., Coreynen, W., Matthyssens, P., Shen, L., 2021. Platform-based servitization and business model adaptation by established manufacturers. Technovation. https://doi.org/10.1016/j.technovation.2021.102222.

Toufaily, E., Zalan, T., Dhaou, S. ben, 2021. A framework of blockchain technology adoption: an investigation of challenges and expected value. Inf. Manag. 58 https://doi.org/10.1016/j.im.2021.103444.

Tucker, B.P., Lowe, A.D., 2014. Practitioners are from Mars ; academics are from Venus ? An investigation of the research-practice gap in management accounting. Account Audit. Account. J. 27, 394–425. https://doi.org/10.1108/AAAJ-01-2012-00932.

Tufféry, S., 2011. Data Mining and Statistics for Decision Making. Wiley. Wiley, Chichester.

Ullah, F., Ullah, I., Khan, A., Irfan Uddin, M., Alyami, H., Alosaimi, W., 2020. Enabling clustering for privacy-aware data dissemination based on medical healthcare-Iots (MH-IoTS) for wireless body area network. Journal of Healthcare Engineering. https://doi.org/10.1155/2020/8824907, 2020.

Umeh, J., 2019. Dark side of the blockchain. Itnow 61, 54–55. https://doi.org/10.1093/itnow/bwz022.

University of Jinan, 2017. Credible Gene Detection and Data Sharing Method Based on Blockchain and Proxy Re-encryption Technologies. Application N. 494548030.

Urbinati, A., Bogers, M., Chiesa, V., Frattini, F., 2019. Creating and capturing value from Big Data: a multiple-case study analysis of provider companies. Technovation 84 (85), 21–36. https://doi.org/10.1016/j.technovation.2018.07.004.

Vial, G., 2019. Understanding digital transformation: a review and a research agenda. J. Strat. Inf. Syst. https://doi.org/10.1016/j.jsis.2019.01.003.

Wallberg-Henriksson, H., 2013. Global health. Technovation. https://doi.org/10.1016/j.technovation.2013.03.006.

Yadav, P., 2015. Health product supply chains in developing countries: diagnosis of the root causes of underperformance and an agenda for reform. Health Systems and Reform 1, 142–154. https://doi.org/10.4161/23288604.2014.968005.

Zarour, M., Ansari, M.T.J., Alenezi, M., Sarkar, A.K., Faizan, M., Agrawal, A., Kumar, R., Khan, R.A., 2020. Evaluating the impact of blockchain models for secure and trustworthy electronic healthcare records. IEEE Access 8, 157959–157973. https://doi.org/10.1109/ACCESS.2020.3019829.

Zhang, J., Xue, N., Huang, X., 2016. A secure system for pervasive social network-based healthcare. IEEE Access 4, 9239–9250. https://doi.org/10.1109/ACCESS.2016.2645904.

Zhao, Z., Zhong, R.Y., Kuo, Y.H., Fu, Y., Huang, G.Q., 2021. Cyber-physical spatial temporal analytics for digital twin-enabled smart contact tracing. Ind. Manag. Data Syst. https://doi.org/10.1108/IMDS-11-2020-0634.

Maurizio Massaro, Ph. D., is Associate Professor at Ca' Foscari University of Venice. Before joining academia, he was founder and CEO of multiple consultancy firms. He has also served as a research center Vice President in the field of metal analysis. He has been a visiting Professor at Florida Gulf Coast University and Leicester University. He enjoys several contacts and research partnerships with universities in the USA, continental Europe, UK, Asia and Australia. His research interests include knowledge management, intellectual capital, sustainability in international business, and research methods. His research has been applied in multiple research contexts.