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Blockchain technology design in accounting: Game changer to tackle fraud or technological fairy tale?

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Abstract

Purpose – This paper aims to design, build and evaluate a blockchain platform in the accounting domain, taking an ecosystem perspective. To achieve this aim, the research provides evidence for developing a decentralised architecture rooted on blockchain technology, designing a proof of concept and modelling an accounting blockchain-based system.

Design/methodology/approach – Moving from the analysis of previous literature and leveraging on the design science approach, this paper provides a framework grounded on the main pillars of blockchain and accounting functions, identifying technical and non-technical issues that must be addressed embrace blockchain technology's full potential.

Findings – We propose and discuss a conceptual framework for a blockchain-based accounting context, moving from the identification of a typical accounting scenario. The framework is organised around three scalable levels: the first level is a technological infrastructure based on a distributed database with peer-to-peer storage; second, in the intermediate level, increasing control levels are assured through permissions and validation and third, in the higher level, the system provides the integration of business and security applications. The deployment of this system relies on a private network of nodes that validates transactions.

Practical implications – The proposed conceptual framework about blockchain development in accounting allows closing the knowledge gap between blockchain developers and accounting experts by suggesting technological and strategic issues for practitioners.

Originality/value – We provide practical guidelines to design and adopt blockchain in the accounting domain.

Keywords Accounting, Blockchain technology, Distributed ledger technology, Ecosystem perspective, 4.0 digital transition

Paper type Research paper

1. Introduction

1Blockchain is widely regarded as a disruptive technology in a variety of industries (Smith and Castonguay, 2020; Ruzza *et al.*, 2020; Dai and Vasarhelyi, 2017). Blockchain adoption has

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resulted in radical innovation in the fields of currency, supply chain and knowledge management (Centobelli *et al.*, 2021a, b). Blockchain adoption in accounting is among the most recent and promising fields, and blockchain is one of the most impacting technologies in the current digital transformation scenario (Caldarelli *et al.*, 2020).

The consequences of its adoption are disruptive, and they can be considered revolutionary in the same way that the internet was (Smith and Castonguay, 2020; Dai and Vasarhelyi, 2017). As a distributed technological data system that ensures the certainty of transactions through a distributed public ledger and a network of computers (Kwilinski, 2019; Cong and Klotz, 2018; Morabito, 2017), blockchain allows all participants to access the same ledger records by making all changes that occurred visible (ACCA, 2017; Kokina *et al.*, 2017; Centobelli *et al.*, 2021a, b). Blockchain use in accounting, auditing and assurance is expected to contribute to ensure the integrity of financial data, prevent financial reporting risks and outline implications for external auditors and firms' corporate governance practices (Smith and Castonguay, 2020).

According to Stafford and Treiblmaier (2020), one of the most intriguing information accounting models is the distributed ledger based on blockchain. Blockchain's application has evolved from banking and financial markets to insurance and leasing, and from voting systems and governmental services to collaborative practices and knowledge sharing (Morgan *et al.*, 2018; Tsanos and Zografos, 2016; Dai and Vasarhelyi, 2017). Recently, blockchain has piqued the interest of academics and practitioners in the accounting field (Dal Mas *et al.*, 2020; Secinaro *et al.*, 2021), where it is envisioned to transform principles and rules due to its distributed and tracked data functions (Sinha, 2020; Kokina *et al.*, 2017).

Blockchain is reviving interest in this field due to the convergence of various issues, with theoretical and practical implications for auditing, assurance and accountability (Demirkan *et al.*, 2020). Its application in these domains reveals the more significant benefits of controlling all recorded transactions, which is assumable as a paradigm shift in accounting practices and theories (Fuller and Markelevich, 2020). This is due to the coherence of blockchain properties in terms of dependability, truth and counterparty confidence, which can play a significant role in accounting (Kwilinski, 2019). Blockchain provides complete information to all participants and prevents operations from being tampered with, broken or altered as a distributed data system. This is because transactions are registered on data blocks, and an encrypted copy of the previous one is included (Kwilinski, 2019). Meanwhile, the presence of a distributed ledger ensures that no information can be deleted or changed (Kokina *et al.*, 2017). While the financial services sector is already leading the way, using blockchain to re-examine processes and functions that have been static for decades, the accounting sector is more conservative and lags far behind in terms of blockchain exploration (Deloitte Development LLC, 2018).

Blockchain use in accounting reveals some unresolved issues and highlights some barriers to its widespread adoption. The knowledge gap between blockchain developers and accounting experts is one of the primary reasons for the lack of blockchain development in accounting (Cai, 2021; Dal Mas *et al.*, 2020). On one hand, accounting professionals and academic researchers are unaware about blockchain concepts and infrastructures. However, to transform business processes (including accounting), blockchain experts will require more support from accounting professionals and academics in terms of specific business and accounting knowledge. According to Bonsón and Bednárová (2019), scalability, flexibility, architecture and cybersecurity are other outstanding issues. Blockchain in accounting has the potential to transform the profession by affecting the accounting information system's database engine (Schmitz and Leoni, 2019). Because of the digital validation process, accountants will no longer be the central authority of the process behind the transactions. This is expected to produce benefits in terms of cost reduction, although some critical issues persist in terms of data ownership and transparency (Secinaro *et al.*, 2021; Kokina *et al.*, 2017).

Despite the advancements mentioned above and the interest that this issue has recently recalled, the full comprehension of the benefits of the adoption of blockchain in accounting still needs clarification (Lombardi *et al.*, 2021; Secinaro *et al.*, 2021; Bonsón and Bednárová, 2019). Several critical issues remain unexplored and new theoretical interdisciplinary research topics can be identified in the attempt to shed new light on this process of digital transformation resulting from the adoption of blockchain in accounting. In this context, the adoption of a sociological perspective of accounting is promising since it allows focusing the attention on the different elements of the community of stakeholders populating the ecosystem built around a blockchain platform. Indeed, embracing a sociological perspective in accounting has demonstrated its usefulness for capturing the different dimensions of accounting simultaneously, in terms of technological solutions, institutional and social issues (Covaleski and Dirsmith, 2012). Based on these assumptions, this paper aims to answer to the following research question (RQ):

RQ. What are the main benefits that a blockchain platform can bring to the accounting domain?

Given that blockchain technology represents a ground-breaking solution in this field and may radically change current accounting practices, it is worthwhile to examine this technology's potential and challenges in accounting from an ecosystem perspective and determine the degree to which this domain may be transformed. To address the key effects and influence of technical solutions, a conceptual framework for a blockchain-based accounting context, moving from the identification of a typical accounting scenario is proposed. The framework is organised around three scalable levels: the first is a technological infrastructure based on a distributed database with peer-to-peer storage; second, in the intermediate level, increasing control levels are assured through permissions and validation; third, in the higher level, the system provides the integration of business and security applications. The deployment of this system relies on a private network of nodes that validates transactions. Then, leveraging on the design–science approach (March and Smith, 1995; Hevner *et al.*, 2004), this paper aims to design, build and evaluate a blockchain platform in the accounting domain, taking an ecosystem perspective. This methodology provides the theoretical foundation for developing artifacts that can be used for system evaluation and decision-making in line with a theory-building approach (Whetten, 1989). The design science process adopted in this study follows the design–science research guidelines proposed by Hevner *et al.* (2004). To achieve this aim, this research provides evidence for developing a blockchain architecture design based on three phases related to: blockchain-based accounting system analysis; proof of concept (PoC) framework design and deployment and accounting blockchain-based modelling. Implications for practices prove that organisations adopting blockchain must adapt their policies and procedures over internal controls and counterparty risk assessment to address increasing regulation over the distribution of financial data. At the same time, their audit committees must be prepared to address these challenges leading up to financial statement preparation. Implications for theory highlight technological and strategic elements to leverage for assuring effective blockchain use for the accounting process by overcoming the infancy of this practice.

The remainder of this paper is organised as follows: Section 2 introduces the literature background demonstrating the need for this study in the accounting body of literature. Section 3 presents the theory and analytical framework, establishing the lens through which we analyse the data and present our results. Section 4 describes the methodology. Section 5 describes the results, and finally, Section 6 presents the discussion and conclusion of the research.

2. Literature review

2.1 Blockchain in accounting: An overview of an expected revolution

Blockchain is regarded as a new technology based on existing technologies. The ongoing digital evolution resulted in the creation of blockchain, a peer-to-peer-based distributed network that enables the exchange of value by registering and transferring it in a tamper-proof manner (Bonsón and Bednárová, 2019). Blockchains are shared databases maintained and verified by network participants, ensuring digital transparency and confidence in information records in the absence of a trusted third party (Pilkington, 2016; Deloitte, 2016). Despite its novelty, blockchain is the orchestration of three well-known technologies (the Internet, private key cryptography and a protocol governing incentivisation) that, when combined, result in a secure system that allows interactions without the use of a third trusted party to facilitate digital relationships (Bauerle, 2017). In other words, this new ledger system has the potential to enable a completely new level of information exchange both within and across industries (Deloitte Development LLC, 2018). Blockchain-based applications have the potential to change the way businesses operate. This type of disruption is known as a "democratisation of trust" (Cai, 2021).

Whereas the financial sector was an early adopter, demand for the technology has increased in recent years and comes from a variety of industries, including healthcare and logistics. Accounting is one major business sector expected to benefit from the blockchain features. This demand is unsurprising, given blockchain's ability to enable decentralised autonomous business models defined by self-governed programmes via decentralised governance and collective consensus (Probst, 2016). In particular, blockchains may make it easier to keep permanent and timely records of financial transactions. Its decentralised and transparent nature also implies potential immutability, which means that financial records cannot be changed ex-post, and if they are, the likelihood of detection is very high (Andersen, 2016).

The blockchain poses myriad questions for its use in accounting and auditing (Cong *et al.*, 2018), and understanding why we need blockchain technology in accounting represents the starting issue. The basic paradigm change is the idea of sharing data among organisations instead of organisations keeping data within four walls. Every accounting transaction is typically recorded in two or more organisations and updated independently (Cai, 2021). With the evolution of online technologies and ubiquitous networks, customers already have the ability to query inventory and automatically place orders. For example, vendor-managed inventory allows for a better response to customer preferences at retail stores. Some applications would clearly benefit from a secure data stream that may even be public in some forms. For example, property records, vehicle registrations, security trades and government procurement are already public information. Technology allows companies to book transactions and almost immediately post them into public or private ledgers for stakeholders' use (Rückeshäuser, 2017; Bonsón and Bednárová, 2019). Every transaction has built-in risks, as well as controls that exist for the management of those risks. Blockchain technology allows for the public display of transactions or public recording of encrypted transactions (Kwilinski, 2019). It also benefits from multi-party validation. Because of these advances, companies could provide real-time balance sheets, income statements, labour reports, inventory records, patent applications, capital investments and a wide range of internal information. This system would have relevance to some business partners, clients, auditors and regulators in the value chain.

Nowadays, alternative technologies are used for accounting purposes, such as distributed databases or enterprise resource planning (ERP) systems. Peters and Panay (2016) and Dai and Vasarhelyi (2017) compare blockchain with these alternative technologies, identifying the similarities and the flaws that blockchain can solve. Blockchain can be considered a new type of database used in conjunction with an ERP system. Dai and Vasarhelyi (2017) list blockchain's advantages compared to traditional ERP systems, pointing to decentralisation (which can help prevent manipulation), preventing any unauthorised data changes and a design that operates autonomously with little human intervention. This aspect brings the possibility of major disruption to core ERP systems by a new generation of directly cloud-based systems that enhances and expands ERP systems' capacity. In addition to the evolution or potential disruption of corporate-owned systems, a new model of "shared trustless databases" has been developed and is known as a blockchain (Nakamoto, 2008; Dai and Vasarhelyi, 2017). A blockchain is a different paradigm where entities keep data in external stores and share these with partners in the value chain (Dai and Vasarhelyi, 2017).

Blockchain changes the management of transactions (Carlin, 2018; Dai and Vasarhelyi, 2017), and for this reason, blockchain can be interpreted as both an opportunity and a threat. For instance, Deloitte has released its first software platform, Rubix, that allows applications to be built on top of blockchain infrastructure. Rubix has four application areas: reconciliation (automate financial reconciliations among internal departments of a company or with trading partners), audit (obtain real-time assurance on components of financial statements and lessen the reliance on an auditor), land registry (digitise and decentralise a jurisdiction's property deed transfers while eliminating the possibility of corruption) and loyalty points (create a loyalty points program that is more cost-efficient and allows for added features and insights for customers). Deloitte clients can use the platform for every need, while the company can enhance the automation of some internal auditing processes. KPMG has also developed its digital ledger services in collaboration with Microsoft to seize blockchain potential in the financial services industry, healthcare and the public sector. It allows faster and more secure transactions, automates back-office operations and reduces costs (KPMG, 2017). Ernst and Young launched the EY Ops Chain, described as a set of applications and services (such as payments, invoicing, inventory information, pricing and digital contract integration) that can include digital contracts, shared inventory and logistics information, pricing, invoicing and payments (Prisco, 2017).

On the one hand, some authors claim that blockchain has the potential to make accounting information more trustworthy and timelier by providing a better alternative to current accounting and auditing systems (e.g. Coyne and McMickle, 2017; Kokina *et al.*, 2017). On the other hand, given its potential to automate specific accounting and auditing processes, blockchain is also feared as a threat to the status quo of the profession of accountants and auditors, their practices and traditions (Tapscott and Tapscott, 2016; Casey and Vigna, 2018). Thus, blockchain-based accounting could rule out conducting improper accounting methods, illicit structuring of transactions and financial database manipulations (Feng *et al.*, 2011).

Another novel application of blockchain for accounting, including measurement processing, auditing and communicating financial information about economic entities, is ultimately based on ensuring *truth, trust and transparency*. The meaning and implication of those concepts have been debated mainly in several domains of application of blockchain technologies, mainly regarding cryptocurrency (Yen and Wang, 2019) and supply chain management (Chang *et al.*, 2019a, b). Despite scholars' and researchers' growing interest in the accounting domain about the opportunities of blockchain adoption (Anderson, 2016; Bonsón and Bednárová, 2019; Cai, 2021), the attention reserved for these critical factors is still in an initial state and calls for further investigation and research. Specifically, it seems that the current debate on the digitalisation in accounting, mainly regarding the adoption of blockchain, has been more focused on the comprehension of their implications in terms of technical issues and flows of data than in understanding the impact of these technologies on the transparency, trust and trustworthiness of an accounting system. Lombardi *et al.* (2021) and Secinaro *et al.* (2021) emphasise how the notions of truth, trust and transparency are crucial factors affecting the success of this revolution in accounting and auditing. In this direction, Cai (2021) and Chowdhury (2021) have recently argued that the shift from a double-entry accounting system to a triple-entry one, caused by the adoption of blockchain technology, can make the system more efficient by allowing companies to achieve trust and transparency and causing a radical transformation in the accounting industry. When properly implemented, triple-entry accounting with blockchain can fundamentally improve accounting-based mainly on a double-entry model (Cai, 2021). Thus far, few triple-entry accounting blockchain products and services are fully living in the accounting area (Chowdhury, 2021). Despite the massive potential of the triple-entry accounting framework in accounting, the amount of academic research on this topic is limited, mainly regarding antecedents and consequences of truth, trust and transparency.

Furthermore, auditors might use the blockchain comprehensive syntactic programming to evaluate company information, confirming its truth directly. In this context, the blockchain application establishes an automatic method for data transfer and, later, confirmation by all users in the case of information revision. According to Tiberius and Hirth (2019) and Turker and Bicer (2020), information immutability ensures that multiple stakeholders, such as banks, courts, tax institutions, regulators, accountants and auditors, can verify the consistency of records, thereby supporting corporate decision-making processes.

The trust that distinguishes the blockchain's consensus mechanism allows the various players in the network to exchange information in previously unthinkable ways, with a positive effect on accounting and auditing theories and frameworks, such as support for the International Financial Reporting Standards framework (Brown-Liburd *et al.*, 2019; McCallig *et al.*, 2019). The trust obtained is consistent with the theoretical auditing component, which calls for an audit committee to review corporate efficiency measures. However, these theoretical concerns are not backed by strong data or empirical models (Lombardi *et al.*, 2021; Secinaro *et al.*, 2021). Transparency, connected with decentralisation, allows all system members to share and access data equitably and safely, obtaining history datasets, real-time updates and final reports. These features are reminiscent of the three moments of the rational administrator, which regards financial statements as representations of the decision-maker choices. Besides, according to agency theory, improved transparency minimises information asymmetry between parties and, as a result, can mitigate possible agency issues (Bonsón and Bednárová, 2019). One of the pillars of this theory is the notion of information asymmetry between agents. Nyumbayire (2017) asserts that blockchain enables the verification of whether a specific agent has performed a specific action at a certain time. The blockchain's operations are traceable thanks to the usage of proofs of existence. With this technological approach, the risk of an agent misbehaving can be lowered if not eliminated. Because the blockchain permits quick verification of each computable transaction, it strengthens agent responsibility and helps to reduce agency expenses. Indeed, it eliminates the legal system's requirement for most of the intermediaries to validate economic and financial transactions' preconditions, execution and post conditions (Nyumbayire, 2017). Blockchain technology enables users to execute and verify complicated contracts at a minimal cost as a result of proofs of existence, smart contracts and autonomous agents. Control dimensions represent another important factor. Control is further improved by the consensus required to add a transaction to a block, and as a result, this consensus leads to increased data confidence since transactions are validated by numerous nodes (Swan, 2015).

2.2 Blockchain in accounting: An ecosystem perspective

The impact of blockchain in accounting is disruptive (Smith and Castonguay, 2020), and it represents a promising field for future research (Secinaro *et al.*, 2021; Lombardi *et al.*, 2021). This is due to the actuality of the issue of digital transformation in accounting (Secinaro *et al.*, 2021) as in the rest of the society as well as on a dynamic profile of both accounting practice and theory called to be always at the frontiers of the innovation for measuring and communicating information about an entity's performances to the stakeholders (Carnegie *et al.*, 2021).

Extant studies on the issues of blockchain in accounting allow depicting a complex scenario where the technological features end up being mixed with technical and social implications of accounting (Secinaro *et al.*, 2021; Lombardi *et al.*, 2021; Xu *et al.*, 2019;

Bonsón and Bednárová, 2019). A general consensus arises in the literature about the opportunities offered by blockchain in accounting, although several dimensions of this digital transformation process remain unexplored and need further clarification from a cross-disciplinary perspective to include its societal implications (Secinaro *et al.*, 2021). In this direction, the recent research of Secinaro *et al.* (2021) allows identifying theoretical areas for future exploration by integrating different disciplinary perspectives to provide a comprehension of both the technological and social dimensions of blockchain adoption in accounting.

All this finds confirmation in the recent study of Carnegie *et al.* (2021) about the meaning of accounting today, where an interesting perspective arises about its meaning as an increasingly relevant sociological practice due to its "pervasive, enabling and disabling social phenomenon . . . progressively conceived as an instrument of power and control" (Carnegie *et al.*, 2021, p. 67). Consistent with the theory on the sociological perspective of accounting including technological solutions, institutional and social issues (Covaleski and Dirsmith, 2012; Carnegie *et al.*, 2021), the adoption of blockchain can be assumed as an enabling platform for the creation of a community of stakeholders populating an accounting ecosystem.

The issue of *ecosystem* arises as a promising perspective in the extant literature on blockchain adoption in accounting (Cai, 2021; Bonsón and Bednárová, 2019). More specifically, Dai and Vasarhekyi (2017) provide evidence on blockchain's potential contribution in enabling a real-time, verifiable and transparent accounting ecosystem. Furthermore, Kwilinski (2019) highlights the contribution that blockchain can provide to network accounting. As a distributed data system allows the instant information of all participants, the presence of a single register of the transaction is assumable as a decentralised structure for collective decision-making. According to Smith and Castonguay (2020), the blockchain adoption for accounting calls for a more extensive and specialised stakeholders' community, including internal and external actors operating to assure the updating of internal policies and procedures, and monitoring the regulation transactions. With a specific focus on the initial coin offerings (ICOs), Feng *et al.* (2019) highlight the need to assure the credibility of the information related to the transactions and evaluate buyers and investors.

The network importance in the effective blockchain implementation for accounting is highlighted in Kwilinski's study (2019) in terms of collective approval by all the participants. According to the author, some technical factors can impact this participatory process's effectiveness, such as the high speed of the service, interface with smart devices, optical data recognition systems and user-friendly management of introductory documents (Kwilinski, 2019).

The analysis of blockchain's effects in accounting in terms of smart contracts, cryptocurrency and ICOs provides several elements for our speculation from an ecosystem perspective. Dai and Vasarhelyi (2017) demonstrated how blockchain in accounting suggests the creation of an ecosystem of actors and the full integration of blockchain technology into a real accounting ecosystem, which requires a consensus among regulators, auditors and other parties. Nevertheless, Dai and Vasarhelyi (2017) introduce three different areas of challenges (technological, organisational and environmental) that may hinder the adoption of this technology in accounting and auditing. The technological context refers to the technical complexity of blockchain platforms, which require financial and time resources. The organisational context refers to managers' willingness to accept this innovative approach. The environmental context refers to regulators' essential role in the adoption of blockchain technology within the accounting ecosystem. Despite all the challenges highlighted by Dai and Vasarhelyi (2017) that are relevant for the successful adoption of blockchain in accounting, the ecosystem perspective resulting from this digitalisation process suggests the need of deepening a further challenge associated with the sociological dimension of the ecosystem as well as the comprehension of the impact of truth, trust and transparency on the flows and interactions among the nodes of the blockchain network.

From an ecosystem perspective, Cai (2021) highlights how the adoption of blockchain in accounting suggests the opportunity to transition from a single entry to a triple entry accounting system that more efficiently addresses fundamental trust and transparency issues.

According to Schmitz and Leoni (2019), the perspective of the ecosystem resulting from the adoption of blockchain in accounting suggests the need to invest in human capital to create a new generation of accountants and auditors with competencies able to provide solutions to changes of this radical innovation. The focus on the role of human capital in the debate about the blockchain accounting ecosystem arises in the work of Schmitz and Leoni (2019) as a critical factor impacting all four thematic areas identified in their literature reviews, such as governance, transparency, trust, smart contracts and the new role of accountants and auditors. Human capital is relevant for the implementation of new mechanisms of governance, in assuring the level of transparency and trust request by stakeholders' collaboration (George and Patatoukas, 2020; Schmitz and Leoni, 2019) and facilitating the technology implementation by demonstrating favourable behaviours in adoption and use of technological solutions (Caldarelli *et al.*, 2019).

In the same direction, the contribution of the blockchain to the creation of a performing accounting ecosystem has been recently highlighted by Gökten and Özdoğan (2020). According to the authors, blockchain in accounting allows overcoming the presence of an intermediary and regulatory platform for transactions related to the value exchange in terms of stocks, derivatives and entities' accounting operations. That is because, in coherence with the principle of "internet of values," blockchain works as a reliable infrastructure without any regulators and intermediaries and enabling the collaboration between a broad and differentiated stakeholders' community (Gökten and Özdoğan, 2020). The focus on the stakeholders' network resulting from a blockchain accounting ecosystem suggests the opportunity to investigate the nature of the technology by distinguishing between public and private blockchain. In a recent study on the revolutionary role of blockchain for accounting and audit, George and Patatoukas (2020) provides an analysis of the benefits and limitations of both the two typologies by highlighting in a context where it is necessary to protect and limit the access to the data shared so that it could be useful to adopt a private blockchain. That is more coherent with the accounting objectives. However, from this perspective, the need for a more in-depth investigation arises regarding disclosure and reporting, where the public nature could probably be more useful.

Overall, the application of blockchain technology in the accounting context could be conducive to the industry, which is still mainly based on standardised technology, such as computer-assisted audit techniques (Andersen, 2016). As the digitisation of accounting is still in its infancy, the application of blockchain technology may lead to the technological progress needed. Specifically, previous literature has clearly shown that the ecosystem represents an important and largely debated issue associated with the adoption of blockchain in accounting (Bonsón and Bednarova, 2019; Dai and Vasarhekyi, 2017). However, its comprehension remains normative, analysed mainly in theory, or limited to understanding the technical implications of the blockchain in accounting practice, as in the recent study of Cai (2021) that focuses on the shift from the double to the triple-entry accounting system. In the same direction, Bonsón and Bednárová (2019) highlighted the need to investigate the effects of blockchain adoption on the jobs of accountants and auditors and the stakeholders' awareness and acceptance. Their research focuses primarily on the technological perspectives of revolution caused by the adoption of blockchain in an accounting ecosystem, suggesting the need of further investigations on the sociological implications.

3. Theory and analytical framework for a blockchain-based accounting ecosystem

According to the previous background, it is necessary to provide scenarios of contextualisation to the transformation of accounting caused by the blockchain, deepening the meaning of the ecosystem perspective and its sociological implications in terms of truth, trust and transparency. Even though the previous literature on blockchain in accounting has reserved great attention to each of these issues, the full comprehension of their impact on the effectiveness of the network of actors populating the accounting ecosystem built on blockchain is still fragmented and limited to a technological perspective. In the meantime, the debate on the blockchain ecosystem from the managerial point of view has recently focused on comprehension of the sociological implications of this phenomenon as well as on the meaning of factors such as truth, trust and transparency into the process of interaction between humans and machines (Schneider *et al.*, 2020) or in the relationships between the nodes of a digital supply chain (Batwa and Norrman, 2021). Despite the interest reserved for these topics in the accounting field, exploring their meaning in the same perspective provides areas for further investigation. This aspect represents the primary motivation for addressing this study.

Moving from the above literature and research gap, we propose a customised adoption of a blockchain technology system for accounting from an ecosystem perspective, as illustrated by the architecture reported in Figure 1. The next points describe the different levels:

(1) At the ground level, the blockchain provides a *technological infrastructure* based on the logic of the distributed database, in which the data is not stored on a centralised server (client-server) but several interconnected peer-to-peer nodes. Each node keeps a complete replica of all data stored. Before data are stored, they must be validated through the network solving a non-trivial problem in a distributed network, known as the Byzantine general problem. This problem is solved by the exertion of computer power by which a particular target value must be found in accordance with the proof-of-work (PoW) mechanism. After consensus, data are permanently stored in the

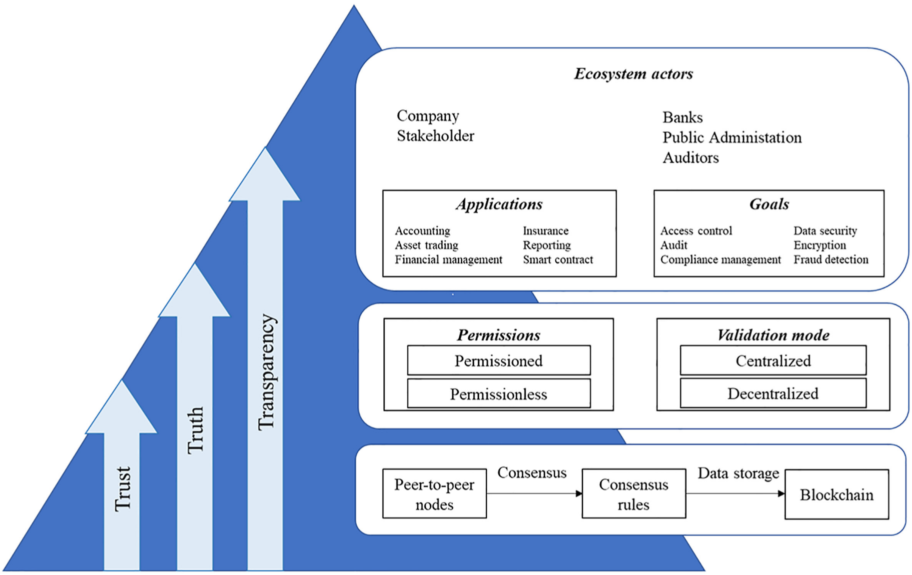

Figure 1.
Blockchain architecture in accounting from an ecosystem perspective

blockchain. At this level, the blockchain customisation for an accounting domain is represented by the definition of consensus rules.

(2) At the middle level, the blockchain provides the selection of different *deployment modes based on permission and data validation procedures* for service-oriented infrastructure, business process management and user interaction. As for permissions, blockchain can be permissioned or permissionless (Swanson, 2015; Peters and Panayi, 2016). Concerning data validation, it can be performed in a centralised or decentralised mode. In the blockchain domain, the centralised mode is represented by the fact that the validation is transmitted to a sample of changing nodes, such as nodes delegated proof-of-work, responsible for the validation to achieve low latency. Permission-less blockchains are typically characterised by decentralised validation, whereas permissioned blockchains adopt centralised validation (Swanson, 2015).

(3) At the top level, the blockchain provides *system design decisions* concerning business and security application integration. Business applications include blocks for accounting, financial management, asset trading, reporting, insurance and smart contracts. Security applications comprise access control, audit, data security, encryption, fraud detection and compliance management blocks. Nevertheless, customisation may include other accounting blocks and system design decisions related to different business sectors.

At the top level, it is possible to evaluate how changes in processes and behavioural dynamics within the impacted ecosystem (Adner, 2016; Khurana and Dutta, 2021) are based on the blockchain technology's characteristics, namely trust, truth and transparency. Trust is one of the primary characteristics of blockchain technology (Notheisen *et al.*, 2017). Trust denotes an exchange of actors' expectations on which the other party can depend heavily, to behave as expected and act reasonably (Nakamoto, 2008). Blockchain protocols' main feature is providing an immutable record of transactions by combining a distributed database with transaction blocks linked chronologically and cryptographically via decentralised consensus mechanisms (Nofer *et al.*, 2017). This structure prevents the spread of incorrect or false information and self-regulates behaviour without the need for central authorities (Douceur, 2002). If the participants in the private network are known, as is the case of an accounting ecosystem, there is no threat of an attack, and thus the costs associated with security are reduced. As a result, identity-based authentication (e.g. hash-based users) provides more efficient alternatives that allow for varying levels of privacy (Meng *et al.*, 2018; She *et al.*, 2019).

Truth represents the possibility to monitor the non-manipulation or tampering of information and operations as well as the provision of information about them (Vladu *et al.*, 2017). In response to these issues, customers, banks and stakeholders require greater traceability and knowledge about integrity of transactions, particularly about their financial and social consequences (Awaysheh and Klassen, 2010). As a result, the real economic and social challenge is to close the control gap in the accounting network, even if the transactions are ethical, sanction-compliant or safe (Galvez *et al.*, 2018). Defining the origin or the end of a transaction and its integrity is frequently difficult due to networks' complexity. Because of this complexity, transactions must be tracked throughout their entire life cycle (Lu and Xu, 2017; Xu *et al.*, 2019).

The degree to which information is easily accessible to both counterparties in exchange and external observers is referred to as transparency (Bai and Sarkis, 2020). Given the emerging secure environment associated with blockchain, transparency is thus a critical parameter in evaluating the ecosystem's performance. In this way, transparent and accurate information can be managed for each phase, ensuring compliance and accuracy while also focusing on social responsibility requirements (Kashmanian, 2017; Zhu *et al.*, 2018). Current markets necessitate the transparency of ecosystem information as well as environmental and social sustainability of accounting network dynamics (Mann *et al.*, 2018; Zhu *et al.*, 2018). Greater transparency improves productivity, provides better customer service and reduces internal and external auditing costs. As a result, transparency becomes a critical factor in improving the entire ecosystem's performance (Zelbst *et al.*, 2019).

4. Methodology

This section explores how design science is used as a research technique to design, build and evaluate a blockchain platform in the accounting domain. The section for the representation of the design's theoretical and functional effects also provides information on data collection and processing.

This research follows the approach proposed by March and Smith (1995), intending to create a more robust IT-solution artifact to better understand how blockchain can improve organisational processes and capability (i.e. the ability to make strategic information faster, safer, more traceable and transparent). March and Smith (1995) contended that design research could yield four types of research outcomes (i.e. constructs, models, methods, instantiations) and includes four main activities (i.e. build, evaluate, theorise, justify).

In our study, we design a framework as an artifact consisting primarily of a distributed database, a selection of different deployment modes based on permission and data validation procedures for service-oriented infrastructure, and a system design involving the integration of business and security applications. Starting from the contribution of March and Smith (1995), Hevner *et al.* (2004) provide seven practical guidelines for the building and application of an artifact. In their recommended structure, Hevner *et al.* (2004) provide a description in practical terms to explain the level of artifact abstraction and contribution to knowledge. These guidelines on the development of the research design artifact results provide useful, but not strictly prescriptive, criteria for defining the space for research design and specifying a design-based solution artifact.

To achieve our design objectives, we divided the guidelines into three phases: identification of the relevant problem and design artifact required (e.g. design as an artifact, problem relevance); development and evaluation of the artifact (e.g. design evaluation, research rigour, design as a search process) and dissemination and knowledge creation of the research (e.g. research contributions; communication). Leveraging on the above phases, Figure 2 represents a framework identifying how, through knowledge and contextualisation of the problem, a blockchain-based platform can be created using a design–science approach and how this, being constructed with rigour and relevance, can contribute to development of the knowledge base and the environment.

The ecosystem describes the problem space in which the phenomena of interest exist. It consists of blockchain actors, their current and expected technologies (Silver *et al.*, 1995). It contains the priorities, responsibilities, challenges and opportunities that identify business needs, taking an accounting ecosystem perspective. The higher the ecosystem definition, the higher will be the relevance of the artifact.

The knowledge base serves as the raw material for analysis, and it is composed of the foundations and methodologies. Previous scientific studies include the foundational theories, structures, tools, constructs, models, processes and instantiations used throughout the research study. To achieve rigour, established foundations and methodologies are used. In design science, computational and mathematical approaches are commonly used to determine the quality and efficacy of artifacts; however, analytical techniques can also be used. Contributions are evaluated as they are applied to a business requirement in a

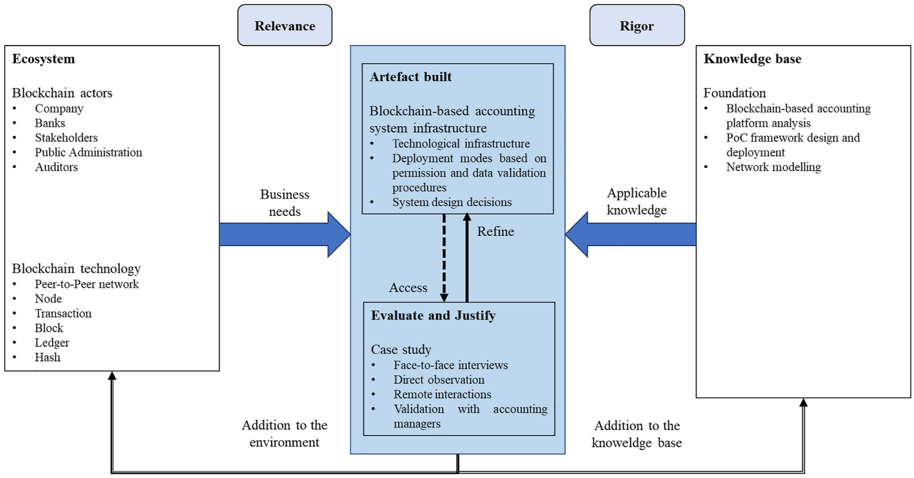

Figure 2. Blockchain based accounting system using a design science approach

suitable setting and as they contribute to the knowledge base content for future study and practice.

Design science approaches allow creating and evaluating an artifact, in this case a blockchain-based accounting system infrastructure that is developed to fit the market's requirements. Design science research aims to create something useful in describing the ecosystem processes and helping in process evaluations. Truth and utility are inseparably linked. Design is influenced by reality, while theory is influenced by utility. In order to produce the most efficient artefact that met the needs of the investigated situation, incoming and outgoing interviews with various figures involved in the process (i.e. accounting managers and employees) were conducted using the case study methodology approach (Eisenhardt, 1989; Yin, 2018). The incoming interviews supported in developing a blockchain system that responds profoundly to the system's requirements.

Following the implementation of the blockchain platform, we conducted additional interviews with accounting managers and employees to investigate the benefits of the blockchain platform. Respondents, for example, were asked to assess how different the process is after the blockchain introduction. The interviews were recorded, transcribed and double-checked by the interviewees to avoid transcription errors or misunderstandings during the interview in the material to be analysed later.

5. Results

The findings from the deployment of the blockchain platform will be presented in the following sections, which will be separated into different phases: design and development, testing and evaluation of *a blockchain-based accounting system*.

5.1 Design and development of a blockchain-based accounting system

This section aims to identify the technical and functional requirements that the technological architecture of a blockchain should possess to facilitate the development and consolidation of the relationships between the various actors operating in the accounting ecosystem, considering the socio-economic and management processes.

Figure 3 reports the basic blockchain-based accounting system infrastructure. The blockchain deployment model is a private intra-corporate blockchain with a network of nodes

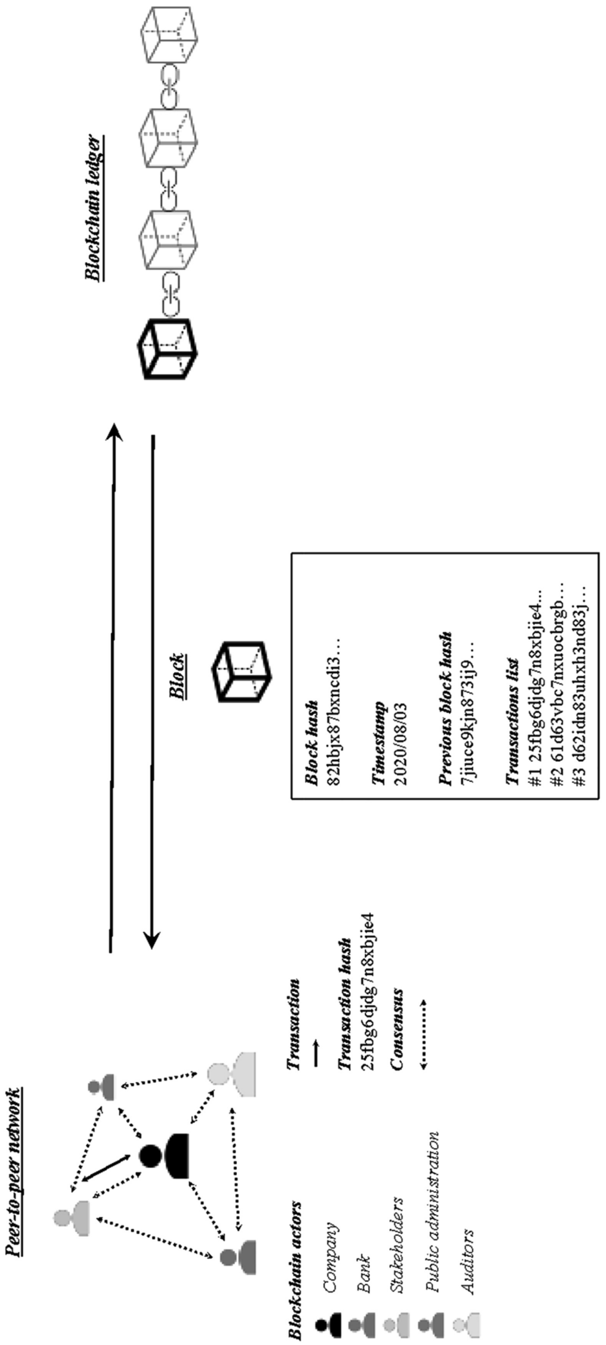

Figure 3.
Blockchain-based accounting system infrastructure

that validates transactions within the company. This network comprises company managers operating in the accounting department and managers operating in associated control entities. In line with several contributions that propose a blockchain technology for accounting (Andersen, 2016; Byström, 2016; Yermack, 2015), the consensus is defined following the PoW mechanism. According to this mechanism, the consensus is established if transactions are under the pre-specified rules. On the contrary, the node accounting network rejects transactions that are not compliant. Valid transactions are subsequently stored and transmitted to authorised employees within the company and to selected external actors (e.g. external auditors).

Blockchain makes it possible to innovate the current management of transactions through a process that connects distributed, cryptographic primitives useful for guaranteeing the security and traceability of information. Distributed systems' main advantage in the accounting domain is the presence of information on all the machines connected to the network. This type of database is based on two fundamental processes, useful for guaranteeing correct operations and limiting the loss of information:

(1) Database replication: There is software to identify any logical internal change to the database; once the database has been identified, this software allows replicating the change on all the machines connected to the accounting network.

(2) Duplication: This is a useful process to ensure that the same data is present on each machine connected to the accounting network. This process allows identifying a master database that will be duplicated on all the other network machines.

Blockchain functioning is based on the following components:

(1) Transaction: Logical processing unit which coincides with a sequence of elementary operations that must be verified, approved and then archived;

(2) Node: Representation of a single blockchain actor and physically constituted by a server;

(3) Block: Logical unit represented by the union of a set of transactions grouped to be verified, approved and archived;

(4) Ledger: Master book in which all transactions are recorded immutably, in order and sequentially;

(5) Hash: Non-invertible algorithmic function allows representing a text and/or numeric string of a variable length in a unique string of predefined length.

The blockchain is a chain of blocks, where the set of transactions represents the block. Therefore, the block can be considered a container of transactions; inside it is useful information to temporally and spatially reconstruct the chain of blocks that are created. Each block contains within it a pointer called a hash, located in the header, which records the information relating to the block in position n and the information relating to the block placed in position $n-1$; based on this principle, the entire chain of blocks can be built. From the technological perspective, the hash is the result of an algorithm called hash function. Hash functions have two main features: they are characterised by a string of arbitrary length (input) and a string of defined length (output) and (2) they are irreversible functions, that is, from the knowledge of the generated string (output) it is not possible in any way to trace or generate the starting string.

An example is the SHA-256, which is one of the best-known hash functions used to obtain an alphanumeric string that is always 64 characters long, regardless of the (arbitrary) length of the starting string. This function is called SHA-256 because it identifies a binary number of

256 digits/bit (or a succession of 256 zeros and ones), transformed into hexadecimal, results in a string of 64 characters. Each block contains a hash, and this allows a unique and secure identification. Moreover, the hash allows the construction of the entire blockchain's spatial mapping, which is continuously updated as new blocks are added. In addition to the hash, there is also a timestamp in the block through the practice of timestamping. This practice consists of a specific sequence that allows unambiguous block identification and, therefore, the transactions. This timestamp allows development of a timeline map useful for understanding the order in which the transactions take place.

To sum up, in a distributed system applied to the blockchain, it is necessary to know both the hash and the temporal brand to be able to recreate both the chain of blocks spatially and temporally. Instead, the transaction contains the following information: (1) IP address of the sender and recipient, the cryptographic signature necessary to guarantee the security of the transaction and information regarding the transaction content and characteristics. Since the number of transactions varies continuously over time, the blockchain can be continuously updated on all network nodes. That is possible thanks to the use of cryptographic primitives that guarantee the correct functioning of the system. Furthermore, the transactions are unchangeable; any change requires the consent of all the nodes present in the accounting network. All transactions are noted with maximum transparency and in an unchangeable manner in the ledger. The ledger can be considered as the aggregation of several blocks interconnected using cryptographic primitives and hash.

The blockchain is the realisation of the distributed ledger, which is the evolution of centralised and decentralised logic. In the centralised logic (centralised ledger), each transaction is managed by a central node, which has a centralised authority, acts as an intermediary and verifies information correctness and security. There is no single centralised authority to refer to in the case of decentralised logic (decentralised ledger), but more central subjects are set up in a local centralisation logic. The blockchain is based on distributed logic (distributed ledger); i.e. there is no longer any centralised authority but parity between the accounting network actors. Consensus between peer-to-peer nodes, an essential requirement in the centralised system, is replaced by cryptographic primitives and protocols, and the figure of the intermediation nodes is definitively eliminated. There is no central point of vulnerability in blockchain platforms allowing attempts to tamper with the system. These characteristics substantially distinguish the blockchain from centralised databases. These factors guarantee the security of the information shared in the network.

As for the mechanism that leads to the creation of blocks starting from transactions, the following procedure is followed to interact with the system: (1) creation of the transaction and public cryptographic key; (2) creation of the block containing the transaction mentioned above; (3) verification and approval of the block by the accounting network actors; (4) verification of the truthfulness of the information by the actors of the accounting network; (5) evaluation of previous checks and adding blocks to the accounting network; (6) authorisation and validation of the transaction; and (7) publication of the transaction in the ledger.

The blockchain-based accounting system design was associated with research conducted in the accounting department of an innovative company located in the South of Italy. It provides industrial waste disposal services for multinational companies operating in the automotive and railway manufacturing business. It is currently based in a relevant district for mechanical and railway engineering and production at the national and international level. This investigation context seems to be a suitable choice because management accounting is a critical process in this industry. Rethinking business operations can help managers identify, measure, analyse, interpret and communicate information to support short- and long-term decisions.

A primary research activity was based on interviews, mapping the accounting processes and validation workshops. A secondary research activity was based on analysis of accounting reports and databases from the past 12 months, accounting process descriptions and monthly/quarterly reports. This second activity was used to include and triangulate sources with primary data. Triangulation activity was necessary to strengthen this research's validity and reliability. The first data collection consisted of over 80 h of direct contact:

(1) Face-to-face interviews with company managers and employees for the accounting departments;

(2) Shadowing accounting processes by direct observation. The researchers followed a sample of processes, mapping their activities and timing them.

The other data collection method used over 12 months of the study included:

(1) Active remote interactions: For example, multiple questions and clarifications over the phone, e-mail and Skype;

(2) A validation workshop with accounting managers;

The next subsections present the development and application of a blockchain-based accounting system. The three main steps conducted for the blockchain architecture design process are (1) blockchain-based accounting system analysis, (2) PoC framework design and deployment and (3) network modelling.

A detailed description of each phase is provided in the paragraphs that follow.

5.2 Test

5.2.1 Phase 1: Blockchain-based accounting system analysis. A blockchain-based accounting system is particularly significant for companies, banks and public administrations operating as accounting providers for private/public clients or companies. In such a complex system, the possibility to have information always available, with no intermediaries and already verified, represents an increasingly critical success factor in the new accounting business model (Dal Mas *et al.*, 2020). This critical success factor could be supported by the rapid technological changes taking place in the contemporary scenario. Organisations typically do not have dedicated resources to monitor, follow and respond to the dynamic technological evolutions, which means they soon find themselves out of touch, a situation that highlights the importance of having a blockchain able to support decision-making and operational strategies of individual actors and networks. Many accountancy organisations have expressed their interest in blockchain technology, and several projects have been started. Many financial and professional institutions have conducted various initiatives that aim to explore this technology's potential for accounting and auditing.

The company accounting cycle is structured in eight steps. The first step consists of identification of transactions. The company has many transactions simultaneously in the cycle, and great attention is needed to record them on its books correctly. Sales technology points are linked with their books to record sales transactions; other times, there are intermediaries to add other costs to the transactions. Afterward, as the second step, there is the creation of entries for each transaction. The several sale technology points can help combine the first two steps, but the company must also monitor costs. The choice between accrual and cash accounting can dictate when transactions are officially recorded. Cash accounting requires transactions to be recorded when cash is either received or paid. Double-entry bookkeeping calls for recording two journal entries with each transaction to manage a thoroughly developed balance sheet along with an income statement and cash flow statement.

With double-entry accounting, each transaction has a debit and a credit equal to each other. In the third step, once a transaction has been posted as a journal entry, it should be published to an account in the general ledger. General ledger provides all accounting activities breakdown by account. That allows dedicated employees to monitor positions and financial status. One of the most commonly referenced accounts is the cash account, which details the available amount of money.

At the end of the accounting period, a trial balance is calculated as the fourth step to find unadjusted balances in each account. The unadjusted trial balance is then carried over to the fifth stage for testing and analysis. A worksheet is created and used to ensure that debits and credits are equal. If there are any discrepancies for matching income and expenses, changes must be made to adjust line items. In the sixth step, a bookkeeper makes adjustments. Adjustments are recorded as journal entries where necessary. Downstream of all adjustments, the system generates its balance sheet in the seventh step. For most businesses, these statements include an income statement, balance sheet and cash flow statement. Finally, the company ends the accounting cycle in the eighth stage by closing its books on the specified closing date. The closing statements provide a report for analysing performance over the period. After closing, the accounting cycle starts over again from the beginning with a new reporting period. Accounting managers can analyse data and try to summarise any performance indicators.

With a blockchain-based approach, a transaction can be directly recorded and verified between debtors and creditors. A smart contract is subscribed with all the transaction information and the asset flow. Information and asset tracking are necessary only for a new entry in the blockchain platform; all the others can be easily verified through the related smart contract hash. A balance sheet can be created automatically at the end of the accounting period or in middle time steps, focusing on each transaction classification. Recorded transactions will include monetary exchanges between two parties and the accounting data flow within a company. In this way, it will be possible to get indicators close to real-time reporting by instantly broadcasting accounting information to interested parties, such as managers, auditors, creditors and stakeholders.

5.2.2 Phase 2: PoC framework design and deployment. In computer science, a PoC is defined as a practical demonstration of a software application's basic operations or an entire system, integrating it into an already existing environment. The PoC development is used to demonstrate the existence of a vulnerability in a software or in a computer system, the exploitation of which may allow unauthorised access to the data contained in the system or compromise its functionality.

For the realisation of this structure for the company, the research team involved in this project decided to use Hyperledger Fabric, an open-source project founded by Linux Foundation in 2015, created to enable the construction of permissioned blockchains. The feature that distinguishes Hyperledger Fabric is represented by modularity that allows defining consensus mechanisms and membership management. It also offers the possibility of creating private channels (e.g. financial team, accounting process team, auditing process team), allowing a group of company participants to create a ledger where transactions are recorded in a completely confidential manner, which can only be viewed by the nodes that participated in it.

Currently, the blockchain platform has been configured on-premises. Installing an on-premises program means installing it on a local device – i.e. a machine that physically resides within the company that uses it or still owns it (namely a company server).

5.2.3 Phase 3: Network modelling. The network modelled in Figure 4 was used to identify the main ecosystem actors involved as nodes of the blockchain platform to be developed.

The specific testing network included:

(1) *Stakeholders (S)*: This node represents the private clients or company stakeholder level aiming to buy titles, stocks, tokens or other types of assets.

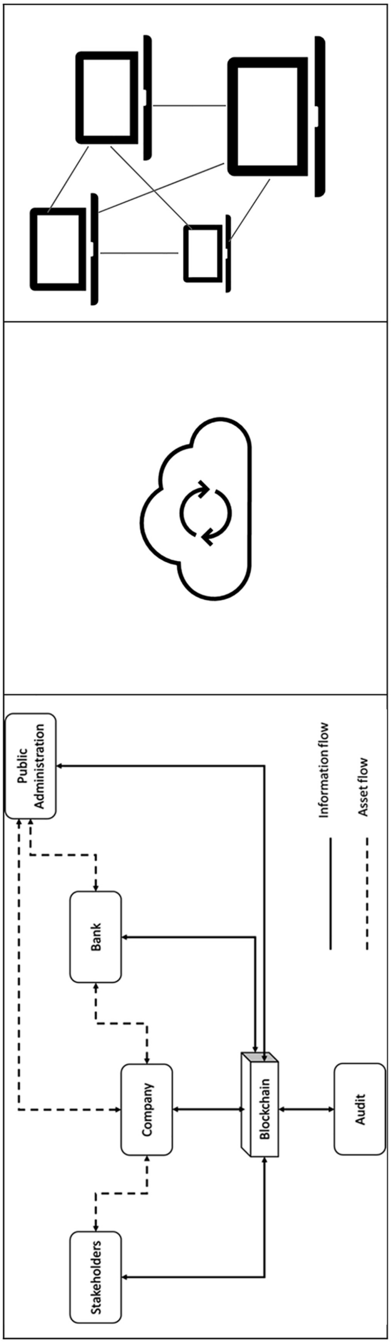

Figure 4.
PoC framework and business network deployment

(2) *Company (C)*: This node represents the enterprise-level aiming to invest in accounting operations.

(3) *Bank (B):* This node represents the bank level where accounting operations happens financially.

(4) *Public Administration (PA):* This node represents the public owner of accounting assets and the leading accounting regulator.

(5) *Auditor (A):* This node represents a third-party service provider with the role to investigate the quality and security of accounting operations.

Each node has a single well-known identity. The node identity is used to represent the node in transactions. These identities are distinct from the remote procedure call user accesses to connect to the node remotely on a computer other than the one on which the program is run. Each network has a network mapping service that maps each well-known node identity to an IP address. These IP addresses are used for messaging between nodes. Nodes can also generate confidential identities for individual transactions. The certificate chain linking a confidential identity to a well-known node or a real-world legal identity is distributed only as needed. This aspect ensures that even if an attacker gains access to an unencrypted transaction, it is impossible to identify the transaction participants without further information if confidential identities are used.

A fundamental aspect of the accounting blockchain platform design is creating private channels to perform operations with each of the actors participating in the network, shielding their privacy, further strengthening their position in the network. However, the accounting blockchain platform allows transparency in displaying any asset transaction that occurs among the various nodes in the network, although it does not participate directly in operations. Furthermore, this technology guarantees greater transparency in the origin and reliability of the accounting services provided and simplifies the auditors' control. An asset is identified as any property owned by a company that can be monetised. Tracking company assets is a fundamental process and an investment for a company that wants to save money and time. Developing and implementing asset traceability reduces administration costs and streamlines the business, improving the quality of service and pushing the scalability of its business. All these processes favour organisational efficiency, reducing management costs and anticipating needs by administering company assets.

5.3 Evaluation

This section analyses the characteristics of blockchain technology pre- and post-implementation, and the related improvement carried by the blockchain adoption into the accounting ecosystem. We provide some excerpts from interviews conducted following the implementation of the blockchain platform to highlight key aspects.

The accounting manager reports: "During the implementation period of the blockchain platform, I discovered that employees were more efficient in the exploitation of economic and financial databases because more data become available and a series of information related to their control was already present, eliminating the need for an analysis to validate their origin or correctness."

Adopting blockchain technology increases efficiency and saves time and money in operations like access control, data and identity validation and compliance verifications. Generally, during the transaction moderation, intermediation of other nodes was necessary (i.e. for identity validation, data integrity) and human errors could occur (Rückeshäuser, 2013; Cai and Zhu, 2016).

An accounting employee reports: "Using distributed accounting registers, compilation is much easier because, even if a compilation error occurs, the system indicates that the data has not been verified; all cost items are coded in digital format, making it easy to find the information required to justify them. Recursive or interconnected cost items can be analysed together, saving time and increasing confidence in the result that is carried forward in the accounting registers." With the support of the blockchain, all these operations are solved rapidly through the hash-integrity validation of the smart contracts linked with the block to be verified, significantly reducing human errors. These results can improve both company efficiency and effectiveness and stakeholders' satisfaction (Palfreyman, 2015; Tapscott and Tapscott, 2016a, b; Cai and Zhu, 2016; Laguir *et al.*, 2019; Spanò *et al.*, 2019).

An employee states: "When a contract is stipulated or an economic transaction is carried out, all information related to these processes, such as the identifiers of the actors involved and the relative authorizations, is recorded in the block. As a result, it is no longer necessary to contact the bank to find out if a transaction has been authorised. This data is already present in the block. Even in the case of tenders, specific blocks that certain people can only consult after a certain time can be created. The tender is thus safer and more equitable, as there is no possibility of changing offers after they have been made."

Blockchain technology use reduces the number of intermediary nodes necessary in the accounting process and as consequence the necessary actors working in the ecosystems. Since the blockchain technology transaction mechanisms are trusted and transparent, and the information is available in real-time, the accounting blockchain-based process does not require a middle-node. Data registered in the blockchain are immutable. This allows reaching a system where the company can negotiate directly with stakeholders, banks and public administration (Andreassen *et al.*, 2018). The direct negotiation has additional benefits on efficiency, service cost reduction, and fraud detection (Palfreyman, 2015; Atzori, 2015; Tapscott and Tapscott, 2016a, b; Rückeshäuser, 2017). This is a key characteristic since it allows automatic contract execution and payment, bypassing intermediaries, most notably lawyers (in the case of smart contracts), banks (in the case of cryptocurrencies) and governments, which may find themselves out of business because of the strong privacy possible for both contract terms and payments (Bednárová and Bonsön, 2019; Marrone and Hazelton, 2019).

An internal auditor reports: "Previously, controlling and validating balance sheets was a very time-consuming process for checking the information reported and locating what appeared to be missing. In some cases, this search for information or documents was impossible because archives do not allow for the storage of a large amount of material for an extended period of time. Despite the fact that many documents have gone digital, retrieving them is still difficult in most cases because they are scattered across multiple archives. The use of a technology that stores the codes of previous blocks in digital blocks so that they can be recalled proving the veracity of the information reported is not only more practical and safer, but also much more efficient." The audit process becomes faster and more accurate. Before introducing blockchain technology, the audit process had to verify all the information related to the accounting process and verify each actors' profile in the network. Additionally, the audit process could not use all historical data before blockchain implementation because they were deleted periodically due to storage issues. As explained before, all the transactions are tracked and verified directly by the technology when a new block is added, and no information is deleted; blocks are immutable. Many audit checks and security operations are unnecessary, so the process is smarter and faster (Ming and Rui, 2017; Anwar *et al.*, 2019). Data is chronologically stored so that it can also be tracked continuously and in a timely manner, and the efficiency of financial audit work can be improved. The ledger decentralisation and distribution allow achieving a reduction of the storage cost of financial audit data (Ming and Rui, 2017; Anwar *et al.*, 2019).

The accounting manager states: "When a user authorises his credentials to the platform, he receives his own identifier, which allows whoever creates a block to be identified in a unique and secure manner. Each action always reports the signature of the person who performed it, and this allows us to not only attribute the work to the person who perform it, but also to understand if there have been errors or, worse, attempts to falsify transactions or documents."

By analysing blockchain architecture, private blockchain architecture seems to be the better choice for accounting solutions. It would help avoid manipulations and fraud, enable the instant sharing of information and enhance information integrity with the right process scalability. A public blockchain allows every node in the network to view confidential information. On the contrary, this does not happen with a private blockchain (Andersen, 2016; Bonsón and Bednárová, 2019). Private blockchains' use allows companies to achieve secure and encrypted transactions, avoiding the possibilities of malicious actions or behaviours. Transactions are stored in distributed ledgers, and every actor gets a ledger copy. To modify the information fraudulently in one block, it would be necessary to modify the same block in each of the different ledgers of all the network nodes (Rückeshäuser, 2017; Bonsón and Bednárová, 2019).

Furthermore, the use of cryptocurrencies or other tokenised assets into a blockchain platform is preferred for two reasons. The first reason is linked directly with the ICO. The use of tokens to participate in crowdfunding allows the system to keep track of the different tokens used for the ICO, since they can easily flow on the network and register smart contracts (Dai and Vasarhelyi, 2017; Del Mas, 2020). As a result, the system has better financial traceability, decreases the number of fraud incidents and gives the possibility to achieve truthful information. The second reason is that token use can increase the stakeholders' satisfaction. If the company creates its token to sell to stakeholders, they will obtain specific rights to participate in the company's decisions through an ICO, with the maximum transparency granted by blockchain platforms (Del Mas *et al.*, 2020).

Some issues arise during blockchain implementation. It became evident that if several networks use different blockchain platforms in the same company, they cannot communicate directly among them because information needs to be decrypted and re-encrypted. Users authorised on different chains can check their information, but no merging action has been possible between blocks of different chains. Ledger duplication also generates losses in terms of efficiency and storage capacity (O'Leary *et al.*, 2017; Dib, 2018). It would thus be convenient in future research to disseminate the benefits of using the same blockchain platform for different networks to create a blockchain consortium where information can flow quickly and with transparency, but with the highest privacy for the various actors (O'Leary *et al.*, 2017).

The creation of this blockchain consortium could also be extended to the entire accounting supply chain. In this way, with the creation of a single cloud database, several private blockchains can branch with high positive effects (i.e. processing capacity, efficiency, cost reduction). With a high number of ledgers, the blockchain platform obtains a high-security rate, and fraud actions become very difficult. Decision-making and forecasts can be performed more easily considering real-time and transparent information (BitFury, 2016; Mearian, 2017; O'Leary *et al.*, 2017).

The identity validation process could be improved by using the national digital identity system (Benedict *et al.*, 2021). The validation of several identities simplifies the actors' verifiability in entry and improves communication with banks and government authorities.

An internal auditor states: "Trust in the quality of the final product, in our case financial statements, is now placed in technology rather than people. If it was previously necessary to check each operation step by step by conducting cross-checks with third parties to avoid human tampering in information, potentially duplicating the work done in the reporting phase, this is no longer necessary. Once the accountant has verified an expense, all we have to do is check if the block relating to this operation is not corrupt, and obviously that gives us the opportunity to perform more in-depth analyses and assessments with greater security; all the operations done previously are monitored and controllable by all those who have access to that type of information."

More in detail, the adoption of blockchain technology alters the concept of trust among accounting ecosystem participants. Storing and maintaining data, information and transaction records in a decentralised and distributed ledger increases trustworthiness among actors who do not have a centralised authority (Notheisen *et al.*, 2017). Trust in ecosystem actors or in the accounting system was replaced by trust in the technology (Nofer *et al.*, 2017). As a result, it is no longer dependent on trusted partners or intermediaries to manage data, information, contracts and transactions.

To summarise, the blockchain implementation provides a trust mechanism for the various actors in the accounting ecosystem (Farooque *et al.*, 2019; Wang *et al.*, 2019).

Before implementing blockchain technology, monitoring processes' integrity relied on labour resources to acquire, store and distribute up-to-date and confirmed data from different transactions. Individual actors used various traditional methods to manage the technical details of truth, such as e-mail, correspondence, phone calls, electronic data interchange (EDI), value-added network or ERP systems. Individual actors, however, did not adopt a coordinated monitoring system, which reduces large data volumes among multiple partners; the monitoring of decision-making processes has always represented a costly and time-consuming activity resulting in potential profits and efficiency loss.

Following implementation, blockchain technology enables a near-real-time anti-tampering monitoring system that allows for timely and automatic updates of data status to make efficient and effective business decisions and auditing actions.

From a theoretical point of view, the contribution of this research is represented by both the proposed design science model and the formal PoC. This contribution allows better understanding how to manage accountability operations in a digital environment. According to March and Smith (1995), empirical papers conducted in collaboration with organisations blur the lines between academic research and industrial adoption of technological solutions. Publication of these findings will support the development of domain-independent and scalable solutions to large-scale information system problems within organisations.

6. Discussion, conclusion and implications

In the accounting digitalisation process, blockchain represents the most promising and powerful technologies. Despite the great interest in the literature, full comprehension of the scenarios for adopting blockchain technology in accounting is still fragmented and limited to the associated technical issues. Digital transition seems to be advancing rapidly, and new consortiums have emerged to accelerate the definition of industrial standards and to foster collaboration (Kokina *et al.*, 2017). New approaches to security and privacy controls are also emerging. Blockchain's transformative potential in accounting and auditing can be acknowledged despite the pending challenges, particularly concerning continuous accounting, auditing and reporting. The motivation to design and implement a blockchain platform was influenced by the demand for transparency across accounting processes. Eliminating centralised authorities improves transparency, which influences how ecosystem partners collaborate. Higher transparency is also achieved thanks to the inherent tamper-proof mechanism that distinguishes blockchain technology.

Storing distributed records on a blockchain platform improve transparency in the flow of process status information, which improves individual actors' and the ecosystem's operational efficiency in terms of time efficiency and system automation (Fahimnia *et al.*, 2015; Selmi *et al.*, 2018).

Furthermore, recording data on the blockchain platform eliminates the need for a combination of on-chain and off-chain systems. A private and permissioned blockchain improves transparency by requiring access control to authorised data, making information access more effective and secure. Finally, the immutability of the distributed ledger ensures transparency over time through inviolable and node-verified mechanisms, disintermediation and automatic processes, convenience and streamlining in terms of data extraction and comprehension (Swan, 2015; Zhu *et al.*, 2018; Leng *et al.*, 2019).

Through the blockchain-enabled concepts of distributed consensual accounting records, smart audit procedures and blockchain-based triple-entry bookkeeping, continuous accounting and auditing have gained new dimensions and appear to be moving increasingly towards being realised (Cai, 2021; Inghirami, 2020; Rozario and Vasarhelyi, 2018). In comparison to other alternatives such as ERP or distributed databases, the added value of blockchain stems from the combination of all its elements, including immutability, consensus, decentralisation and encryption.

With the aim of contributing to the advancement of knowledge in this domain by demonstrating the implications of blockchain in the creation of an accounting ecosystem, this paper has presented a conceptual framework supporting the creation of a technology-based accounting environment. Organised around three scalable levels, the framework presents at the first level a technological infrastructure founded on a distributed database, with peer-to-peer storage based on interconnection and after consensus in the system. At the intermediate level, increasing control levels are assured through permissions and validation. At the higher level, the system provides integration of business and security applications. The deployment of a structured blockchain-based accounting ecosystem relies on a private network of nodes that validates transactions. However, blockchain is disruptive in terms of how processes can be carried out and how the ecosystem works. Individual actors no longer need to control data or monitor what the remaining actors are doing. They can simply trust technology, as blockchain contributes to the creation of an accounting transaction system that is verifiable and transparent in real time (Dai and Vasarhekyi, 2017). Furthermore, the presence of a distributed transaction ledger is assumed to be a decentralised decision-making structure, reducing information asymmetry and the possibility of tampering (Kwilinski, 2019). Blockchain adoption for accounting requires a more comprehensive and specialised culture of stakeholders, including internal and external actors, to ensure proper rule and procedure updating and monitoring (Smith and Castonguay, 2020). Blockchain can also support developing a performing accounting ecosystem (Gökten and Özdoğan, 2020), eliminating the need for intermediaries and regulatory platforms for value exchange transactions, reducing manual registration and verification and enabling the automation of many processes and activities with consequent improvement in terms of efficiency (Chang *et al.*, 2019a, b; Pereira *et al.*, 2019; Gökten and Özdoğan, 2020).

The analysis of dynamics characterising the ecosystem as well as the comprehension of the meaning of issues such as truth, trust and transparency in social interactions undertaken within the community of actors populating the system allows contributing to the debate on blockchain's transformation of accounting by overcoming the limitations highlighted in the literature.

Furthermore, this paper provides evidence for developing a blockchain architecture design based on three phases related to platform analysis, PoC framework design and deployment and accounting blockchain-based modelling. The implementation of this blockchain platform is associated in this paper with the analysis of antecedents and consequences. By allowing increased efficiency, time and money saving in operations, access control, data and identity validation, the adoption of blockchain in accounting is associated with a reduction of human errors (Cai, 2021; Cai and Zhu, 2016) as well as meaningful improvement of efficiency and effectiveness (Laguir *et al.*, 2019). From the ecosystem perspective, the adoption of a blockchain accounting system is expected to optimise the management of the complexity of the network of actors by enhancing trust, transparency and real-time availability for the whole stakeholders' community (Andreassen *et al.*, 2018) as well as disclosing new scenarios of digital accounting transformation by enriching the meaning of the shift from the double to the triple-entry system (Cai, 2021; Chowdhury, 2021) with intangible issues.

The proposed value-added tracking process will allow ecosystem participants to share a ledger and use smart contracts to monitor changes in transaction state. Individual actors can monitor a status change triggered by an automated event mechanism through the use of smart contracts (Swan, 2015; Zhu *et al.*, 2018). Because smart contracts can automatically activate information push mechanisms, the updated process status can be monitored in real time by partners who are registered on specific contracts.

The proposed blockchain platform ensures greater operational efficiency through real-time notification of information changes based on push mechanisms. As a result, ecosystem partners can reduce the costs associated with traditional monitoring methods to achieve information synchronisation among themselves (Xu *et al.*, 2019). In summary, the implementation of a blockchain platform allows for synchronisation of monitoring information and the reduction of resources required to confirm process status. This in turn accelerates process automation and disintermediation through the use of smart contracts (Chang *et al.*, 2019a, b; Pereira *et al.*, 2019).

6.1 Implications for practices

As a conceptual paper based on the investigation of the existing literature, this research sheds new light on blockchain's meaning and implication for accounting. In this perspective, the conceptualisation of the three-level framework for a blockchain accounting environment is primary, and the details of its technological requirements are the study's main practical contribution. Nevertheless, the technology is still at an early stage. Developers and designers must face many challenges to lead it to its maturity. Issues such as suitable architecture designs, flexibility and cybersecurity must be addressed (Coyne and McMickle, 2017; Dai and Vasarhelyi, 2017). More pilot programs and research are therefore needed to tackle technological issues and shed more light on the potential of this technology and its use in accounting. Finally, to include blockchain technology fully into a real ecosystem, non-technical issues would inevitably arise, such as reaching a consensus among regulators, auditors and public administrators. Due to its cross-disciplinary nature resulting from the combination of the issues of digital technologies, stakeholders' perspective and ecosystems, the proposed framework represents an original and novel contribution to the current debate on blockchain and accounting.

6.2 Implications for theory

Several implications can be identified also in this research. First, it addresses overcoming gaps emerging in the literature about the adoption of blockchain in accounting, by confirming the importance of embracing a cross-disciplinary perspective for the full understanding of the several benefits resulting from the adoption of blockchain in accounting (Secinaro *et al.*, 2021; Lombardi *et al.*, 2021). This contribution provides evidence for a greater comprehension of the phenomenon and the meaning of disruptive innovation and digital transformation caused by blockchain in accounting theory and practices (George and Patatoukas, 2020; Sinha, 2020; Smith and Castonguay, 2020). Second, adoption of a sociological perspective in the proposal of the conceptual framework for the creation of a digital accounting ecosystem has highlighted the multidimensional nature of blockchain-based accounting by demonstrating the scalability of the technological model associated with increasing levels of trust, transparency and truth (Andreassen *et al.*, 2018; Dai and Vasarhelyi, 2017; Schmitz and Leoni, 2019) as well as by offering a good test for experimenting with the opportunity of investigative work in accounting nurtured by different disciplinary approaches (Secinaro *et al.*, 2021).

In contributing to the debate on the ecosystem perspective resulting from the blockchain's adoption in accounting as a still under-researched perspective (Gökten and Özdoğan, 2020; Stafford and Treiblmaier, 2020), this study has allowed identifying some strategic features as the basis for the successful adoption of blockchain in accounting, such as human capital competencies, new governance mechanisms and the use of smart contracts (Lombardi *et al.*, 2021; Carnegie *et al.*, 2021; George and Patatoukas, 2020; Schmitz and Leoni, 2019). This is a third important implication for the future advancement of the research agenda in a cross-disciplinary perspective. Fourth, the relevance and rigour of our study is assured by the use of the design–science approach that guided us in the construction of the blockchain platform. Furthermore, the theoretical perspective in using the design science approach for an IT artifact is compelling, given that the proposed blockchain platform explains accounting ecosystem behaviours, has a clear perceived usefulness and impacts both single actors and ecosystem organisations (Hevner *et al.*, 2004). In confirming the multifaceted nature of the digital transformation process, this perspective suggests the better understanding of the role of blockchain in the dynamics of collaboration among the different categories of stakeholders as well as exploring its implication in creation of an accounting ecosystem (Bonsón and Bednárová, 2019; Dai and Vasarhekyi, 2017). In the meantime, by contributing to a major comprehension of the principle of "internet of values" (Gökten and Özdoğan, 2020), it has allowed identifying a contribution in terms of new bases in research about the disclosure of intangible value (Dumay and Cai, 2014; Massaro and Dumay, 2017; Yu *et al.*, 2018; Dumay and Guthrie, 2019; Yen and Wang, 2019).

6.3 Limitations and future research

The study limitations refer to the need for empirical evidence and scenarios of contextualisation focused on the adoption of blockchain platforms in the accounting ecosystem. To test the proper rigour of schema proposed, the application of the framework in real settings of accounting discloses bases for future investigations. Research methods can be extended to include experiments, surveys, interviews and case studies. Additionally, to provide more significant foundational support, the conceptual and theoretical bases must be further examined in a sample composed of a larger number of empirical contexts. Given the complex nature of blockchain, more cross-disciplinary studies utilising technology, economics and psychology are also required in future research. It could be useful to compare different industrial contexts to derive common and specific patterns and deepen the implications of the blockchain in accounting from the ecosystem and sociological perspectives.

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