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Research article

Centralized vs. decentralized ledgers in the money supply process: a SWOT analysis

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Abstract: This study aims to better understand the role of centralized and decentralized ledgers in the money supply process. The aim is to highlight the strengths, weaknesses, opportunities, and threats of these tools in the context of finance and banking. A thorough investigation of the prior literature was carried out using sources extracted from various academic databases. A SWOT analysis based on an integrative literature review methodology was conducted to synthesize various research contributions and analyze relevant information related to centralized and decentralized ledgers. The findings reveal that centralized ledgers are still critical in the record-keeping of financial transactions, despite the strengths and opportunities of decentralized ledgers outweighing those of centralized ledgers. This study helps to increase the understanding of financial and banking sector managers concerning the importance of decentralized ledgers in delivering more value to customers.

Keywords: centralized ledgers; decentralized ledgers; SWOT; money; financial system

JEL Codes: E42, G21, G23

1. Introduction

Over the years, the market economy brought about a dominant economic model primarily based on the centralized structure of financial institutions. In this sense, centralization denotes the creation of a few financial institutions and banks that are organized and managed from the top (Kuschpèta, 1978). According to Neuberger (1959), centralization can be conceptualized as the desirability of central control over decisions on credit allocation. In finance, centralization can be manifested in control exerted by financial institutions over the economy's total money supply. For example, centralization implies that central banks can perform and supervise all the country's banking operations, exerting an influence over other independent banks, regardless of their geographic location. Examples of these operations include the issuance of money by the central bank, a specific commercial bank, and other private issuers (Bech and Garratt, 2017), identifying the type of money (electronic or physical) and controlling the transfer of money. Centralization is a crucial aspect, and it lies in the power of the central bank to create currencies and ensure price and financial stability. The centralized structure of the financial system has contributed to the privatization of profits and socialization of losses. For example, the weaknesses of financial systems and the breakdown of their dynamic stability have resulted in a persistent and significant rise in unemployment in the United States during the 2007–2009 global financial crisis (Avouyi-Dovi and Neto, 2004). The 2008 global financial crisis has urged the general public to question the monetary instruments' effectiveness and reliability and the ability of central banks and government authorities to respond to the crisis (Drašković, 2018). The global financial crisis has also influenced the regulatory space of both banks and financial markets.

After the 2008 global financial crisis and the loss of trust in financial institutions, a mysterious person or group operating under the name of Satoshi Nakamoto released a paper entitled "Bitcoin: A Peer-to-Peer Electronic Cash System" in which the author introduced a new protocol for a novel cryptocurrency "Bitcoin" (Nakamoto, 2008). Nakamoto has brought forth a "blueprint" or procedure for developing a digital transaction system using as a medium of exchange its own digital currency, independently of the conventional money or so-called fiat currencies, such as the EURO or the USD. More than a decade later, thousands of cryptocurrencies have been introduced and used to conclude online transactions. Other cryptocurrencies, including Litecoin, GeisGeld, SolidCoin, BBQcoin, and PPcoin are similar to Bitcoin. They claim to offer technological improvements to improve financial transactions' efficiency and security (Hughes and Middlebrook, 2014). The market capitalization of these digital currencies has been high, exceeding USD 500 billion and showing no signs of slowing down (Rosenfeld, 2015; Gyamerah, 2019). The success and proliferation of cryptocurrencies are attributed to the technology of decentralized ledgers, blockchain (Fosso Wamba et al., 2020; Rejeb, 2018a; Rejeb and Rejeb, 2020; Rejeb et al., 2018; Treiblmaier et al., 2020). As per Treiblmaier (2018), blockchain is defined as a "*digital, decentralized, and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamper-proof records."* A specific blockchain represents a configuration of multiple technologies, tools, and methods that address a particular problem or business use case (Keogh et al., 2020a; Keogh et al., 2020b; Rejeb, 2018b; Rejeb et al., 2019a; Rejeb et al., 2018). Decentralized ledger-based currencies and systems are commonly used as payment instruments to purchase goods and services, exchanged and traded in marketplaces either for fiat currencies or other cryptocurrencies (Drašković, 2018). An

essential characteristic of decentralized ledgers is the system participants' financial incentives in exchange for their concerted efforts to verify and record transactions on the ledger. The interest in the finance applications of decentralized ledgers has significantly increased because of the immutable financial transactions registered in the system, the strong governance, and the system's resiliency against security threats such as the DDoS attacks and single point of failure (Tasca and Tessone, 2018). The decentralization of the ledger has diverse implications on the money supply process. The most important one is independence from national and political control, including the central bank's dominant role in the financial system. Therefore, the role of decentralized ledgers in the money supply process is to create digital currencies that can compete with central banks. Recall that the Bitcoin creator's key objective is to allow network participants to exchange value and transfer money directly between them without the intervention of trusted third parties, such as the central bank or any other financial institutions. In the age of cryptocurrencies, the position of central banking in the money supply can be replaced with blockchain technology because the decentralized and distributed mechanism of the ledger enables to prevent the double-spending problem (Nakamoto, 2008; Treiblmaier, 2019) and to create a system that would bridge the trust gap inherent in the centralized ledger system for money supply (Morgan, 2017).

Unlike blockchain-based digital currencies, the centralized ledgers for money supply are controlled and governed by financial institutions. The centralized ledger used in the money supply process is not accessible to all parties involved in the transaction; instead, it is managed by a third party (Green, 2018). Historically, centralized ledgers have been used in registries (land, shipping, tax), exchanges (stock and bonds), or libraries (indexing and borrowing records), just to name few examples (Mainelli and Smith, 2015). Likewise, centralized ledgers are considered the widely used data storage means in finance (Zetzsche et al., 2018). Before the inception of the cryptocurrency Bitcoin, centralized ledgers are indispensable in transferring value and payments between the transaction parties. Financial institutions are viewed as trusted third parties in charge of centralized ledgers and are responsible for preventing the double-spending problem and validating transactions among the system participants (Nabilou, 2019). However, the introduction of decentralized ledgers typified by the Bitcoin blockchain system has significantly reshaped how money and transactions are carried out in the digital arena. Therefore, this research investigates the role of centralized and decentralized ledgers in the money supply process by conducting a SWOT analysis based on an integrative literature review methodology. SWOT stands for strengths, weaknesses, opportunities, and threats. The compilation of this information in the SWOT quadrant form provides useful insights to improve the strategic planning of various applications.

Although academic literature investigating the industrial applications of centralized and decentralized ledgers has recently attracted significant attention, a sharp focus on these tools in the context of finance is missing so far. For example, Raskin and Yermack (2018) discuss the challenges and opportunities of digital currencies and how central banks can use blockchain to maintain greater control over monetary transactions and policy. However, the authors fail to explain decentralized ledgers' advantages over centralized ledgers for central banks, especially after the widespread adoption of Bitcoin and other algorithmic digital currencies. Chen and Bellavitis (2020) examine blockchain's role in reducing transaction costs, building distributed trust, and supporting decentralized platforms, thereby paving the way for decentralized business models. According to the authors, decentralized finance makes

financial systems more decentralized, efficient, innovative, transparent, and borderless. In contrast, these systems' challenges include regulatory uncertainties, privacy concerns, increased computational overheads, lack of accountability, and the failure to leverage human judgements. A significant limitation of Chen and Bellavitis (2020)'s study is the lack of comparison between decentralized and centralized financial systems. Similarly, Schär (2020) explores the opportunities and risks of the decentralized finance ecosystem and concludes that certain security issues still accompany this emerging niche market. The author is biased in favour of decentralized financial systems, ignoring the inefficiencies that might arise due to decentralized ledgers' immutability and the obstruction of efficient corrective actions (Wu et al., 2019). Therefore, to reduce these knowledge gaps, the present study aims to provide a more balanced picture of centralized and decentralized ledgers from the finance perspective. It is crucial to comprehend the potential strengths, weaknesses, opportunities, and threats of these ledgers to present solutions that increase the utility of these systems and mitigate the political, social, and technical issues related to the operationalizing of these tools money supply process. Moreover, we intend to contribute to the literature and enrich this scientific body of knowledge since this topic has not yet been addressed in academic research. To the best of our knowledge, this is the initial attempt to conduct a SWOT analysis examining the usage of centralized and decentralized ledgers in finance. We consequently supplement previous research works and join the efforts of those researchers who would have studied these tools going beyond their narrow focus on one specific type of ledgers.

The structure of this paper is as follows. Section 2 introduces the integrative literature review methodology used for the SWOT analysis. Subsequently, Section 3 constitutes the paper's central part, providing a general overview of centralized ledgers and decentralized ledgers. The SWOT analysis of using these tools in the money supply is conducted, aiming at offering a comprehensive, unbiased overview of centralized and decentralized ledgers in the money supply process. The last section briefly concludes the paper and highlights the study's implications and future research directions.

2. Methods

Several approaches and methodologies exist for carrying out a literature review. These include systematic reviews (Davis et al., 2014; Liberati et al., 2009), semi-systematic reviews (Braun and Clarke, 2006), and integrative reviews (Snyder, 2019). As previously stated in the introduction, this study's objective is to better understand the strengths, weaknesses, opportunities, and threats of centralized and decentralized ledgers in the money supply process. To attain this aim, a SWOT analysis based on an integrative literature review method is conducted. We consider an integrative literature review as the most adequate and appropriate method for this research because it helps to evaluate and synthesize the literature on the use of centralized and decentralized ledger in the financial sector, allowing to form a taxonomy or categorization of main strengths, weaknesses, opportunities, and threats of these tools. Pertinent literature on the specificities, characteristics, enablers, and challenges of centralized and decentralized ledgers was retrieved from different academic databases, including Scopus, Google Scholar, and Web of Science. The keywords used for the search of literature were the following: ("centralized ledger*" OR "decentralized ledger*") AND (financ* OR bank* OR money). The retrieved literature and secondary research were used to identify the potentials and challenges of centralized and decentralized ledgers in the money supply and to obtain comprehensive clusters of the critical issues surrounding these tools in finance.

As a theoretical lens, we used SWOT theory. The origins of SWOT date back to the 1960s (Learned, 1969), and it became more popular after the work of Weihrich (1982). SWOT is commonly applied as a business environment scanning tool (Arslan and Deha Er, 2008; Helms and Nixon, 2010; Tam and Tummala, 2001). However, the method has some limitations because of the uncertainties associated with the factors obtained during the analysis (Khatri and Metri, 2016). Being a situation analysis and a well-established research tool, the paucity of studies using SWOT to analyze decentralized and centralized ledgers in the money supply was noticed, making this study the initial attempt to address this research gap.

3. Results and discussion

3.1. Overview of centralized and decentralized ledgers

3.1.1. Overview of centralized ledgers

Today, most financial ledgers are centralized in nature (Rahmadika et al., 2018). They are created, controlled, and maintained by a central and dominant party (Morgan, 2017). Systems based on centralized ledgers have necessitated a trusted third party to keep a record of transactions between organizations and individuals (Inghirami, 2019). Furthermore, centralized ledgers represent the final guarantors of trust in the entire financial system because they enable to credibly record fund transfers (or changes in terms of ownership over financial assets, including those created and existing digitally) and simplify the settlement of mutual obligations of counterparties to payments or other financial transactions (Athanassiou, 2017). Aside from being physical storage of precious metals and other financial assets, banks can be defined as centralized ledgers of transactions, capital or payments, which record balances between several parties (Drescher, 2017). In centralized ledgers, transactions are stored on the ledger. The ledger's trusted administrator is tasked with maintaining the ledger, the record of asset transfers, and the receipt of appropriately verified notifications (Zetzsche et al., 2018). The centralization of the ledger helps establish trust and ensure adequate documentation of property titling, contracts, funds, and so on, resulting in consolidating the government with the modern form of capitalism (Allen et al., 2019). With the increasing digitization of society (Compañó et al., 2006; Corradini, 2020; Frehe et al., 2017), online centralized ledgers have been widely utilized as record-keepers that are maintained by a set of interconnected financial institutions and financial market infrastructures, ranging from central banks, commercial banks, to clearing houses and insurance companies (Johnstone, 2018). These systems function through transaction reconciliation and tight control of financial processes. To illustrate the importance of these ledgers, we simply recall the example of the transfer of funds between two parties; the payer (Buyer) and the payee (Seller) (see Figure 1). In this typical scenario, the transaction execution involves the payer's bank and the payee's bank, or the correspondent bank, if the money transfer is international and spans across national borders. Each of these banks will have its ledger to record this money transfer by debiting one account and crediting another.

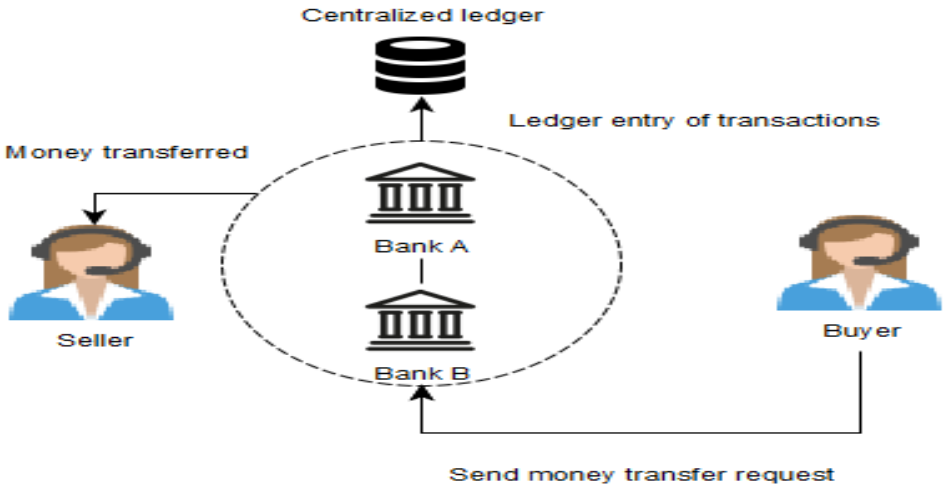

Figure 1. A typical financial transaction recorded in a centralized ledger system.

As can be seen from the figure, the centralized ledger needs the interventions of banks for managing the flow of data transactions in the ledger (Lemma, 2020b), wherein transactions are recorded according to the double-entry accounting principle (Casey and Vigna, 2018; Sheel and Nath, 2019; Wiatt, 2019). Financial institutions need to maintain their ledgers (Laroiya et al., 2020) to reflect their perspective of truth, as they are transacting with each other.

3.1.2. Overview of decentralized ledgers

As per Markus et al. (2019), a decentralized ledger is defined as a set of members, and each of them retains a local copy of the whole ledger. In simpler words, decentralized ledgers represent a specific data structure maintained by several parties through a consensus protocol, and each party holds a copy of the ledger (Xu et al., 2020). The key difference between the centralized and decentralized ledger is that the latter represents a collection of connected computers, forming the ledger and storing all data simultaneously. The distributed consensus protocol is the key technology behind the ledger's decentralization, ensuring that all network members agree on a unified transaction ledger without a third party's intervention. Based on their open and decentralized operations, the so-called decentralized ledgers or blockchain technologies are perceived as foundational innovations with high potentials in many sectors (Iansiti and Lakhani, 2017). In the form of blockchain technology, decentralized ledgers are bringing together concepts, tools, and methods from several fields, such as computing, communication networks, cryptography, and have profound societal impacts on many domains (Treiblmaier et al., 2020), including computer science, economics, law, business, tourism (Erceg et al., 2020; Joo et al., 2021; Leal et al., 2020; Rejeb et al., 2019b), healthcare (Khatoon, 2020; Rejeb and Bell, 2019), supply chain management (Clohessy and Acton, 2019; Clohessy et al., 2019; Duan et al., 2020; Hackius and Petersen, 2017, 2020; Kamble et al., 2019; Pournader et al., 2019; Queiroz and Wamba, 2019), and finance (Kamilaris et al., 2019; Rejeb et al., 2019b; Rejeb et al., 2020; Rejeb and Rejeb, 2019; Swan, 2015; Yli-Huumo et al., 2016). According to Hughes et al. (2019), decentralized ledgers have made blockchain a powerful innovation in modern internet architecture. The power of blockchain-based

financial ledgers is attributed to the decentralized transactional model that the new technology facilitates. The decentralization of financial transactions can be maintained by the use of consensus mechanisms and reward incentive engineering. As such, when a new record or transaction needs to be added to the ledger, all network users run a consensus protocol and use their local copies of the ledger to decide whether it should be approved or not (Markus et al., 2019). For example, in the Bitcoin system, decentralized ledgers use the proof-of-work mechanism to validate transactions (Nakamoto, 2008). The proof-of-work is designed to generate new blocks that contain financial transactions (Milutinovic et al., 2016). This consensus mechanism also suggests that the system participants should engage in a mining process to report verified blocks (Nakamoto, 2008). In other words, in the decentralized network, someone has to be selected to record transactions. If a specific member wants to initiate one transaction, much work must be accomplished to prove that this member is not likely to attack the network or corrupt the ledger (Zheng et al., 2017). The proof-of-work is also developed to make the chain of records interdependent and force the chronological order of data in the decentralized ledger or the blockchain (Swan, 2015). In doing as such, tampering with the ledger becomes extremely difficult, if not impossible, because attempting to reverse previous transactions necessitates the recalculation of the proof-of-work of all the succeeding blocks (Borah et al., 2020; Cha and Yeh, 2018; Iqbal and Matulevičius, 2019; Liang et al., 2017). The miners designate the users responsible for solving the proof-of-work puzzles (Huang, 2013). That said, miners are the backbone of decentralized ledger networks that ensure the blockchain's integrity in exchange for a fee (Alqaryouti et al., 2020; Burley, 2018; Lewis and Regan, 2020). For instance, the design principles of several decentralized ledger-based cryptocurrencies require the commitment of enormous amounts of energy, time, and capital to prevent malicious actors from tampering with the ledger (Dolenc et al., 2020; Mylrea, 2019). In the Bitcoin network, miners are rewarded and paid with Bitcoins for their role in generating blocks and securing the entire network (Nojoumian et al., 2019; Vujičić et al., 2018; Wang and Liu, 2015). Unlike the proof-of-work mechanism used in the Bitcoin system, Chuen et al. (2017) argue that the proof-of-stake (i.e. a consensus algorithm for digital currencies that is used to validate transactions and generate blocks in the network) implies that no additional work is needed under this scheme since miners are rewarded based on the number of coins they hold. According to the authors, systems based on this scheme commit less computation and ensure higher currency security.

Decentralized ledgers can be roughly divided into two main categories; public ledgers and permissioned ledgers (Markus et al., 2019). The public ledgers are cheap, safe, reliable, and designed to support the decentralized record-keeping of financial transactions (e.g., settlement payments) carried out within large groups of traders who do not necessarily know or trust one another (Camera, 2017). The critical attribute of public ledgers is their openness to every participant in the system (Duke, 2019; Fan et al., 2020). As a result, transactions recorded in public ledgers are immutable, transparent, and viewable to all entities (Yan et al., 2020; Healy and Christiansen, 2016). In contrast, in permissioned ledgers, the addition and reading of transaction records are restricted to specifically designated parties (Azgad-Tromer, 2018). Based on Donovan (2018)'s study, permissioned ledgers have accelerated the uptake of distributed ledger technologies by the financial services industry. Permissioned ledgers can be otherwise called private blockchains as they often require authentication of participant identities and authorization of participants' permission-level of access on the blockchain (Lafarre and Elst, 2018; Samavi et al., 2017).

3.2. SWOT analysis of centralized and decentralized ledgers in the money supply process

3.2.1. SWOT analysis of centralized ledgers

Strengths of centralized ledgers

The use of centralized ledgers is frequently reported as the most extensive data storage medium used in finance (Zetzsche et al., 2018). Centralized record-keeping systems rely on a trusted administrator to ensure the reliability of stored data and the proper recording of financial assets (Natarajan et al., 2017). For instance, in the financial sector, centralized ledgers are utilized in most security-clearing and settlement systems, central counterparts, and large-value payment systems (Zetzsche et al., 2018). Currently, the international payment value chain comprises many communication networks, intermediaries, settlements, clearing, access interfaces, and other highly complex and integrated infrastructures with agreed rules and rights (Kokkola, 2011). The importance of centralized ledgers is rooted in need for mitigating trust issues in international payments and the ability of centralized financial systems to ensure the proper handling of transactions and their veracity (Arjani, 2007). There is also a growing realization that neutral intermediaries and centralized ledgers are necessary to reduce the risks related to the settlement and clearing of financial transactions. In this regard, the Basel Committee on Banking Supervision (Goodhart, 2011) identified that these risks are accentuated due to inefficiencies of central bank's payment systems, time zone differences, inconsistencies of cross-border payments, and use of multiple currencies. Moreover, some of these risks include market risk, liquidity risk, principal risk, legal risk, and operational risk. Centralized ledgers provide the financial system participants with an increased sense of trust because the risk of being recorded differently is very low (Hellani et al., 2018). The record-keeping approach of these systems implies that a singular entity or a subset of entities maintains control over the validation of transactions and prevents the double-spending problem (Chen and Chou, 2015; Ureche and Plamondon, 1999; Wright, 2002). For example, all data related to the banking sector participants are monitored by banks, and all money transactions triggered by clients have to be verified by the bank. The bank is also responsible for resolving the double-spending problem by permanently assigning a serial number to each transaction and preventing malicious agents from attacking the ledger (Hellani et al., 2018). All commercial mechanisms for payment clearance should go through the specific financial institution in order to be checked for validity. Accordingly, account balances are adjusted (Ammous, 2016), thereby making transaction data private (Hsieh et al., 2018). Besides being prevalent and reliable record-keeping systems, the widespread use of centralized ledgers in the money supply is also explained by their high efficiency in transaction throughput and energy consumption. As a case in point, payment services based on centralized ledgers such as Visa can perform about 2300 transactions per second on average, and more than 56000 transactions per second can be processed at maximum (Drašković, 2018).

Weaknesses of centralized ledgers

The application of centralized ledgers to the money supply process is fraught with several weaknesses. In this respect, Mainelli and Smith (2015) illustrate three weak points of implementing centralized ledgers in finance, including the likelihood of transaction forgery, reversal, and censorship.

Transaction forgery refers to modifying the original documents by different means, such as imitating other people's signatures and writing. For example, if banks intend for forgery, they can take away all the money and bring about serious financial impacts to all their clients (Nair and Sebastian, 2017). In centralized ledgers, individuals and entities might be involved in modifying original documents without valid authorization. Ainsworth and Magauran (2018) note that centralized ledgers are not secure and can be vulnerable to different cyberattacks, data corruption, and fraud. Likewise, the likelihood that banks require a complicated process to make and reverse transactions is high, resulting in inefficiencies and high transaction costs (Bogucki, 2017). Moreover, the ledger is not resilient to financial institutions' opportunistic behaviour and their intentions to carry out dishonest interventions, manipulations, and censorship of payments. Abadi and Brunnermeier (2018) argue that centralized ledgers are often managed and controlled by monopolists that generate distortionary rents from the ledger's users. The authors further reported that record-keeping based on centralized ledgers stunts competition as only one entity is allowed to write on the ledger. Collomb and Sok (2016) note that the primary deficiencies of centralized ledgers that are controlled by trusted third parties are: (1) the lack of trustworthiness in third parties due to their exposure to bribery and other forms of corruption, (2) the censorship and rejection of individual market participants due to subjective and discriminatory grounds, and (3) the risk of record losses.

Several inefficiencies and agency problems arise with the intermediated and centralized banking model (Minn, 2019). As an illustration, to perform an international wire transfer between China and Canada, the money goes through different financial institutions such as correspondent banks, national payment systems, and international settlement services (e.g., SWIFT). This typical international transaction often takes between 3 and 15 business days to finalize, depending on the receiving destination. It requires several actors, including managers, employees, and bank tellers from the previously mentioned financial institutions. Other financial burdens still apply throughout the international money transfer process, such as the expensive bank fees and exchange rates (Mohamed, 2020). Morgan (2017) points out that economies operating on centralized ledgers are inherently slow, inefficient, costly, non-transparent, and prone to several risks. The reason is that transactions in these systems are conducted based on blind trust or some combinations of verification (due diligence) and insurance.

Opportunities for centralized ledgers

In the money supply process, the ledger's centralization can present several opportunities for the financial ecosystem actors. Utilizing centralized ledgers, auditors would have the chance to solve several jurisdictional issues while maintaining a clear idea of the nature of the financial assets and transactions carried out, the consistency and centralization of records, and the effectiveness of the control environment (Malhotra et al., 2020). A financial system reliant on centralized ledger systems can be more efficient in transaction throughput, scalability, and performance (Xu and Zou, 2020). Centralized ledgers offer several benefits, including reducing system complexity and the easy retrieval of data (Mainelli and Smith, 2015). The lack of centralized ledger storage results in increasing difficulty and cost of accessing aggregated data, especially when data have to be collected from various sources. The centralization of recording activities can enhance the network's synchronization and ensure a higher level of bank accountability, appropriate safeguards, and standards of judicial scrutiny (Nabilou, 2019). Therefore, centralized ledgers can simplify the collection process of financial data, contribute to high-

quality financial analyses, and enable financial institutions and companies to achieve substantial cost savings. To confirm these benefits, Abadi and Brunnermeier (2018) prove that centralized ledgers, if being leveraged in the financial ecosystem, will help reduce consumption of resources (e.g., energy and computational power) and maximize coordination efficiencies. Although centralized ledgers have played a critical role in the money supply process, financial actors are increasingly shifting toward the use of decentralized ledgers for several reasons we present in the next section.

Threats of centralized ledgers

The exchange of digital money through centralized ledgers requires trust third parties (banks) to authorize financial transactions. In these systems, the trust in the quality of the financial and economic information maintained in centralized ledgers rests on the authority's reputation that manages and controls the ledger (Cappa and Pinelli, 2020). At any time, fraud can happen by a malicious actor pretending himself as the holder of the bank account in what is called identity theft (Zetzsche et al., 2018). Also, the structures of centralized systems pose several threats. For instance, financial data stored in centralized ledgers can be destroyed, hacked, compromised, manipulated, and replaced by inaccurate data (Zetzsche et al., 2018). Similarly, Jia and Zhang (2017) state that centralized-based economies are inefficient and unable to face the environment's uncertainty and the future. In the usual circumstances, banks combat identity theft by issuing credentials that can help identify customers, such as bank cards, PINs, and tokens (Zhou et al., 2018). Businesses face inconvenient situations to ensure protection by requesting customers to provide additional information, including permanent addresses and card verification values. This practice accentuates privacy intrusions and allows malicious actors to acquire sensitive information, resulting in severe inconveniences for customers and businesses interacting along the process (Inghirami, 2019a). At an aggregate level, financial institutions used centralized ledgers to store all transactions. Related to transparency and visibility, customers have only access to their bank statements. They must trust that these ledgers will be maintained reliably and honestly and that their personal information will be protected from cyberattacks and abuses (Collomb and Sok, 2016). Nevertheless, human agents are subject to agency problems, resulting in higher risks of fraud and misconduct (Yau, 2001). Centralized ledgers strengthen the stranglehold of monopolistic record-keepers on the data stored in their ledgers, encouraging them to impose higher costs on customers (Abadi and Brunnermeier, 2018). The reliance on a central hub for recording financial transactions increases the system vulnerability and the exposure to the single point of failure (SPOF). SPOF is a critical technical problem that can arise from hardware and software flaws or malicious attacks (Zheng et al., 2017). If the central ledger fails, the entire system is compromised. Furthermore, centralized ledgers are commonly siloed, not sufficiently integrated, and cause transaction delays when there is a need to access another centralized ledger (Singh, 2018). Kropotkin (1970) argues that centralized ledgers could be detrimental to the autonomy and creativity of individuals who are ready to engage in collaborative arrangements and mutual aids.

Figure 2 depicts the summary of SWOT analysis of centralized ledgers in the money supply process.

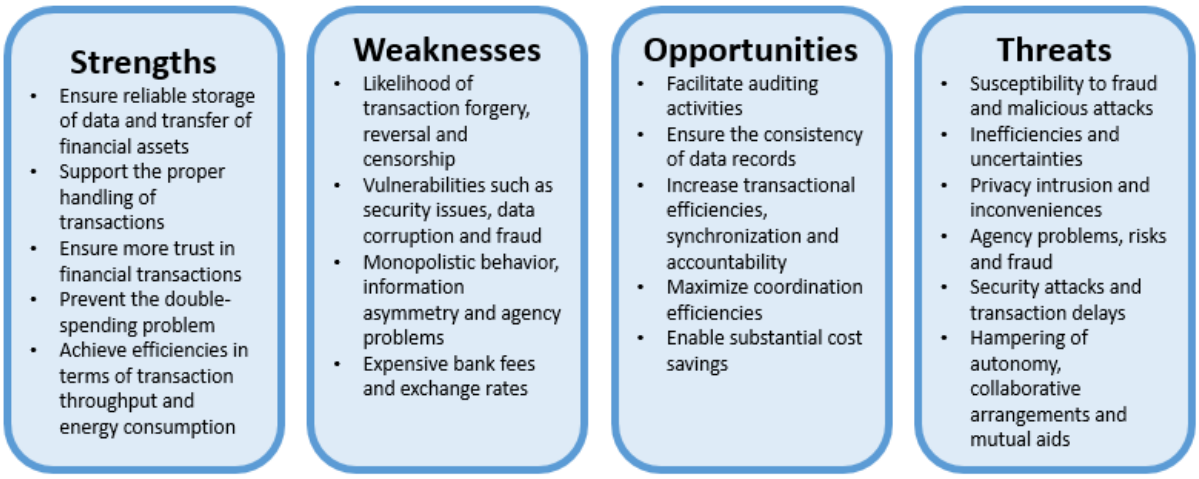

Figure 2. SWOT analysis of centralized ledgers in the money supply process.

3.2.2. SWOT analysis of decentralized ledgers in the money supply

Strengths of decentralized ledgers

Decentralized ledgers represent an emerging game-changer in the field of finance (Andersson and Styf, 2020; Mao and Xiao, 2018). Decentralization has raised the prospect of performing financial transactions without the need for central intermediaries, be it a bank or a centralized digital platform (Collomb and Sok, 2016). As already mentioned in the definition of a decentralized ledger, all nodes (or actors) connected and participating in the ledger are equal, and none of them can exert control over the others (Drašković, 2018). Depending on their design, decentralized ledgers enable them to disclose more information than centralized peers (Athanassiou, 2017). Records in decentralized ledgers are not created, monitored, and maintained by a single, central party. Instead, financial transactions are stored on many computers owned by the system's participants (Sarmah, 2018). In an economic system based on decentralized ledgers or blockchain, several business problems can be easily overcome with the rich features of technology such as irreversibility, security, and transparency (Wang and Kogan, 2018). Irreversibility signifies immutability, and it represents one of the core features of decentralized ledgers (Liu, Chang, 2019). Transaction immutability is a core value in leveraging decentralized ledgers in the money supply process because it makes the system more trustworthy for all parties involved (Subramanian et al., 2020). Any transaction/data, once indexed in the decentralized ledger, becomes inconceivable to temper and compromise (Tiwari et al., 2019). Immutability reduces the need for reconciliations and provides historical, unique, and one truth of the records (Chen, 2019). The history of financial transactions is recorded in perpetuity, and it is challenging to tamper with the ledger because of the need for high computing power (Dai et al., 2017). Therefore, decentralized ledgers enable participants to operate in a secure ecosystem and maintain a high confidence level in the unalterable and accurate data chain. Moreover, the security of decentralized ledgers is manifested in the following potential aspects:

Provenance: Decentralized ledgers provide a data provenance system that tracks who has created, updated, deleted, and, in some cases, read particular data points (Freire et al., 2008). Moreover,

decentralized ledgers ensure complete information about the origin and evolution of data throughout the stages of data creation and modifications, allowing to know who triggered them, and when and how they were carried out (Freire et al., 2008). Provenance is an intriguing record-keeping category of decentralized ledgers that helps track a range of physical things (e.g., cotton, fashion, coffee, and organically farmed food products) (Visser and Hanich, 2017).

Auditability: Decentralized ledgers offer a new way of recording transactions or any digital interactions with keeping the data manipulation process transparent and auditable. While the difficulty of mapping complex supply networks remains an issue, blockchain auditability allows driving trust, openness, visibility and integrity (Cole et al., 2019). Auditability is a beneficial feature in asset authentication, rapid accessibility to records, and automation of manual processes (e.g., product recalls).

Confidentiality: It is the need for an increasing number of firms who are searching for leveraging decentralized and distributed ledger technologies for digital confidentiality (Crosby et al., 2016). From the business perspective, private blockchains can be considered a suitable choice for companies who do not want their information to be publicly divulged while overseeing users' changes and behaviors through a strict governance model (Molina et al., 2019). Privacy is guaranteed by rigid credential checking techniques and protected through modern asymmetric encryption (Brandon, 2016).

Trust: In almost all industries, trust in the authenticity of the collected data and the transactions carried out with individual partners, service providers, manufacturers, suppliers, and even government is necessary (Fernández-Caramés and Fraga-Lamas, 2019). As an immutable and tamper-proof ledger, blockchain decentralized ledger guarantees a single version of the truth that helps to forge trust in the stored information (Wang et al., 2019). The underlying architecture and the trust-by-design model of decentralized ledgers are useful for optimizing global financial transactions and generating a secure and trust-less means to exchange information and value (Nakamoto, 2008).

The distributed nature of decentralized ledger and blockchain systems increases the stored transactions' visibility and transparency (Chandra et al., 2019; Lacity, 2018; Wang et al., 2019). For instance, from its inception to underpin cryptocurrencies, blockchain technology has been touted as having the potential to solve the problems encountered when trying to achieve end-to-end transparency (Cole et al., 2019). A configured blockchain is recommended to establish greater transparency and disclose relevant data for individuals (Yiannas, 2018). Similarly, decentralized ledgers ensure increased transparency in the case of exchanging cryptocurrencies (Nakamoto, 2008). In the Bitcoin blockchain, all transactions are publicly available, and all parties benefit from maximum transparency and protection against online threats and attacks. Due to transparency, decentralized ledgers can support corporate managers who need to attract and reach out to investors in various situations, namely, a merger, an acquisition, and a corporate election.

Weaknesses of decentralized ledgers

Although decentralized ledgers' applications are promising in finance, these tools are still in a nascent stage of development. In this context, Del Río (2017) argues that even though central banks have expressed interest in using decentralized ledger technologies, they are still far from applying these systems in their operations. The reasons for the immature use of decentralized ledgers in the money supply process are mainly the speed of financial transactions, the cost of processing, security and privacy concerns, limited scalability, and uncertainty (Adams and Tomko, 2018; Catalini and Gans, 2016; Riehl

and Ward, 2020). For example, the Bitcoin blockchain system's speed for confirming transactions is very low (Athanassiou, 2017). In some instances, a 10-minute block processing time might be adequate (Nakamoto, 2008), yet the speed of transaction settlement within the infrastructure itself might not be satisfactory and far slower than when centralized ledgers are being used. Additionally, the speed of transacting and achieving the finality of transactions could take more time than real-time gross settlement systems as the validation of transactions can be delayed due to the congestion and increasing complexity of the system (Suikkanen, 2017). Another potential weakness of decentralized ledgers relates to security issues. While decentralized record-keeping systems are highly resilient in contrast to traditional centralized ledgers thanks to their decentralized and distributed structure and the utilization of advanced cryptographic techniques, they are not immune from security issues (Ganne, 2018). The integration of decentralized ledgers in the existing financial systems could generate additional security loopholes resulting in severe operational and financial damages. In their study, Tama et al. (2017) note that decentralized ledgers' security weaknesses are mainly related to the misuse of network access by untrustworthy entities. Security issues contribute to the slow large-scale deployment of decentralized ledgers in the financial services and money supply processes.

The replacement of trust in a central authority by transparency constitutes the critical advantage of decentralized ledgers and blockchain-based financial applications. Of course, permissionless and public decentralized ledgers allow everyone registered in the system to instantly verify who wrote what and how the ledger is updated. However, the downside of increased transparency is the lack of privacy, which is the most reported issue in academic literature (Joshi et al., 2018; Yu et al., 2018). The open nature of decentralized ledgers paved the way for several problems surrounding data confidentiality between the system's parties. Cermeño (2016) notes that there is still a pressing question on how to combine the public nature of decentralized ledgers with the need to ensure anonymity and privacy of sensitive information. The author suggests that encryption identifiers such as private keys can address privacy issues; however, operating with private keys would require careful control and monitoring. Unlike centralized ledgers, regardless of their design, decentralized ledgers disclose more information to every network participant despite the multiple anonymizing payments.

Several scholars also identify that the operational capacity and performance-based scalability of many decentralized ledgers and blockchain designs is a critical concern for the financial system's stakeholders (Ben Dhaou and Rohman, 2018; Hileman and Rauchs, 2017). For instance, as block capacity tends to increase and accommodate more transactions, the decentralized ledger arrangements may take a longer time to achieve financial transactions and settlements (Chen et al., 2020; Shu et al., 2020). The scalability of decentralized ledgers and blockchain technology has so far ignited too many debates within the scientific community regarding the technological adjustments that would be needed, including whether the block size should be enlarged or not (Collomb and Sok, 2016). If not adequately addressed, the scalability issues of decentralized ledgers might result in the failure of the money supply process. As an illustration, Ethereum, despite being the biggest decentralized platform for cryptocurrencies, is dragged down by scalability problems that could not be solved quickly enough (Cointelegraph, 2020). Collomb and Sok (2016) maintain that decentralized ledger applications could not be suitable for all financial transactions, and they suggest that these systems should not be used for trivial payments.

Opportunities of decentralized ledgers

Like many financial innovations, decentralized ledgers have emerged to address the existing frictions in the financial system and the inefficiencies of the traditional payment platforms (Lemma, 2020a; Nakamoto, 2008). The rise of shadow banking and the need for bank disintermediation have led many to speculate on the potential "end of banking" (McMillan, 2014) and replace current centralized ledger models with decentralized systems. Without any doubt, the use of decentralized ledgers has the potential to remarkably reshape how digital finance, crowdfunding, and peer-to-peer lending platforms operate. The removal of trusted third parties aids borrowers and lenders to find each other (Collomb and Sok, 2016), effectively circulate money, and efficiently allocate credits (Nabilou, 2019). Decentralized ledgers increase the ability to match the two sides of the financial markets, namely, the capital borrowers and investors, and improve the probability of finding a suitable partner. For example, to take advantage of decentralized ledgers' capabilities, two consortiums in South Korea have tested and operated based on shared-ledger technology. One of them consists of 16 Korean banks planning to develop a blockchain-based system to simplify international wire transfers (Korea JoongAng Daily, 2020). Simultaneously, the other consortium comprises 25 securities companies that planned to apply decentralized ledger technologies to identity authorization. Moreover, the Bank of England economists agree that decentralized ledgers represent a key innovation that enables a financial payment system to operate more efficiently and at low financial transaction costs (Wessel, 2016).

The advent of the Bitcoin blockchain has been considered the most promising financial technology because it permits for the first time to transfer digital property from an internet user to another more safely and securely, with everyone knowing when and what transfer has occurred without any doubt in the legitimacy of the transaction (Fosso Wamba et al., 2020). After this revolutionary paradigm, a wide range of alternative decentralized ledger applications have been designed, and new cryptocurrencies have been introduced to improve the Bitcoin system's original protocol. These include Altcoins, Zerocash, and Zerocoin, which offered greater anonymity and more robust consensus mechanisms such as Peercoin (Erhardt, 2017). The advantages of using decentralized ledger-based cryptocurrencies are numerous. They include the high flexibility of domestic and international transactions, the increasing number of businesses endorsing cryptocurrencies, and the future appeal and global reach of digital currencies (Wilson, 2019). To illustrate, the number of businesses across the world that accept payments in cryptocurrencies exceeded 12600, according to a report published by Coinmap in May 2018. The more significant part of these businesses is located in North America and Europe. In contrast, several others are situated in Central America, South America, South-East Asia, and the East Coast of Australia (Coinmap, 2020).

Aside from underpinning cryptocurrencies, the applications of decentralized ledgers have accelerated financial innovations. In this regard, decentralized ledgers have significantly facilitated raising funds on a blockchain, in what constitutes Initial Coin Offerings (ICOs) (Azgad-Tromer, 2018). In the analogy of initial public offerings where a company initially offers shares to the public via a regulated stock market, the ICO is a similar process in which a company presents a project for funding and attracts interested investors to buy the company's cryptocurrencies in hopes that the value of the obtained shares increased over time and possible profits can be achieved from their sale (Drašković, 2018). Utilizing these reward-based crowdfunding mechanisms, businesses would be able to raise

capital without the intermediation of trusted third parties (Momtaz, 2019). The ICO represents a new way of financing business projects in which potential investors can participate and trade their shares or obtained tokens in very liquid secondary markets (Fasolato and Raggio, 2018). Furthermore, cryptocurrencies-based decentralized ledgers are beneficial for achieving increased financial inclusion (Ganne, 2018). Thanks to decentralized record-keeping systems, cryptocurrencies aid in transactional banking and make it more inclusive by enabling the unbanked population to participate in the digital economy (Härdle et al., 2020).

Threats of decentralized ledgers

Decentralized ledgers are considered the most game-changing innovation in finance. Despite their growth potential, several threats still exist, inhibiting the wide-scale implementation of these systems in money supply processes. As business activities and government services transition toward decentralized ledgers, the centralization of social and economic power will likely be concentrated in the hands of the designers and developers of decentralized ledger technologies (Marks, 2019). This implies that the programmers who write the underlying decentralized ledger code, the client applications, and smart contracts (i.e., self-executable computer programs) would exert control and influence over the conduct of financial transactions. Decentralized ledgers may increase the risk of delegating unlimited power and control to the developers responsible for creating and hosting the system. Marks (2019) argues that decentralized public ledgers might lack system participants with the technical skills to enhance the system's governance. Regulation is another pressing challenge. Decentralized ledgers can be used to increase government control and surveillance over the financial activities of citizens. Moreover, there is still a regulatory uncertainty related to the use of decentralized ledger-based cryptocurrencies (Cumming et al., 2019). According to Stratfor (2020), a clear regulatory framework surrounding cryptocurrencies should be established to promulgate this currency type in the money supply process. The costs of uncertainty in decentralized ledger applications and blockchain technology are profound (Azgad-Tromer, 2018). Related to a consensus protocol, Hautsch et al. (2020) concluded that settlement through decentralized systems generates non-trivial frictions, negatively affecting market efficiency and price formation. Governments and financial institutions need to be cognizant of the threats posed by decentralized ledger systems as they can be used for illicit activities such as money laundering, terrorism financing, illegal commerce, and other nefarious activities (Foley et al., 2019). Although decentralized ledgers can secure the use of cryptocurrencies, the development of state-backed cryptocurrencies represents a threat that undermines the existence of privately-issued cryptocurrencies (Wilson, 2019). Herein, recall that the impetus behind blockchain decentralized ledger is to eliminate the banking control over the money supply process (Nakamoto, 2008).

Figure 3 depicts the summary of SWOT analysis of decentralized ledgers in the money supply process.

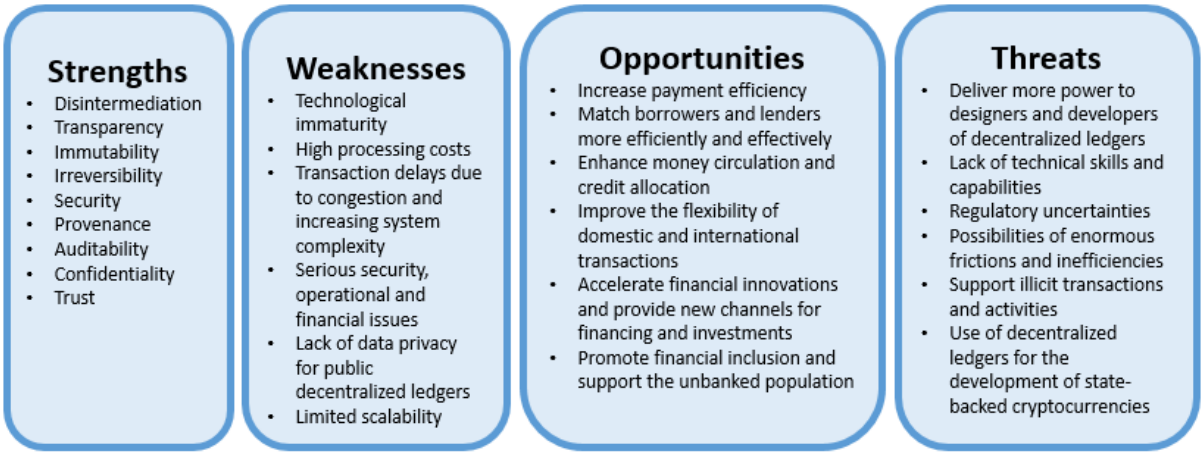

Figure 3. SWOT analysis of decentralized ledgers in the money supply process.

4. Conclusions and future research directions

This research has focused on the role of centralized and decentralized ledgers in the money supply process. A SWOT analysis was conducted to identify the strengths, weaknesses, opportunities and threats of using both systems in finance. This review provides several implications for academics and practitioners, aiming at better understanding the use of these ledgers and their applications. Based on the analysis mentioned above, this paper concludes that centralized ledgers are still critical in the record-keeping of financial transactions; however, the use of decentralized ledger systems is expected to induce several disruptions in the future of money supply, and they are likely to become a widely used tool in finance. From the perspective of technology futurists and over-enthusiastic professionals, the promotion and praise of the economic potentials of decentralized ledgers are often justified by their ability to address the ever-increasing cybersecurity risks encountered in finance. While these ledgers may strongly be more secure than conventional centralized ledgers, there is a need to analyse who will incur losses and responsibility when decentralized ledgers are used in the money supply process.

In several aspects, the strengths and opportunities of decentralized ledgers outweigh those of centralized ledgers. Decentralized ledgers are characterized by disintermediation, high transactional efficiency, security, immutability and transparency. On the contrary, centralized ledgers emphasize the high institutional control over the financial system. Despite being the most widely used data storage tools in finance, centralized ledgers may be destroyed, hacked, or compromised, resulting in original data being manipulated, replaced by inaccurate data, or held for ransom. Therefore, future research should investigate how mathematical approaches can determine how much effort is required to manipulate any given centralized ledger. In other words, it is recommended to examine the sufficient level of computing power that is necessary to manipulate centralized ledgers.

The expectations of decentralization in finance are high and include the better allocation of financial resources, the efficient matching of capital borrowers and investors, transaction cost savings, support of entrepreneurship, provision of financing resources, and increased financial inclusion. In this regard, more research should be devoted to understanding whether the transition from very costly centralized ledgers to decentralized and distributive financial ledgers is conducive to substantial cost savings and

transactional efficiencies. Moreover, further analysis is needed to look into the existing and future applications of decentralized ledgers, including the role of these tools to facilitate financial transactions, use of digital currencies, and smart contracts. Even though the adoption of decentralized ledgers in today's financial systems can help address the security threats associated with centralized ledgers, they may generate additional security loopholes that raise serious operational concerns. Thus, the early detection of potential attacks represents a challenging task for programmers and tech-savvy professionals to increase decentralized ledgers' resilience against data corruption and network attacks.

It should be noted that most of the benefits and challenges of decentralized ledgers are mainly a consequence of their strengthening of cryptocurrencies. While decentralized ledgers are expected to disrupt finance and introduce unprecedented opportunities, centralized ledgers ensure the continuity of the current financial systems. This research supports the argument that decentralized ledgers will be widely used in new financial systems. Nevertheless, it is likely that they will be significantly advanced than the existing ones and will be heavily controlled by regulatory bodies.

Conflict of interest

The authors declare no conflict of interest.

References

Abadi J, Brunnermeier M (2018) Blockchain Economics. National Bureau of Economic Research. Working Paper No. 25407. Available from: https://doi.org/10.3386/w25407.

Adams B, Tomko M (2018) A Critical Look at Cryptogovernance of the Real World: Challenges for Spatial Representation and Uncertainty on the Blockchain (Short Paper), In: S. Winter A, Griffin, & M. Sester (Eds.), *10th International Conference on Geographic Information Science (GIScience 2018),* Dagstuhl, Germany: Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 18: 1–6.

Ainsworth RT, Magauran B (2018) Taxing & Zapping Marijuana: Blockchain Compliance in the Trump Administration Part 3, SSRN Scholarly Paper No. ID 3239977, Rochester, NY: Social Science Research Network. Available from: https://doi.org/10.2139/ssrn.3239977.

Allen DWE, Berg A, Berg C, et al. (2019) Some economic consequences of the GDPR, C/O John Conley, Department of Economics, 414 Calhoun Hall, Nashville, TN 37235 USA: Economics Bulletin.

Alqaryouti O, Siyam N, Alkashri Z, et al. (2020) Users' Knowledge and Motivation on Using Cryptocurrency, In: M. Themistocleous & M. Papadaki (Eds.), *Information Systems*, Cham: Springer International Publishing, 113–122.

Ammous SH (2016) Blockchain Technology: What is it Good for? *SSRN Electron J*. Available from: https://doi.org/10.2139/ssrn.2832751.

Andersson K, Styf A (2020) Blockchain Technology and Volatility of Stock Returns: A Quantitative Study that Examines Blockchain Technology's Impact on Volatility in Swedish Stocks. Master Thesis, Umeå University, Faculty of Social Sciences, Umeå School of Business and Economics (USBE), Business Administration, Sweden.

Arjani N (2007) Management of Foreign Exchange Settlement Risk at Canadian Banks. *Financ Syst Rev* 8: 71–78.

Arslan O, Er ID (2008) SWOT analysis for safer carriage of bulk liquid chemicals in tankers. *J Hazard Mater* 154: 901–913.

Athanassiou P (2017) Impact of Digital Innovation on the Processing of Electronic Payments and Contracting: An Overview of Legal Risks. SSRN Scholarly Paper No. ID 3067222, Rochester, NY: Social Science Research Network.

Avouyi-Dovi S, Neto D (2004) Equity market interdependence: The relationship between European and US stock markets. *Financ Stab Rev* 4: 108–126.

Azgad-Tromer S (2018) Crypto Securities: On the Risks of Investments in Blockchain-Based Assets and the Dilemmas of Securities Regulation. *Am Univ Law Rev* 68: 69.

Bech ML, Garratt R (2017) Central Bank Cryptocurrencies. SSRN Scholarly Paper No. ID 3041906. Rochester, NY: Social Science Research Network. Available from: https://papers.ssrn.com/abstract=3041906.

Ben Dhaou SI, Rohman IK (2018) Everything and its opposite: Socio-economic implications of Blockchain technology: Case of monetary policy. *Proceedings of the 11th International Conference on Theory and Practice of Electronic Governance*, Galway, Ireland: Association for Computing Machinery, 631–639. Available from: https://doi.org/10.1145/3209415.3209502.

Bogucki B (2017) Buying Votes in the 21st Century: The Potential Use of Bitcoins and Blockchain Technology in Electronic Voting Reform. *Asper Rev Int Bus Trade Law* 17: 59.

Borah MD, Naik VB, Patgiri R, et al. (2020) Supply Chain Management in Agriculture Using Blockchain and IoT, In: S. Kim & G. C. Deka (Eds.), *Advanced Applications of Blockchain Technology*, Singapore: Springer, 227–242.

Brandon D (2016) The Blockchain: The Future of Business Information Systems? *Int J Acad Bus World* 10: 33–40.

Braun V, Clarke V (2006) Using thematic analysis in psychology. *Qual Res Psychol* 3: 77–101.

Burley RF (2018) Stable and decentralized? The promise and challenge of a shared citation ledger. *Inf Serv Use* 38: 141–148.

Camera G (2017) A Perspective on Electronic Alternatives to Traditional Currencies, SSRN Scholarly Paper No. ID 2902721, Rochester, NY: Social Science Research Network. Available from: https://papers.ssrn.com/abstract=2902721.

Cappa F, Pinelli M (2020) Collecting money through blockchain technologies: First insights on the determinants of the return on Initial Coin Offerings. *Inf Technol Dev*, 1–18.

Casey MJ, Vigna P (2018) In blockchain we trust. *MIT Technol Rev 121:* 10–16.

Catalinz C, Gans JS (2016) Some Simple Economics of the Blockchain. *Commun ACM* 63: 80–90.

Cermeño JS (2016) Blockchain in financial services: Regulatory landscape and future challenges for its commercial application. *BBVA Res Pap* 16: 20.

Cha SC, Yeh KH (2018) An ISO/IEC 15408-2 Compliant Security Auditing System with Blockchain Technology. *2018 IEEE Conference on Communications and Network Security (CNS)*, 1–2.

Chandra GR, Liaqat IA, Sharma B (2019) Blockchain Redefining: The Halal Food Sector. *2019 Amity International Conference on Artificial Intelligence (AICAI)*, 349–354.

Chen CJ (2019) Developing a model for supply chain agility and innovativeness to enhance firms' competitive advantage. *Manage Decis* 57: 1511–1534.

Chen J, Zhang X, Shangguan P (2020) Improved PBFT Algorithm Based on Reputation and Voting Mechanism. *J Phys* 1486: 032023.

Chen Y, Chou JS (2015) On the Privacy of "User Efficient Recoverable Off-Line E-Cash Scheme with Fast Anonymity Revoking". *IJ Network Secur* 17: 708–711.

Chen Y, Bellavitis C (2020) Blockchain disruption and decentralized finance: The rise of decentralized business models. *J Bus Ventur Insights* 13: e00151.

Chuen DLK, Guo L, Wang Y (2017) Cryptocurrency: A New Investment Opportunity? *J Alternative Invest* 20: 16–40.

Clohessy T, Acton T (2019) Investigating the influence of organizational factors on blockchain adoption: An innovation theory perspective. *Ind Manage Data Syst* 119: 1457–1491.

Clohessy T, Acton T, Rogers N (2019) Blockchain Adoption: Technological, Organisational and Environmental Considerations, In: H. Treiblmaier & R. Beck (Eds.), *Business Transformation through Blockchain: Volume I*, Cham: Springer International Publishing, 47–76.

Coinmap (2020) Crypto ATMs & merchants of the world Coinmap.org. Available from: https://coinmap.org/.

Cointelegraph (2020) Where To Issue ICO Tokens: Platforms Review. Available from: https://cointelegraph.com/ico-101/where-to-issue-ico-tokens-platforms-review.

Cole R, Stevenson M, Aitken J (2019) Blockchain technology: Implications for operations and supply chain management. *Supply Chain Manage Int J* 24: 469–483.

Collomb A, Sok K (2016) Blockchain/distributed ledger technology (DLT): What impact on the financial sector? *Digiworld Econ J* 103: 93.

Compañó R, Bock AK, Burgelman JC, et al. (2006) Converging applications for active ageing policy. *Foresight* 8: 30–42.

Corradini I (2020) The Digital Landscape, In: I. Corradini (Ed.), *Building a Cybersecurity Culture in Organizations: How to Bridge the Gap Between People and Digital Technology*, Cham: Springer International Publishing, 1–22.

Crosby M, Pattanayak P, Verma S, et al. (2016) Blockchain technology: Beyond bitcoin. *Appl Innovation* 2: 71.

Cumming DJ, Johan S, Pant A (2019) Regulation of the Crypto-Economy: Managing Risks, Challenges, and Regulatory Uncertainty. *J Risk Financ Manage* 12: 126.

Dai F, Shi Y, Meng N, et al. (2017) From Bitcoin to cybersecurity: A comparative study of blockchain application and security issues. *2017 4th International Conference on Systems and Informatics (ICSAI)*, 975–979. Available from: https://doi.org/10.1109/ICSAI.2017.8248427.

Davis J, Mengersen K, Bennett S, et al. (2014) Viewing systematic reviews and meta-analysis in social research through different lenses. *SpringerPlus* 3: 511.

Del Río CA (2017) Use of distributed ledger technology by central banks: A review. *Enfoque UTE* 8: 1–13.

Dolenc D, Turk J, Pustišek M (2020) Distributed Ledger Technologies for IoT and Business DApps. *2020 International Conference on Broadband Communications for Next Generation Networks and Multimedia Applications (CoBCom)*, 1–8. Available from: https://doi.org/10.1109/CoBCom49975.2020.9174188.

Donovan AP (2018) (Shadow) banking on the blockchain: Permissioned ledgers, interoperability and common standards, *Research Handbook on Shadow Banking*. Available from: https://www.elgaronline.com/view/edcoll/9781785362620/9781785362620.00020.xml.

Drašković T (2018) Blockchain at the European Level. Available from: https://dspace.cuni.cz/handle/20.500.11956/102359.

Drescher D (2017) Documenting Ownership, In: D. Drescher (Ed.), *Blockchain Basics: A Non-Technical Introduction in 25 Steps*, Berkeley, CA: Apress, 63–69. Available from: https://doi.org/10.1007/978-1-4842-2604-9_9.

Duan J, Zhang C, Gong Y, et al. (2020) A Content-Analysis Based Literature Review in Blockchain Adoption within Food Supply Chain. *Int J Environ Res Public Health* 17: 1784.

Duke A (2019) What Does the CISG Have to Say about Smart Contracts: A Legal Analysis. *Chicago J Int Law* 20: 141.

Erceg A, Damoska Sekuloska J, Kelić I (2020) Blockchain in the Tourism Industry—A Review of the Situation in Croatia and Macedonia. *Informatics* 7: 5.

Erhardt KD (2017) Bismuth: A blockchain-based program for verifying responsible data usage, Thesis, Massachusetts Institute of Technology, Massachusetts Institute of Technology. Available from: https://dspace.mit.edu/handle/1721.1/119629.

Fan C, Ghaemi S, Khazaei H, et al. (2020) Performance Evaluation of Blockchain Systems: A Systematic Survey. *IEEE Access* 8: 126927–126950.

Fasolato F, Raggio M (2018) ICO or crowdfunding ? An empirical analysis of fundraising strategies [Laurea Magistrale/Specialistica]. Available from: https://www.politesi.polimi.it/handle/10589/145025.

Fernández-Caramés TM, Fraga-Lamas P (2019) A Review on the Application of Blockchain for the Next Generation of Cybersecure Industry 4.0 Smart Factories. *ArXiv:1902.09604 [Cs]*. Available from: http://arxiv.org/abs/1902.09604.

Foley S, Karlsen JR, Putniņš TJ (2019) Sex, Drugs, and Bitcoin: How Much Illegal Activity Is Financed through Cryptocurrencies? *Rev Financ Stud* 32: 1798–1853.

Fosso Wamba S, Kamdjoug K, Robert J, et al. (2020) Bitcoin, Blockchain, and FinTech: A Systematic Review and Case Studies in the Supply Chain. *Prod Plann Control* 31: 115–142.

Frehe V, Mehmann J, Teuteberg F (2017) Understanding and assessing crowd logistics business models—using everyday people for last mile delivery. *J Bus Ind Mark* 32: 75–97.

Freire J, Koop D, Santos E, et al. (2008) Provenance for computational tasks: A survey. *Comput Sci Eng* 10: 11–21.

Ganne E (2018) Can Blockchain revolutionize international trade? World Trade Organization.

Goodhart C (2011) *The Basel Committee on Banking Supervision: A History of the Early Years 1974–1997*, Cambridge University Press.

Green S (2018) Decentralized Agriculture: Applying Blockchain Technology in Agri-Food Markets. Available from: http://dx.doi.org/10.11575/PRISM/34952.

Gyamerah SA (2019) Modelling the volatility of Bitcoin returns using GARCH models. *Quant Financ Econ* 3: 739–753.

Hackius N, Petersen M (2017) Blockchain in Logistics and Supply Chain: Trick or Treat? *Digitalization in Supply Chain Management and Logistics: Proceedings of Hamburg International Conference of Logistics*, 3–18.

Hackius N, Petersen M (2020) Translating High Hopes Into Tangible Benefits: How Incumbents in Supply Chain and Logistics Approach Blockchain. *IEEE Access* 8: 34993–35003.

Härdle WK, Harvey CR, Reule RCG (2020) Understanding Cryptocurrencies. *J Financ Econometrics* 18: 181–208.

Hautsch N, Scheuch C, Voigt S (2020) Building Trust Takes Time: Limits to Arbitrage in Blockchain-Based Markets. *ArXiv:1812.00595 [q-Fin]*. Available from: http://arxiv.org/abs/1812.00595.

Healy NS, Christiansen EN (2016) Anti-Money Laundering and Counter-Terrorist Finance: Year-in-Review 2015. *Int Lawyer* 50: 423.

Hellani H, Samhat AE, Chamoun M, et al. (2018) On BlockChain Technology: Overview of Bitcoin and Future Insights. *2018 IEEE International Multidisciplinary Conference on Engineering Technology (IMCET)*, 1–8. Available from: https://doi.org/10.1109/IMCET.2018.8603029.

Helms MM, Nixon J (2010) Exploring SWOT analysis—where are we now? A review of academic research from the last decade. *J Strategy Manage* 3: 215–251.

Hileman G, Rauchs M (2017) Global blockchain benchmarking study. Available from: https://j2-capital.com/wp-content/uploads/2017/11/GLOBAL-BLOCKCHAIN.pdf.

Hsieh YY, Vergne JP, Anderson P, et al. (2018) Bitcoin and the rise of decentralized autonomous organizations. *J Organ Design* 7: 14.

Huang DY (2013) Profit-driven abuses of virtual currencies. *Univ California, San Diego*, 14.

Hughes A, Park A, Kietzmann J, et al. (2019) Beyond Bitcoin: What blockchain and distributed ledger technologies mean for firms. *Bus Horiz* 62: 273–281.

Hughes S, Middlebrook S (2014) Regulating Cryptocurrencies in the United States: Current Issues and Future Directions. *William Mitchell Law Rev* 40: 814–848.

Iansiti M, Lakhani KR (2017) The truth about blockchain. *Harv Bus Rev* 95: 118–127.

Inghirami IE (2019) AIS in the Time of Blockchain. *Living Digital Ecosyst Technol Organ Human Agency*, 122–136.

Inghirami L (2019a) Accounting Information Systems: The Scope of Blockchain Accounting. *ITAIS and MCIS 2019: A Joint Event: The 13th Mediterranean Conference on Information Systems and the 16th Conference of the Italian Chapter of AIS*, 1–13. Italy. Available from: https://boa.unimib.it/handle/10281/250204.

Iqbal M, Matulevičius R (2019) Comparison of Blockchain-Based Solutions to Mitigate Data Tampering Security Risk, In: C. Di Ciccio, R. Gabryelczyk, L. García-Bañuelos, T. Hernaus, R. Hull, M. Indihar Štemberger, … M. Staples (Eds.), *Business Process Management: Blockchain and Central and Eastern Europe Forum,* Cham: Springer International Publishing, 13–28.

Jia K, Zhang F (2017) Between liberalization and prohibition: Prudent enthusiasm and the governance of Bitcoin/blockchain technology, In: *Bitcoin and Beyond (Open Access),* Routledge, 88–108.

Johnstone M (2018) Catch Me If You Can: Resolving Bitcoin Disputes with Class Actions. *Can Class Action Rev* 15: 45–73.

Joo J, Park J, Han Y (2021) Applications of Blockchain and Smart Contract for Sustainable Tourism Ecosystems, In: V. Suma, N. Bouhmala, & H. Wang (Eds.), *Evolutionary Computing and Mobile Sustainable Networks,* Singapore: Springer, 773–780.

Joshi AP, Han, M, Wang Y (2018) A survey on security and privacy issues of blockchain technology. *Math Found Computing* 1: 121.

Kamble SS, Gunasekaran A, Sharma R (2019) Modeling the blockchain enabled traceability in agriculture supply chain. *Int J Inf Manage.* [In press].

Kamilaris A, Fonts A, Prenafeta-Boldú FX (2019) The rise of blockchain technology in agriculture and food supply chains. *Trends Food Sci Technol* 91: 640–652.

Keogh JG, Dube L, Rejeb A, et al. (2020a) The Future Food Chain: Digitization as an Enabler of Society 5.0, In: D. Detwiler (Ed.), *Building the Future of Food Safety Technology* (1st Edition), London, Oxford, UK; San Diego, Cambridge, USA: Elsevier.

Keogh JG, Rejeb A, Khan N, et al. (2020b) Blockchain and GS1 Standards in the Food Chain: A Review of the Possibilities and Challenges, In: D. Detwiler (Ed.), *Building the Future of Food Safety Technology* (1st Edition), London, Oxford, UK; San Diego, Cambridge, USA: Elsevier.

Khatoon A (2020) A Blockchain-Based Smart Contract System for Healthcare Management. *Electronics* 9: 94.

Khatri JK, Metri B (2016) SWOT-AHP Approach for Sustainable Manufacturing Strategy Selection: A Case of Indian SME. *Global Bus Rev* 17: 1211–1226.

Kokkola T (2011) *The payment system: Payments, securities and derivatives, and the role of the Eurosystem*, European Central Bank.

Korea JoongAng Daily (2020) [Korea and the fourth industrial revolution <10-2 Finance>] The blockchain promises to be the ledger for all ledgers. Available from: http://koreajoongangdaily.joins.com/news/article/article.aspx?aid=3035044.

Kropotkin P (1970) *Anarchism: A Collection of Revolutionary Writings*, ed. R. Baldwin (Mineola, NY: Dover, 2005), 265.

Kuschpèta O (1978) The birth of the banking and credit system of the USSR, In: O. Kuschpèta (Ed.), *The banking and credit system of the USSR*, Boston, MA: Springer US, 23–47.

Lacity MC (2018) Addressing key challenges to making enterprise blockchain applications a reality. *MIS Q Exec* 17: 201–222.

Lafarre A, Elst CV der (2018) Legal tech and blockchain for corporate governance and shareholders. *Research Handbook in Data Science and Law*. Available from: https://www.elgaronline.com/view/edcoll/9781788111294/9781788111294.00015.xml,

Laroiya C, Saxena D, Komalavalli C (2020) Chapter 9—Applications of Blockchain Technology, In: S. Krishnan, V. E. Balas, E. G. Julie, Y. H. Robinson, S. Balaji, & R. Kumar (Eds.), *Handbook of Research on Blockchain Technology,* Academic Press, 213–243.

Leal F, Malheiro B, Veloso B, et al. (2020) Responsible processing of crowdsourced tourism data. *J Sust Tourism*, 1–21.

Learned EP (1969) *Business Policy: Text and Cases*, R. D. Irwin.

Lemma V (2020a) Fintech and Market-Based Financing, In: V. Lemma (Ed.), *FinTech Regulation: Exploring New Challenges of the Capital Markets Union,* Cham: Springer International Publishing, 77–141.

Lemma V (2020b) FinTech Regulation, In: *Springer Books*, Springer.

Lewis AN, Regan AC (2020) Enabling Paratransit and TNC Services with Blockchain Based Smart Contracts, In: K. Arai, S. Kapoor, & R. Bhatia (Eds.), *Intelligent Computing*, Cham: Springer International Publishing, 471–481.

Liang X, Shetty S, Tosh D, et al. (2017) ProvChain: A Blockchain-based Data Provenance Architecture in Cloud Environment with Enhanced Privacy and Availability. *Proceedings of the 17th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing*, Piscataway, NJ, USA: IEEE Press, 468–477. Available from: https://doi.org/10.1109/CCGRID.2017.8.

Liberati A, Altman DG, Tetzlaff J, et al. (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *J Clin Epid* 62: e1–e34.

Liu KH, Chang SF, Huang WH, et al. (2019) The Framework of the Integration of Carbon Footprint and Blockchain: Using Blockchain as a Carbon Emission Management Tool, In: A. H. Hu, M. Matsumoto, T. C. Kuo, & S. Smith (Eds.), *Technologies and Eco-innovation towards Sustainability I: Eco Design of Products and Services,* Singapore: Springer, 15–22.

Mainelli M, Smith M (2015) Sharing ledgers for sharing economies: An exploration of mutual distributed ledgers (aka blockchain technology). *J Financ Perspect* 3.

Malhotra J, Jadhav NN, Sachdeo-Bedi R, et al. (2020) Redefining Trust and Disinter-Mediation With Blockchain in E-Governance, In: I. Willliams (Ed.), *Cross-Industry Use of Blockchain Technology and Opportunities for the Future*, IGI Global, 18–38.

Mao M, Xiao H (2018) *Blockchain-based Technology for Industrial Control System CyperSecurity*. Atlantis Press, 903–907. Available from: https://doi.org/10.2991/ncce-18.2018.151.

Marks J (2019) Distributed Ledger Technologies and Corruption. *Sci Technol Law Rev* 20.

Markus I, Xu L, Subhod I, et al. (2019) DAcc: Decentralized Ledger based Access Control for Enterprise Applications. *2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)*, 345–351. Available from: https://doi.org/10.1109/BLOC.2019.8751479.

McMillan J (2014) The End of Banking: Money, *Credit, and the Digital Revolution,* a Trouver.

Milutinovic M, He W, Wu H, et al. (2016) Proof of Luck: An Efficient Blockchain Consensus Protocol. *Proceedings of the 1st Workshop on System Software for Trusted Execution*, Trento, Italy: Association for Computing Machinery, 1–6. Available from: https://doi.org/10.1145/3007788.3007790.

Minn KT (2019) Towards Enhanced Oversight of "Self-Governing" Decentralized Autonomous Organizations: Case Study of the DAO and Its Shortcomings. *J Intellect Prop Entertrainment Law* 9: 139.

Mohamed H (2020) Implementing a Central Bank Issued Digital Currency with Economic Implications Considerations. *Int J Islamic Econ Financ (IJIEF)* 3: 51–74.

Molina JC, Delgado DT, Tarazona G (2019) Using Blockchain for Traceability in the Drug Supply Chain, In: L. Uden, I.-H. Ting, & J. M. Corchado (Eds.), *Knowl Manage Organ*, Springer International Publishing, 536–548.

Momtaz PP (2019) The Pricing and Performance of Cryptocurrency. *Eur J Financ*, 1–14.

Morgan JS (2017) What I Learned Trading Cryptocurrencies While Studying the Law. *Univ Miami Int Comp Law Rev* 25: 159.

Mylrea M (2019) Chapter 12—Distributed Autonomous Energy Organizations: Next-Generation Blockchain Applications for Energy Infrastructure, In: W. Lawless, R. Mittu, D. Sofge, I. S. Moskowitz, & S. Russell (Eds.), *Artificial Intelligence for the Internet of Everything*, Academic Press, 217–239.

Nabilou H (2019) Testing the waters of the Rubicon: The European Central Bank and central bank digital currencies. *J Bank Regul*.

Nair GR, Sebastian S (2017) Blockchain Technology; Centralised Ledger to Distributed Ledger. *Intl Res J Eng Technol* 4: 2823–2827.

Nakamoto S (2008) Bitcoin: A Peer-to-Peer Electronic Cash System. Available from: https://doi.org/10.1007/s10838-008-9062-0.

Natarajan H, Krause S, Gradstein H (2017) *Distributed ledger technology and blockchain*, World Bank.

Neuberger E (1959) Centralization vs. Decentralization: The Case of Yugoslav Banking. *Am Slavic East Eur Rev* 18: 361–373.

Nojoumian M, Golchubian A, Njilla L, et al. (2019) Incentivizing Blockchain Miners to Avoid Dishonest Mining Strategies by a Reputation-Based Paradigm, In: K. Arai, S. Kapoor, & R. Bhatia (Eds.), *Intelligent Computing*, Cham: Springer International Publishing, 1118–1134.

Pournader M, Shi Y, Seuring S, et al. (2019) Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. *Int J Prod Res*, 1–19.

Queiroz MM, Wamba SF (2019) Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. *Int J Inf Manage* 46: 70–82.

Rahmadika S, Ramdania DR, Harika M (2018) Security Analysis on the Decentralized Energy Trading System Using Blockchain Technology. *J Online Inf* 3: 44–47.

Raskin M, Yermack D (2018) Digital currencies, decentralized ledgers and the future of central banking, In: *Research Handbook on Central Banking*, Edward Elgar Publishing.

Rejeb A (2018a) Blockchain Potential in Tilapia Supply Chain in Ghana. *Acta Technica Jaurinensis* 11: 104–118.

Rejeb A (2018b) Halal Meat Supply Chain Traceability Based on HACCP , Blockchain and Internet of Things. *Acta Technica Jaurinensis* 11: 1–30.

Rejeb A, Bell L (2019) Potentials of Blockchain for Healthcare: Case of Tunisia. *World Sci News* 136: 173–193.

Rejeb A, Keogh JG, Treiblmaier H (2019a) Leveraging the Internet of Things and Blockchain Technology in Supply Chain Management. *Future Int* 11: 161.

Rejeb A, Keogh JG, Treiblmaier H (2019b) The impact of blockchain on medical tourism, *WeB2019 Workshop on E-Business*, Munich, Germany, 1–12.

Rejeb A, Keogh JG, Treiblmaier H (2020) How Blockchain Technology Can Benefit Marketing: Six Pending Research Areas. *Front Blockchain* 3: 1–12.

Rejeb A, Rejeb K (2019) Blockchain Technology in Tourism: Applications and Possibilities. *World Sci News*, 119–144.

Rejeb A, Rejeb K (2020) Blockchain and supply chain sustainability. *Logforum* 16: 363–372.

Rejeb A, Sűle E, Keogh JG (2018) Exploring new technologies in procurement. *Transp Logistic Int J* 18: 76–86.

Riehl JR, Ward J (2020) Transaction Pricing for Maximizing Throughput in a Sharded Blockchain Ledger. *2020 Crypto Valley Conference on Blockchain Technology (CVCBT)*, Rotkreuz, Switzerland, Switzerland: IEEE, 36–42. Available from: https://doi.org/10.1109/CVCBT50464.2020.00008.

Rosenfeld E (2015) Ecuador becomes the first country to roll out its own digital cash. *CNBC February,* 9.

Samavi R, Doyle TE, Topologlou T (2017) The first workshop on blockchain & eHealth: Towards provable privacy & security in data intensive health research. *Proceedings of the 27th Annual International Conference on Computer Science and Software Engineering,* USA: IBM Corp, 333–336.

Sarmah SS (2018) Understanding blockchain technology. *Comput Sci Eng* 8: 23–29.

Schär F (2020) Decentralized Finance: On Blockchain- and Smart Contract-based Financial Markets. SSRN Scholarly Paper No. ID 3571335. Rochester, NY: Social Science Research Network. Available from: https://doi.org/10.2139/ssrn.3571335.

Sheel A, Nath V (2019) Effect of blockchain technology adoption on supply chain adaptability, agility, alignment and performance. *Manage Res Rev* 42: 1353–1374.

Shu H, Qi P, Huang Y, et al. (2020) An Efficient Certificateless Aggregate Signature Scheme for Blockchain-Based Medical Cyber Physical Systems. *Sensors* 20: 1521.

Singh V (2018) *Understand Blockchain Technology: Your quick guide to understand blockchain concepts*, Vivek Singh.

Snyder H (2019) Literature review as a research methodology: An overview and guidelines. *J Bus Res* 104: 333–339.

Stratfor (2020) The Arduous Task of Regulating Bitcoin. Available from: https://worldview.stratfor.com/article/arduous-task-regulating-bitcoin.

Subramanian N, Chaudhuri A, Kayikci Y (2020) Basics of Blockchain, In: N. Subramanian, A. Chaudhuri, & Y. Kayıkcı (Eds.), *Blockchain and Supply Chain Logistics: Evolutionary Case Studies*, Cham: Springer International Publishing, 11–19.

Suikkanen H (2017) Economic and Institutional Implications of Blockchain. Master Thesis, Aalto University, Finland. Available from: https://aaltodoc.aalto.fi:443/handle/123456789/28718.

Swan M (2015) *Blockchain Blueprint for a New Economy*, O'Reilly Media, Inc.

Tam MCY, Tummala VMR (2001) An application of the AHP in vendor selection of a telecommunications system. *Omega* 29: 171–182.

Tama BA, Kweka BJ, Park Y, et al. (2017) A critical review of blockchain and its current applications. *2017 International Conference on Electrical Engineering and Computer Science (ICECOS)*, Palembang: IEEE, 109–113. Available from: https://doi.org/10.1109/ICECOS.2017.8167115.

Tasca P, Tessone CJ (2018) Taxonomy of Blockchain Technologies. Principles of Identification and Classification. *ArXiv:1708.04872 [Cs]*. Available from: http://arxiv.org/abs/1708.04872.

Tiwari STS, Chan SW, Ahmad MF, et al. (2019) Application and Implementation of E-Procurement Technologies in Malaysian Manufacturing Firm. *Int J Supply Chain Manage* 8: 923.

Treiblmaier H (2018) The impact of the blockchain on the supply chain: A theory-based research framework and a call for action. *Supply Chain Manage Int J* 23: 545–559.

Treiblmaier H (2019) Combining Blockchain Technology and the Physical Internet to Achieve Triple Bottom Line Sustainability: A Comprehensive Research Agenda for Modern Logistics and Supply Chain Management. *Logistics* 3: 1–13.

Treiblmaier H, Rejeb A, Strebinger A (2020) Blockchain as a Driver for Smart City Development: Application Fields and a Comprehensive Research Agenda. *Smart Cities* 3: 853–872.

Ureche O, Plamondon R (1999) Document transport, transfer and exchange: Security and commercial aspects. *Proceedings of the Fifth International Conference on Document Analysis and Recognition. ICDAR 99 (Cat. No.PR00318)*, 585–588. Available from: https://doi.org/10.1109/ICDAR.1999.791855.

Visser C, Hanich QA (2017) *How blockchain is strengthening tuna traceability to combat illegal fishing*. Available from: https://ro.uow.edu.au/cgi/viewcontent.cgi?referer=&httpsredir=1&article=4374&context=lhapapers.

Vujičić D, Jagodić D, Ranđić S (2018) Blockchain technology, bitcoin, and Ethereum: A brief overview. *2018 17th International Symposium INFOTEH-JAHORINA (INFOTEH)*, 1–6. Available from: https://doi.org/10.1109/INFOTEH.2018.8345547.

Wang L, Liu Y (2015) Exploring Miner Evolution in Bitcoin Network, In: J. Mirkovic & Y. Liu (Eds.), *Passive and Active Measurement*, Cham: Springer International Publishing, 290–302.

Wang S, Ouyang L, Yuan Y, et al. (2019) Blockchain-Enabled Smart Contracts: Architecture, Applications, and Future Trends. 445 Hoes Lane, Piscataway, NJ 08855-4141 USA: IEEE. Available from: https://doi.org/10.1109/TSMC.2019.2895123.

Wang Y, Kogan A (2018) Designing confidentiality-preserving Blockchain-based transaction processing systems. *Int J Accounting Inf Syst* 30: 1–18.

Weihrich H (1982) The TOWS matrix—A tool for situational analysis. *Long Range Plann* 15: 54–66.

Wessel D (2016) The Hutchins Center Explains: How blockchain could change the financial system (part 1). Available from: https://www.brookings.edu/blog/up-front/2016/01/11/the-hutchins-center-explains-how-blockchain-could-change-the-financial-system-part-1/.

Wiatt RG (2019) From the mainframe to the blockchain. *Strat Financ* 100: 26–35.

Wilson C (2019) Cryptocurrencies: The Future of Finance? In: F.-L. T. Yu & D. S. Kwan (Eds.), *Contemporary Issues in International Political Economy*, Singapore: Springer, 359–394.

Wright D (2002) Comparative Evaluation Of Electronic Payment Systems. *INFOR Inf Syst Oper Res* 40: 71–85.

Wu Z, Williams AB, Perouli D (2019) Dependable Public Ledger for Policy Compliance, a Blockchain Based Approach. *2019 IEEE 39th International Conference on Distributed Computing Systems (ICDCS)*, 1891–1900. Available from: https://doi.org/10.1109/ICDCS.2019.00187.

Xu L, Chen L, Gao Z, et al. (2020) DIoTA: Decentralized-Ledger-Based Framework for Data Authenticity Protection in IoT Systems. 445 Hoes Lane, Piscataway, NJ 08855-4141 USA: IEEE. Available from: https://doi.org/10.1109/MNET.001.1900136.

Xu Z, Zou C (2020) What can blockchain do and Cannot do? *China Econ J*, 1–22.

Yau J (2001) The Inefficient Stock Market: What Pays Off and Why. *J Altern Invest* 4: 73–74.

Yiannas F (2018) A New Era of Food Transparency Powered by Blockchain. *Innovations Technol Governance Globalization* 12: 46–56.

Yli-Huumo J, Ko D, Choi S, et al. (2016) Where Is Current Research on Blockchain Technology?—A Systematic Review. *PLOS ONE* 11: e0163477.

Yu Y, Li Y, Tian J, et al. (2018) Blockchain-Based Solutions to Security and Privacy Issues in the Internet of Things. *IEEE Wireless Commun* 25: 12–18.

Zetzsche DA, Buckley RP, Arner DW (2018) The distributed liability of distributed ledgers: Legal risks of blockchain. *U Ill L Rev*, 1361.

Zheng Z, Xie S, Dai H, et al. (2017) An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. *2017 IEEE International Congress on Big Data (BigData Congress)*, 557–564. Available from: https://doi.org/10.1109/BigDataCongress.2017.85.

Zhou Z, Liu X, Pei J, et al. (2018) Competition of pricing and service investment between iot-based and traditional manufacturers. *J Ind Manage Optim* 14: 1203–1218.

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