Information and Software Technology 157 (2023) 107149

Contents lists available at ScienceDirect

Information and Software Technology

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

A system-based view of blockchain governance

Gabriella Laatikainen *, Mengcheng Li, Pekka Abrahamsson

Faculty of Information Technology, University of Jyväskylä, Finland

ARTICLE INFO

Keywords:
Blockchain governance
Systems theory
Systematic literature review

ABSTRACT

Context: Governance is crucial in achieving the success and sustainability of blockchain systems. However, blockchain governance is multi-faceted, complex, dynamic, and challenging due to its decentralized nature and automatically enforced rules and mechanisms.

Objectives: This study aims to advance the theory of blockchain governance and support practitioners to deepen the researchers' and practitioners' understanding of blockchain governance.

Methods: The study is a systematic literature review of 75 articles that applies systems theory to conceptualize blockchain governance as a system and parsimoniously organize its interrelated elements into a conceptual model.

Results: The paper proposes a holistic definition and a conceptual model of blockchain governance. Blockchain governance encompasses technical and social means to make decisions on the different levels (e.g., individual, community, organizational, national, international) related to actors, roles, rights, incentives, responsibilities, rules, and the business, technological, legal, and regulatory aspects of a blockchain system during its whole lifecycle.

Conclusion: The system-based model of blockchain governance can serve as a reference framework and structured foundation for analyzing, discussing, and developing the governance of blockchain systems.

1. Introduction

"The greatest challenge that new blockchains must solve isn't speed or scaling – it's governance."

Kai Sedgwick

Blockchain and distributed ledger technologies provide means for automatization, business process transformations, and decentralization of power [1–3]. Blockchain relies on cryptography consisting of an interconnected and unmodifiable list of digital records shared within a peer-to-peer network [4,5]. The technology enables the enforcement of automatic rules without intermediaries [6] using smart contracts (i.e., "code deployed in a blockchain environment, or the source code from which such code was compiled" ([7], p. 7)), oracles (i.e., digital interfaces linking external data points to the blockchain system; [8]) and consensus mechanisms (i.e., fault-tolerant methods of authenticating and validating a value or transaction on a distributed ledger). These technological advances enable embedding governance mechanisms into blockchain transactions [9].

Governance refers to the regulation of decision-making processes among actors towards shared objectives that lead to the development, reinforcement, or reproduction of social norms and institutions [10,11]. Blockchain governance has been studied through the lens of several theories, such as open-source software governance, IT governance, platform governance, organizational and corporate governance, agency theory and internet governance (e.g., [3,12,13]). Blockchain governance can be understood as both *governance of the infrastructure* (i.e., means and processes of directing, controlling, and coordinating actors within a blockchain system) and *governance by the infrastructure* (i.e., using blockchain to govern actions and behavior) [14]. There is a distinction between *on-chain governance* (i.e., direct encoding of rules and decision-making processes into the blockchain infrastructure) and *off-chain governance* (i.e., non-technical rules and decision-making processes affecting the development and operation of blockchain systems) [15]. However, there is a clear research gap in the literature: a shared definition and the building blocks of blockchain governance remains elusive in recent work ([13]; see also the SubSection 2.2).

Effective governance of blockchain systems is crucial for their successful development and ability to adapt, evolve and interact [16]. Good governance mechanisms prevent actors from operating in an untrustworthy manner and restrain blockchain systems from entering crisis

* Corresponding author.
E-mail address: gabriella.laatikainen@jyu.fi (G. Laatikainen).

https://doi.org/10.1016/j.infsof.2023.107149
Received 22 April 2022; Received in revised form 12 January 2023; Accepted 18 January 2023
Available online 21 January 2023

situations [17]. Furthermore, governance is a key factor for these systems' successful adoption and growth by providing and managing incentives for possible adopters [18]. However, the governance of blockchain systems has many challenges. First, while the decentralization of power enables a variety of actors to govern a blockchain system collectively, often only a few actors have the power to affect the governance decisions in their own interests, and as such, in practice, these systems fail to implement decentralized governance [17,19]. Second, the governance of blockchain systems differs from existing governance structures, such as markets, hierarchies, platforms, or organizations [12,20]: besides enabling automatization of governance decisions, due to its decentralized nature, blockchain governance needs to balance integrity and autonomy without a central authority [3]. That is, managing and coordinating various actors toward the shared goal requires different approaches than the traditional governance structures offer [21]. Thus, the governance of blockchain systems is crucial and challenging.

Defining blockchain governance from a holistic viewpoint and identifying its building blocks, that is missing from recent work, is important for several reasons. First, blockchain governance models based on a single theory focus on particular aspects while neglecting many others. For instance, on-chain governance rules are more efficient and predictable than their off-chain counterpart. At the same time, on-chain governance is less adjustable to the unknown or changing environment [22]. On the contrary, off-chain governance is ambiguous, but it can respond to unusual cases more humanly and flexibly to the changing circumstances [22]. Therefore, it is crucial to have an integrative view of blockchain governance to balance the pros and cons of models based on a single theory. Second, analyzing blockchain systems from a holistic viewpoint and identifying the decision-making needs is essential, especially in distributed settings. There are contradictory forces of autonomous actors with different incentives and goals in these decentralized systems, while collaboration is needed to achieve the shared objectives. Thus, governance decisions cannot be made to one aspect of the system without considering its possible consequences to other parts. Third, in some of the distributed systems (e.g., self-sovereign identity ecosystems), the governance framework (i.e., consisting of business, legal, and technical rules and policies of a system) is an essential building block besides the technological architecture [23,24]. Developing and managing a governance framework requires similar development work as building the technical architecture. There is a need to provide a shared common language for researchers and practitioners to understand and communicate this concept similarly and avoid confusion.

We answer this research gap by carrying out a systematic literature review of 75 articles and integrating the viewpoints of recent work. This paper reports on the extension of a previous study [25] and answers the research question *"what is blockchain governance, and what are its building blocks?"*. Compared to the conference article, in this journal paper, we provide more details on the phenomenon, and additionally, we apply systems theory [26] to conceptualize blockchain governance as a system and parsimoniously organize its interrelated elements into a new conceptual model. According to systems theory, systems consist of elements and interrelations among the elements, and the boundaries between the systems and the external elements are well defined [26,27]. Conceptualizing blockchain governance as a system is useful for two reasons. First, it provides a structured way to identify and communicate the components of blockchain governance, its objectives (i.e., output), and the factors affecting it (i.e., input). Second, a guiding principle in systems theory is that the sum is more than its part. Applying systems principles (e.g., internal interdependencies, capacity for feedback, equifinality, and adaptation) emphasizes a much more complex and dynamic view of blockchain governance that has typically not been addressed in extant research. This complex view allows us to identify relevant future research areas. Thus, applying a systems theoretical framework enables us to assimilate state-of-the-art knowledge and chart future research directives in a structured manner, leading to the ultimate goal of understanding blockchain governance better.

The paper has several contributions to both theory and practice. First, we propose a system-based model of blockchain governance that offers a holistic viewpoint and a more comprehensive understanding of blockchain systems and their governance. Researchers and practitioners (e.g., users, organizations, and regulators) can use the proposed model as a reference framework in further studies and as a tool to systematically design, analyze and communicate the different aspects of the governance of blockchain systems throughout the various lifecycle stages. Second, this work aims to raise the attention of researchers to the choice of using the systems theory to advance the relevance of systematic literature review studies.

The structure of the article is as follows. Next, we describe the recent work on blockchain and related concepts, blockchain governance, and systems theory. In Section 3, we outline the research methodology. In Section 4, we give an overview of the findings in the form of descriptive statistics, the system-based model of blockchain governance, future research avenues, and illustrative case studies. Section 5 discusses these findings and outlines the implications for theory and practice. Finally, we conclude the work with some remarks.

2. Recent work

In this section, we first describe the blockchain technology and related concepts in a nutshell, then give an overview of blockchain governance, and finally, we introduce the systems theory.

2.1. Blockchain in a nutshell

Blockchain is a distributed ledger, a peer-to-peer database with a synchronization mechanism that allows validation, recording, and distribution of transactions without the need to trust a mediating third-party [20]. In blockchain systems, instead of managing the ledger by a single trusted party, each node holds a copy of the chain. New transactions are linked to previous transactions by cryptography, and every node can verify whether the transactions are valid. During this validation process, the nodes agree on the valid state of the ledger with consensus. The consensus mechanism might differ across the application domains and can be classified in different ways, such as lottery-based and voting-based mechanisms. Lottery-based approaches include proof of work (PoW; i.e., the algorithm rewards participants for solving cryptographic puzzles in order to validate transactions and create new blocks); or proof of stake (PoS; i.e., validators are selected randomly or through a round robin mechanism; however, the vote's weight of each validator depends on the size of his stake that is defined for example, by the amount of cryptocurrency held in deposit or another commodity). Voting-based approaches to validation include the Practical Byzantine Fault Tolerance algorithm, where the nodes transmit votes in a multi-round process [28]. When consensus is not established, forks occur, i.e., the blockchain system can split into two separate and unconnected blockchains [5]. In the case of *soft forks*, a change of rules is generated, but the new blocks are compatible also with the old software. *Hard forks* generate technologically incompatible blockchain systems.

Depending on the access control mechanism, there is a distinction between public permissionless, public permissioned, and private permissioned systems. First, in *public permissionless* blockchain systems, any user can join the network and participate in the data reading, writing, and validation process, and the users can remain anonymous [6]. Second, in *public permissioned* blockchains, every node can read and write transactions, but the validation process is restricted to authorized nodes. Third, in *private permissioned* blockchains, only authorized nodes can read, submit and validate transactions [20]. In permissioned systems, the validation of transactions happens using selective endorsement (i.e., by a small number of authorized actors) instead of a consensus mechanism that is applied to a permissionless system. In permissioned systems, the actors' identity is typically not hidden [10].

One of the key components of blockchain are smart contracts and oracles. Smart contracts are code (or the source code from which the code was compiled) representing computational agreements between parties that may be self-executed and self-enforced [7]. Smart contracts typically provide basic functionalities, such as token issuance and management, conditional or recurrent payments based on a set of predefined conditions, simple lottery systems, etc. However, for smart contracts to be useful, they need access to external data sources outside the blockchain. This external data is provided by oracles that are blockchain addresses controlled by trusted third parties through which the relevant input is provided to the smart contract [29]. Together, smart contracts and oracles enable the implementation of more complex applications.

Blockchain technology is primarily known for cryptocurrency applications, such as Bitcoin. However, blockchain has been proven to be useful also for supply chains [6], the energy industry [28], digital identity [23,30], and finance, to name a few. The blockchain-based decentralized finance (DeFi) is a form of finance that does not rely on central financial intermediaries, such as banks. DeFi services enable for example, crypto-savings, crypto-loans, or trading with them. DeFi services differ from traditional financial services because of their decentralized, interoperable, borderless, and transparent nature [31].

One of the applications of blockchain are the Decentralized Autonomous Organizations (DAOs), which can be considered new forms of decentralized governance. DAOs are decision-making systems that enable for example, transparent decision processes, automation of certain operations, formalized rules, and decentralization of power, among others [32]. They rely on the collective agreement of its members that is achieved and maintained via voting. DAO members can vote for example, to the allocation of the DAO resources, changes in the DAO code, etc. Some of the DAO platforms that facilitate the creation of DAOs are Aragon, DAOstack, and DAOhaus.

In some blockchain systems, token holders are allowed to vote on issues that govern the development and operations of a blockchain system (e.g., adjusting fees, appointing team members, and adopting new rules). In some systems, (e.g., LUNA, BNB), tokens can be used for several purposes besides voting. In other systems, especially in DAOs and DeFi applications, there are specific governance tokens for this purpose. Governance tokens implement a voting logic where the token holders can express their intention for the protocol development in majority-voting schemes in various protocol-specific voting mechanisms [33]. Governance tokens typically follow the principle of one token, one vote, providing means for decentralized governance by distributing the voting power evenly to the community. One of the earliest governance tokens was issued by MakerDAO, an Ethereum-based DAO underpinning the stablecoin DAI, while other examples include Compound, Uniswap, and Curve DAO. For blockchain systems that do not want to invest in implementing their own voting system themselves, there are some decentralized voting tools (e.g., Snapshot) where it is possible to choose a suitable voting strategy and system (e.g., single choice, approval voting), and the system provides the holders the possibility to vote (in case of Snapshot, off-chain), and easy-to-verify results.

2.2. Blockchain governance

Blockchain governance has been studied through the lens of several theories, including IT governance theory, platform governance, the organizational and corporate governance literature, agency theory, internet governance, and open-source software governance (for a more comprehensive list, please refer to Table 1). Several components of blockchain governance have been identified in recent work depending on the theoretical lens or an atheoretical, descriptive research approach. For example, studies building on IT governance theory identify the dimensions of decision rights, accountability, and incentives [12]. Researchers inspired by organizational and corporate governance literature describe decision-making related to (i) owner control on the blockchain level, (ii) formal voting on the protocol level, and (iii) centralized funding at the organizational level [34]. Further, governance has been found to be concerned with decisions related to (i) demand management, (ii) data authenticity, (iii) system architecture development, (iv) membership, (v) ownership disputes, and (vi) transaction reversal [20]. Moreover, studies based on the theory of platform governance identify the following three key components of blockchain governance: (i) access, (ii) control, and (iii) incentives (e.g., [35]).

Table 1
Theories used as a lens for blockchain governance.

Theory	References
Platform governance	[36,37]
Platform/technology ecosystem governance	[35,37–39]
IT governance	[3,12,13]
Digital platform/infrastructure governance	[3]
Open-source governance	[3,13,14,37,40]
Multi-sided market governance; multi-sided platform governance	[41]
Agency theory, principal-agent theory	[12,42]
Transaction cost economics	[3,37,38,43]
Game theory	[11,44,45]
Complexity theory	[46]
Social contract theories	[47]
Organizational and corporate governance	[11,13,38,42,46,48,49]
Collaborative economy, sharing economy	[50]
Contract economics; coordination and adaptation; law and economics literature; legal philosophy/theory; legal order	[15,44]
Internet governance	[14,36]
Nodal governance	[38]
Institutional theory	[42,51]
Stakeholder theory	[42]
Resource-based view	[42]
Mechanism design theory	[36]
(Formal) political theory	[11,45]
Contractual and relational governance	[43]

Recent work defines blockchain governance in several ways, as visible in Table 2. While there is no consensus on one specific definition of blockchain governance, several terms share a common understanding among researchers. First, there is a distinction between the *governance of the infrastructure* (i.e., means and processes of directing, controlling, and coordinating actors within a blockchain system) and *governance by the infrastructure* (i.e., using blockchain to govern actions and behavior) [14]. Second, *on-chain governance* refers to the direct encoding of rules and decision-making processes into the blockchain system, while *off-chain governance* is defined as non-technical rules and decision-making processes affecting the development and operation of blockchain systems [15]. Third, *technology governance* refers to governing the technical development of the blockchain system, while *network governance* implies governance of the associated blockchain networks [52]. Fourth, studies drawing on organizational and corporate governance literature distinguish between external and internal governance [34,46]. *External governance* refers to decisions made outside the blockchain system (e.g., the media, general public) but impacting managerial decision-making within the system [46]. *Internal governance*, in contrast, describes governance practices inside the system [46].

The only work providing an integrative blockchain governance framework has been developed and proposed by van Pelt et al. [13]. The authors build on the definition of open-source software (OSS) governance and define blockchain governance as *"The means of achieving the direction, control and coordination of stakeholders within the context of a given blockchain project to which they jointly contribute"* ([13], p.7). In this work, blockchain governance combines six dimensions (formation and context, roles, incentives, membership, communication, and decision-making) and three layers (off-chain community, off-chain development, and off-chain protocol). While this work provides an excellent framework for studying blockchain governance, it does not

Table 2
Definitions of blockchain governance.

Definition	References
"The means of achieving the direction, control and coordination of stakeholders within the context of a given blockchain project to which they jointly contribute."	([13], p. 7)
"The placement and enactment of decision rights"	([20], p. 1)
"Blockchain governance is about determining who has authority (internal and external actors); how these actors are endowed (e.g., ownership rights vs. decision authority), in what form (formal and informal governance forms/structures), and at which level."	([34], p. 3)
"The processes by which stakeholders (those who are affected by and can affect the network) exercise bargaining power over the network."	([38], p. 1)
"Blockchain governance concerns the way decisions are made, not the decisions themselves—who choses and how choices are made, rather than what is chosen"	([38], p. 2)
"Blockchain governance is the process by which the rules (that is, the software) of these systems are managed."	([45], p. 1)
"Blockchain governance represents a self-contained and autonomous system of formal rules."	([43], p. 13)
"Blockchain governance is the mechanism by which design changes are enacted and regulated on a blockchain."	([53], p.2)
"Governance of blockchains is defined as the formal or informal processes that determine changes to the software protocol and/or to the legal entities which manage each system."	([54], p.2)
"Blockchain governance is about determining who has authority (internal and external actors); how these actors are endowed (e.g., ownership rights vs. decision authority), in what form (formal and informal governance forms/structures), and at which level.	([55], p. 49)
"Governance is the process by which new features are proposed, designed, agreed upon and implemented. Features are not limited to technical details of the blockchain source code, such as the maximum number of transactions that can be put into a single block in the chain, but also other important considerations such as marketing and education."	([56], p. 196)
"Governance is generally understood as a system shaping coordination between different actors."	([46], p. 10)
"Governance refers to the way rules, norms, and actions of how people interact with each other are structured, sustained, regulated, and held accountable."	([11], p. 500)
"Governance is the process through which the governing entities of a system take decisions and enforce them."	([57], p. 2)

emphasize the dynamic, evolving nature of blockchain systems, it does not incorporate the legal and regulatory aspects, and also, the business aspects get less attention. However, governance decisions cannot ignore the legal and business context that both sets the constraints and provides opportunities for alternative governance structures. Furthermore, governance decisions need to consider the lifecycle stage of the blockchain system. For example, governance is typically more centralized in the formation phase, with more ad-hoc decisions made via traditional, social decision-making means. Still, it is continuously evolving towards decentralized governance structures and more routinized and automatized decisions in the operating phase.

2.3. Systems theory

A system is a set of interrelated elements with clearly defined boundaries, where a change in one component also impacts other components in the system [58]. Open systems interact with their external environment. The systems theory assumes that the whole is more than the sum of its parts. However, the interrelated elements of a system are designed to work together, and function as a whole to achieve a common objective.

The systems theory includes specific principles that emphasize the system's complexity [59]. First, the key assumption (called the *congruence* hypothesis) for system-based models is that the system exists in a relative balance state where the elements of a system "fit" with each other, and the system quality depends on the quality of the congruence between the elements. Second, the *interdependence* principle states that the components of a system are interdependent and affect each other. Third, the *capacity of feedback* suggests that the system's output provides feedback about the system's operation and, as such, can be used to correct the system. Fourth, the *equifinality* principle emphasizes that the same output can be achieved in several ways using different configurations of the system components. Fifth, systems aim to achieve a state of *equilibrium* by continuously adapting to changing environmental conditions (inputs) [27,59].

2.4. Summary

Despite the growing body of literature, existing research fails to provide a holistic understanding of blockchain governance. Applying the systems theory provides an opportunity to integrate the findings of recent work on blockchain governance, and identify the inputs, outputs, and components of blockchain governance based on recent work. Furthermore, the principles of systems theory provide us an opportunity to derive future research directions that have not been identified before in recent work.

3. Research methodology

A systematic literature review is an appropriate approach to synthesizing the existing studies to facilitate theory development and support policymakers and entrepreneurs for better decisions [60]. This methodology has high reproducibility and objectivity due to its transparency in data collection and synthesis [60]. Following the five-stage grounded theory method of Wolfswinkel et al. [61] for conducting a systematic literature review, we applied a review by defining, searching, selecting, analyzing, and presenting, which we will describe in the following subsections.

3.1. Defining

A well-written and detailed protocol document is essential for ensuring consistency throughout the review process by defining the scope of the review, criteria for inclusion, the fields of research, the appropriate sources, and specific search terms. We did not want to restrict the scope of our review, and thus, we set the scope to cover the entire phenomenon: governance "of" and "by" all different type of blockchain systems (private, public, permissioned and permissionless). For our study, all articles focusing on or partially mentioning blockchain governance can provide valuable insights into blockchain governance's definition and components. Therefore, we defined the inclusion criteria as follows: articles focused on studying blockchain governance or presenting the occurrences of blockchain governance. Since research on blockchain governance has just emerged in recent years, any relevant article might provide interesting views for our study from different perspectives. Therefore, we did not limit the fields of research, which may result in a multi-disciplinary or holistic perspective for the studies on blockchain governance.

In this study, we used three multi-disciplinary electronic databases for keyword searching: the Web of Science, Proquest, and ScienceDirect. Those databases were considered appropriate sources since they cover a wide range of literature and are frequently used by previous scholars (e.g., [62,63]).

Blockchain governance can be discussed using different terms. Finding the right keywords and their combination was an iterative process. After several iterations, we decided on the following string for searching in the three databases:

(blockchain OR

((distributed OR decentralized)
AND (ledger OR platform OR "autonomous organization")))
AND (governance OR management OR ecosystem)

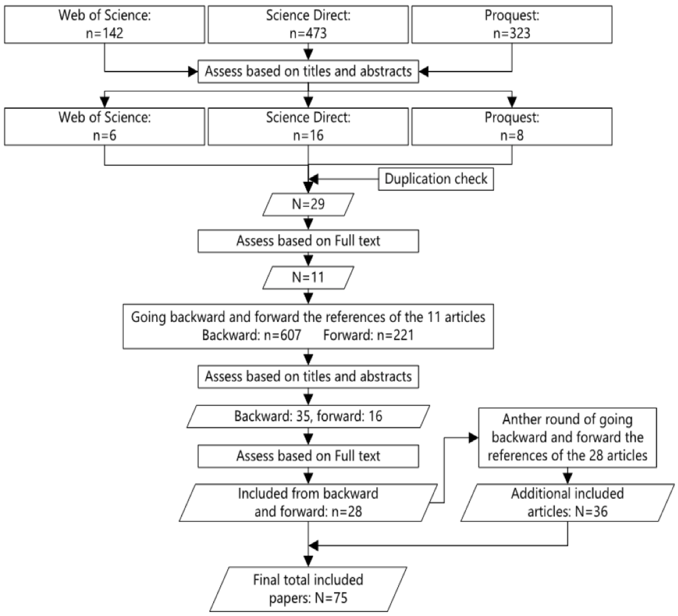

Fig. 1. Searching and selecting stages of the systematic literature review process.

3.2. Searching and selecting

In Fig. 1, the searching and selecting stages are presented. We applied the defined search terms to the three online databases in the Searching phase. We got the following results: 142 articles from the Web of Science, 323 from Proquest, and 473 from ScienceDirect.

In the selecting phase, we filtered the articles based on their titles and abstracts using the defined inclusion criteria. This phase resulted in six relevant articles from the Web of Science, eight relevant articles from Proquest, and 16 relevant articles from ScienceDirect. In this step, we eliminated duplicates and identified 29 primary articles based on title and abstract. Next, we filtered the articles based on their content against the same inclusion criteria and received 11 articles. Later, we went through the backward and forward references of the 11 articles to find additional relevant articles with the same inclusion criteria. We found 607 articles by going backward through the references, and 35 articles were included based on the titles and abstracts. Within forward references (i.e., from the papers citing the referred articles), 16 out of 221 articles were found relevant based on the titles and abstracts. Then, we went through the 51 articles, filtered them based on their content against the same inclusion criteria, and got 26 articles. Next, we did another round of backward and forward reference searches at the 26 included articles and found an additional 36 relevant articles. Therefore, the total number of final included articles was 75. During this stage, we made descriptive notes about each included article to offer a general overview.

3.3. Analyzing

We performed the data analysis of the final articles in three phases, each phase in an iterative manner. We used the qualitative data analysis software ATLAS.ti [64] for open and axial coding. First, we did open coding using the constant comparative method [65] to identify the main characteristics of blockchain governance and gather descriptive statistics of the articles (e.g., objective, theories, and the research method). In this phase, we used the code in vivo and the automatic coding functionality of the software. As a result, the coding was detailed and, in many cases, followed the wording of the original articles [66,67]. Example codes of this phase include “exit strategy”, “benevolent dictator”, “platform developers”, and “economic rewards”.

In the axial coding phase, we reorganized these codes into larger, overlapping categories using the code group functionality of the Atlas.ti software. These categories represented the different aspects of blockchain governance, such as “business aspects” and “actors and roles”. Then, we reduced the number of codes by renaming and merging the codes that referred to similar issues. This task resulted in a hierarchical code structure with a maximum of three levels (for example, “actor: developer”, “incentive: nonpecuniary: networking” and “descriptive: method: design science”). This code structure represented the building blocks of blockchain governance and the understanding of previous literature, providing a base for developing our conceptual framework.

In the theoretical coding phase, our objective was to formulate a definition and dynamic blockchain governance model from a holistic perspective. We chose to apply the systems theory lens to provide a conceptual framework for a better understanding of the phenomenon. Using systems theory, we identified, aligned, merged, and organized the components of blockchain governance resulting from the axial coding phase into a conceptual system-based model. In particular, we identified the system’s inputs, outputs, and key components. Furthermore, guided by the systems theory, we identified future research needs that have not been answered yet in recent work.

All phases of the data analysis have been carried out as an ongoing, iterative, co-creative process. First, the authors discussed the code structure several times and modified it according to the agreements. The code structure was considered final when all the codes belonged to a category, and there were no more questions from any authors. Second, several blockchain practitioners discussed the conceptual model during several meetings. After the first meeting, the model was refined based on the feedback. Later on, the attendees found the model easy to understand, and they used it as a tool to discuss issues related to the governance of their blockchain system. As a final step, we reviewed the quotations behind the codes and summarized the findings in this article.

4. Findings

In this section, we first describe the articles’ descriptive statistics. In the second subsection, we present a system-based model of blockchain governance. Third, we suggest future research avenues. Finally, we provide two illustrative case studies for the model.

4.1. Descriptive statistics

Fig. 2 presents the number of different article types each year. The articles were collected in spring 2021. As visible from the figure, blockchain governance has gained increasing attention since 2018. More than half of the included articles were published between 2018 and 2020; the data was collected in spring 2021. The included articles are journal articles (36%), conference articles (23%), and others (such as book chapters, theses, and university publications; 41%).

Various research methods have been applied in the included papers. The case study was the most frequently used approach, accounting for more than 50% of the included papers. Most of these case studies offered discussions related to Bitcoin and/or Ethereum, while some other studies analyzed EOS.IO [13], the Swarm City [12], Cardossier [20,68], and Tezos [38]. In addition to case studies, other research methods included the design science research approach [13,69] and action research [52].

Based on the 75 included articles, most research focuses on public blockchains, including 17 for general public blockchains (not specifying permissioned or permissionless), 13 for public permissionless, 2 for public permissioned, and 2 for public permissionless and private permissioned (c.f. Fig. 3). Eleven articles have discussed all types of blockchains, and 22 papers are unspecified with the blockchain types.

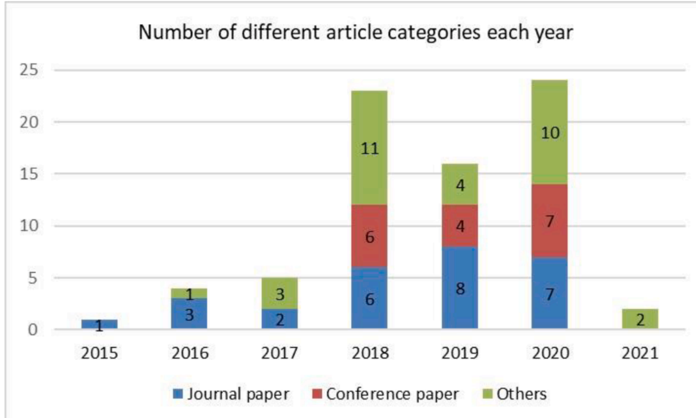

Fig. 2. Number of different article categories each year.

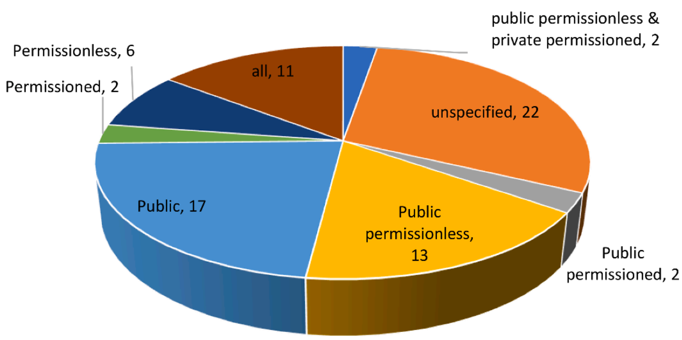

Fig. 3. Different types of blockchains discussed.

4.2. *A dynamic, system-based model of blockchain governance*

The diversity of theoretical lenses and viewpoints and the various dimensions of blockchain governance mentioned in the included articles lead us to investigate blockchain governance from a holistic perspective. Thus, as a result of our systematic literature review, we define blockchain governance as follows:

Blockchain governance encompasses technical and social means to make decisions on the different levels (e.g., *individual, community, organizational, national, international) related to actors, roles, rights, incentives, responsibilities, rules, and the business, technological, legal, and regulatory aspects of a blockchain system during its whole lifecycle.*

Furthermore, we propose a system-based model of blockchain governance that can be seen in Fig. 4. In line with the definition, the model captures the dynamic nature of blockchain governance, where technology-based and social means impact the various facets of blockchain governance. The key concepts and their definitions are presented

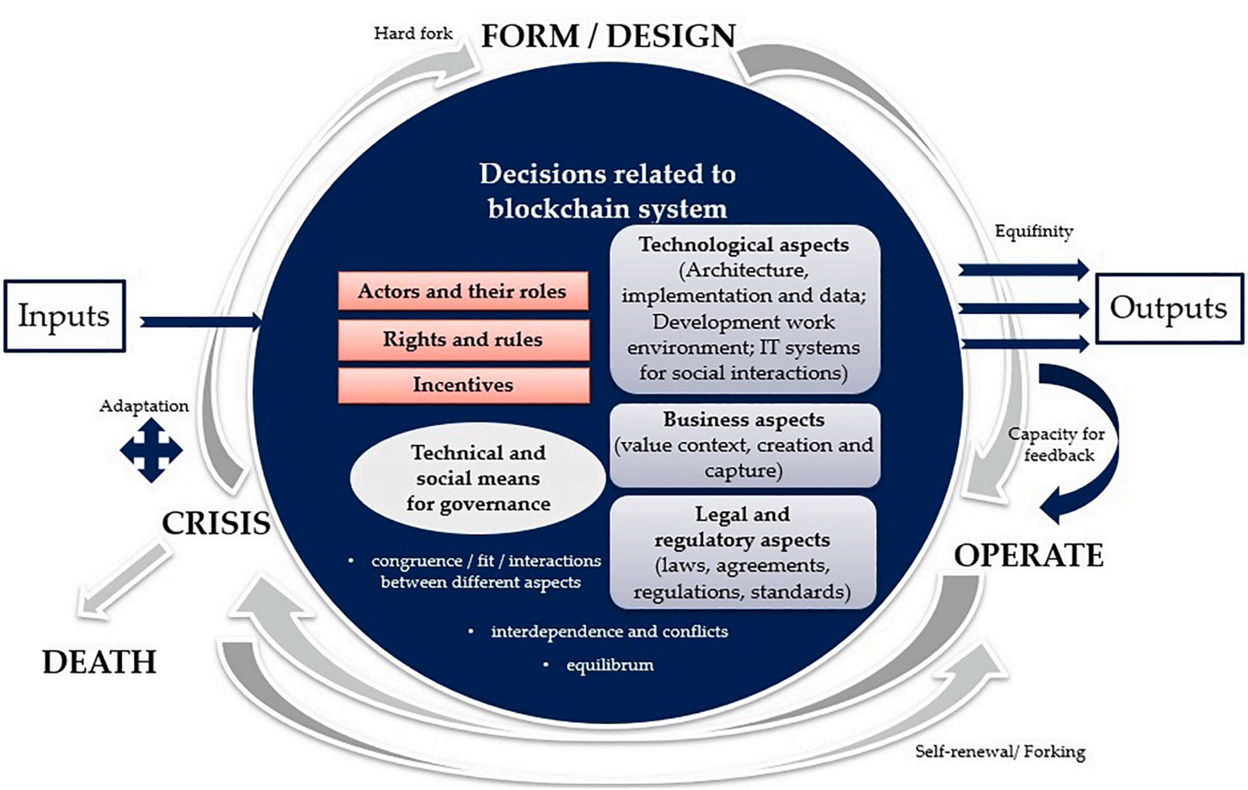

Fig. 4. A system-based model of blockchain governance.

in Table 3.

In the following subsections, we describe the different aspects of the blockchain governance model.

4.2.1. Inputs: factors affecting blockchain governance

The system's inputs are "given": this refers to the context, the environment, the existing resources, and the starting conditions of the system. Identifying the key factors affecting the governance decisions is crucial. Governance decisions are affected by culture, market, and public interest [3,9,43,70]. Lumineau et al. [43] predict that the information asymmetry and unpredictable disturbances (e.g., uncertainty in R&D environment, technological changes) impact the efficiency of blockchain governance because the transactions are not easily codifiable and verifiable. Furthermore, Chen et al. [36] found that experienced leaders are more likely to adopt semi-decentralized governance structures. Rikken et al. [9] emphasize that various factors affect blockchain governance differently in each lifecycle stage: for example, the fluidity of the actors or lack of organizational structure is a bigger challenge in operational and crisis life stages than in the design phase.

4.2.2. Technical and social means for governance

This building block encompasses both governance *of* and governance *by* the infrastructure. Governance means refer to actions, systems, methods, and processes designed for decision making. Blockchain technology facilitates *on-chain governance* (referred to also as automated self-governance): governance decisions can be automatized by technical means, in the form of voting mechanisms, smart contracts, DApp frameworks, consensus algorithms, forks, and blockchain network protocols (e.g., [9,22,71]). Embedding governance into technology refers to automatically managing and maintaining systems of legal agreements, voting and property rights, and validating, maintaining, and enforcing social and functional properties or contracts [47]. Technical means enable the standardization of interactions, embedding quality standards into the technical architecture, and providing incentives [35]. Automatizing governance decisions entails embedding social trust and determining the bargaining power of the actors [14,38].

However, the technology cannot solely be held accountable for governance decisions. Besides these technical means, there is a need for *off-chain governance* enabled by traditional, social means for governance, such as communication, collaboration, and coordination among actors [13]. Social interactions among the actors are needed in different forms and channels [12–14,35,72]. Social governance means refer to formal and informal communication and collaboration among the actors, such as discussions via coordination systems, tracking systems, meetings, forums, and informal online voting over decisions and working groups [13,55]. Furthermore, the media plays an information intermediary form of off-chain governance by influencing key actors through informing, monitoring, public image, and reputation effects [55,73,74].

A key challenge in blockchain governance is to find the right balance between the technical and social means of governance (i.e., what, how, and when to automatize). Understanding when to use the on-chain governance, when to apply human intervention, and when a hybrid approach is needed [75]. A decision on embedding governance into technology should be made based on various aspects of the system, for example, the lifecycle stage [20]. In blockchain systems, on-chain technical governance interacts with traditional governance mechanisms in both substitutionary and complementary ways [43]. Thus, the relationship between technological and social governance means is complex and intertwined.

4.2.3. Blockchain system

4.2.3.1. Actors and their roles. Governing a system requires identifying the actors (i.e., stakeholders, agents) that are influenced by, or can affect the system [38]. Blockchain systems have a boundary problem: defining

Table 3
Key concepts of the system-based model of blockchain governance.

Concept	Definition
Inputs	Inputs are given to the system (e.g., environment, context). As such, they place demands and constraints on systems.
Outputs	The outcome of the system.
Technical means	Systems, components, mechanisms, frameworks, and processes that enable automatizing governance decisions, such as voting mechanisms, smart contracts, DApp frameworks, consensus algorithms, forks, and blockchain network protocols.
Social means	Non-technical, traditional means for governance: actions, methods, and processes, such as communication, collaboration, and coordination among actors.
Actor	An entity capable of performing behaviors or activities in the system.
Role	A characteristic set of behaviors or activities undertaken by ecosystem actors.
Right	A right or privilege to perform a certain behavior or activity.
Rule	A regulation or principle that governs conduct in the ecosystem.
Responsibility	A behavior or action that actors or roles can be held accountable for.
Incentive	Motivational factors of the actors or roles to take actions.
Technological aspects	Architecture, implementation, and data: in this context, this category refers to decisions related to the implementation details of on-chain governance. Development work environment: in this context, this category refers to the tools and methods of developing the technical means of blockchain governance. IT systems for social interactions, knowledge and memory management: this category refers to tools for off-chain governance in this context.
Business aspects	Value context: the purpose and context, the business requirements, and the strategies and mission of the system. Value creation: enablers of developing and increasing the value of a system, such as core activities. Value capture: securing financial or nonfinancial return from value creation, such as revenue streams and pricing models.
Legal and regulatory aspects	Regulations: A set of rules created and enforced through social or governmental institutions to regulate certain aspects or behavior in the system. Standards: A set of specification, established norm, guideline, or requirement that ensures compatibility, safety, and quality of certain aspects or components of the system. Agreements: Legally enforceable contract among the actors.
Congruence/ fit/ interactions between different aspects	The system exists in a relative balance state where the elements of a system "fit" with each other, and the system quality depends on the quality of the congruence between the elements.
Interdependence and conflicts	The components of a system are interdependent and affect each other. Tensions and incompatibility between the components may imply conflicts.
Equilibrium	Systems aim to achieve a state of equilibrium where the inputs and outputs are in a favorable balance with the environment.
Capacity for feedback	The system's output provides feedback about the system's operation and, as such, can be used to correct the system.
Adaptation principle	Systems aim to achieve a state of equilibrium by continuously adapting to changing environmental conditions (inputs).

(*continued on next page*)

Table 3 (*continued*)

Concept	Definition
Equifinity	The same output can be achieved in several ways using different configurations of the system components.
Lifecycle stages	Form/Design: the formation or design stage of a blockchain system. Operate: the operational stage of a blockchain system. Crisis: an acute lifecycle stage characterized by conflicts. Crises typically lead to changes in the system's state.

the actors of the system is challenging [38]. Some actors are not even aware that they contribute to governance decisions [13]. Furthermore, some actors are affected by the decisions but do not interact [38]. Moreover, a group of actors with the same role may not be homogenous in their incentives and actions (e.g., token holders; [38]). Another problem comes from different actors' different preferences towards the chosen governance models that need to be aligned [76].

Actors can be individually governed as a community or according to other affiliations. Actors are classified in different ways in the literature. First, actors can be categorized into *passive* (i.e., users of blockchain, for example, to transfer money) or *active* users (i.e., users who contribute and support the operations of the network) [14,77]. Actors might be *public* or *private* [68]. They can be considered *internal* (i.e., users) or *external* (i.e., regulators or standard-setting bodies) [20]. Finally, actors might be *competitive* or *cooperative* [17].

Based on our review, actors can be grouped based on their roles in the infrastructure development processes or the ecosystem. Roles can be defined as a characteristic set of behaviors or activities undertaken by the actors [13]. Roles related to *infrastructure development* are nodes, miners or validators, users, developers, architects, and so forth (e.g., [13,14,37]). Roles related to a *system* can be owners, founders, leaders, providers, investors, contractors, complementors, standard-setting bodies, regulators, observers, operators, suppliers, service providers, and so on (e.g., [3,35,44,55,76]). In some cases, there is a hierarchy between the roles, and specifying this hierarchy plays an important role in governance decisions [13]. Governance decisions should also consider that actors might act on behalf of others [78].

In certain blockchain systems, the system is managed by a governance authority that may represent any set of actors organized in different forms (for example, government, consortia, cooperative). Typically, governance authorities publish a governance framework that consists of rules, and business, legal, and technical policies for managing the system [23]. For example, governments, large enterprises, or a set of organizations might serve the role of governance authority, and governance frameworks can be published in the form of laws, regulations, standards, or agreements.

4.2.3.2. Rights, rules, and responsibilities. One of the key factors for successful governance is the rights and responsibilities of the roles /actors and the rules in the system [9]. Rights and rules have been mentioned in various forms in the literature. First, access rights and rules have been referred to as rights/rules for entry, membership, input control, and participation (e.g., [13,20,46]). Second, decision rights and rules "concern the rights governing control over certain assets" ([12], p.1022). Third, rights and rules should be developed related to development, software updates, data policies, and hard forks [16,46,76]. Fourth, rules and rights are needed for voting, validation/verification, overrides, and ownership (intellectual property) [20,38,47,48,76]. Rights and rules could be endogenous (i.e., developed by the community for the community, as a form of self-governance) or exogenous (i.e., rules established by external actors that have the power of influence, such as law-bodies or regulatory frameworks) [22]. Rules can be general (e.g., separation of powers, conflict resolution, monitoring, entry and exit rules) or domain-specific (tailored to the domain needs, such as private production or public service provision [17]. The combination of general and domain-specific rules is referred to as the 'constitution' of a polycentric system [17].

Governing a blockchain system implies designing the responsibilities and the accountabilities assigned to the roles [12,13,16,76]. The importance of responsibility management has been emphasized in both the open-source software governance and the corporate governance literature [48,79]. Accountability captures the level at which actors are, and can be held accountable for their actions and behavior [13]. Accountability represents one of the key concepts in the theory of IT governance, platform governance, digital infrastructure governance, and corporate and organizational governance [3,9,11,12,49].

4.2.3.3. Incentives. Incentives refer to actors' motivations for participation and actions [13]. Incentives play a key role in governance decisions because they encourage desirable behavior and punish malicious actions in the system [12,57]. Aligned incentives allow actors to choose their own behavior and actions that coincide with the shared objectives of the system [12]. As a central concept of blockchain governance, incentives should be carefully designed for each actor and their desired behaviors and actions. For example, the system may provide different incentives for technical consensus, system development and maintenance, and users and token holders [12].

Incentives can be pecuniary (monetary) or nonpecuniary (nonmonetary) (e.g., [13])). The pecuniary incentives coded into the system play an important role in blockchain governance and are based on the assumption that humans act in a way that maximizes their monetary rewards [17]. For example, monetary incentives include rewards paid in the system's cryptocurrency, the possibility to collect transaction fees, salaries, etc. Besides financial benefits, blockchain systems offer a wide range of value, such as privileges, reputation, and visibility [12,37]. Some actors contribute to the system to gain experience, research, conduct technical and market testing, simulate business processes, collaborate or build new strategic alliances [52].

4.2.3.4. Technological aspects. Blockchain systems cannot be governed without decisions related to technology. In particular, these decisions are related to (i) the architecture, implementation, and data, (ii) the development work environment, and (iii) the IT systems for social interactions, knowledge, and memory management [8,12–14,20,52,76,80]. The first category, "Architecture, implementation, and data" is related to the implementation details of on-chain governance. Within this category, choices related to consensus and voting mechanisms, smart contracts, and oracles are crucial. Governance rules are executed in smart contracts, while oracles provide information input from the external environment to the blockchain system. For example, smart contracts in DeFi applications often require oracles to execute agreements because of the need for real-time exchange rates. Further, the importance of smart contracts and oracles is highlighted, especially in crisis situations. For example, Poblet et al. [8] describe the case of MakerDAO's DAI from March 2020 where due to network congestion and time-lagged price oracles, US$4 million worth of ETH was taken from the platform and left the platform in deficit. Another important decision is related to the voting mechanism. In particular, blockchain systems might have their own voting system or use third-party voting systems (e.g., Snapshot). Whether to issue governance tokens separately or not, is another crucial governance-related decision.

The second category, "Development work environment", is related to the tools and methods of developing the technical means of blockchain governance. The third category, "IT systems for social interactions, knowledge, and memory management", is related to providing tools for off-chain governance. Some examples of these technical decisions related to governance can be found in Table 4.

Table 4
Decisions related to technological aspects.

Categories of technological decisions	Examples of technological decisions within the category
Architecture, implementation, and data	consensus mechanism, voting mechanism, smart contracts, and oracles executing governance rules technical choices for the software stack third-party software technical requirements on connectivity and firewalls the monitoring and maintenance of key performance parameters the sharing of node-IPs online or offline funding storage transaction enforcement validation and conflict resolution mechanisms data authenticity activity tracking identity management and interoperability
Development work environment	software repository management versioning testing monitoring
IT systems for social interactions, knowledge, and memory management	coordination and other IT systems

4.2.3.5. Business aspects. In blockchain systems, the actors co-create value, and a key question is how to ensure a fair share of value among them. A successful business model is beneficial for all actors [81] and is essential for a sustainable blockchain system. In this view, a fit between value capture, value creation, and value context is key to achieving dynamic stability [82]. According to this view, we grouped the governance decisions related to the business aspects into three groups: decisions related to value context, value creation, and value capture.

The decisions related to *value context* encompass identifying the purpose and context, the business requirements, and the strategies and mission of the system (e.g., [13,20,72]). For this task, there is a need to understand where the value resides in the system, considering all other aspects, such as the actors, their roles, their (possible) incentives, the opportunities enabled by the technology and its limitations, and the legal and regulatory context. Understanding the value context is essential to ensure that governance decisions support the system's ultimate purpose [78].

The decisions related to *value creation* are primarily related to cost factors and funding sources (e.g., [35,37,52]). Furthermore, decisions are needed related to core activities and how to split the funding fairly among the actors to establish incentives and facilitate innovative outputs. For example, splitting the funding on development, marketing, market creation, and assessing the effectiveness of the funding sharing strategy remains a key challenge within public blockchain systems [83].

Value capture entails not only the provision and negotiation but also the realization of value [35]. The decisions related to value capture typically deal with revenue streams and pricing models (e.g., [13,35]). In blockchain systems, different actors might have different revenue models that need to be considered in decision-making processes.

4.2.3.6. Legal and regulatory aspects. While there are considerable advances related to blockchain systems' legal and regulatory environment in different countries, uncertainty still exists related to the legal and regulatory aspects of the technology and the ecosystems built around it [39]. Blockchain governance encompasses decisions related to laws, regulations, and industry policies, standards, and agreements (e.g., [9,16,76]).

In an uncertain *legal and regulatory* environment, decisions are needed on the specific regulations to comply with or regarding lobbying for changes in the existing regulations [39]. In particular industries (e.g., financial or data services), the choice of jurisdiction or accountability over multiple jurisdictions is crucial [9].

Viable blockchain solutions must have a *standard* industry policy strategy or an alternative strategy when standards are not yet fully established. Choices could be, for example, (i) creating a proprietary blockchain protocol, (ii) working with existing standards groups to adopt standards for blockchains, or (iii) joining an industry blockchain consortium [39].

Besides the decisions related to laws, regulations, and standards, one of the key tasks in developing blockchain systems is to create *agreements* among the actors that set out the rules and policies of the system. Agreements can exist in different forms, such as legal documents, shared understanding, social norms, or code (e.g., [20,47,72,84]).

4.2.4. Lifecycle stages

Blockchain governance evolves over time [9,20,76]. Blockchain systems are orchestrated in the *formation/design* phase (also called exploration/ bootstrapping), where the key question is "How should the system work?" In the *operation phase*, the key governance decisions have been made already, and the main question is "How should the system operate?" In some cases, the system can enter the *crisis* phase, when the key question is "How should the system handle the conflicts?" Crisis situations can lead systems to death or to forming a new blockchain system via hard forks, or the system can go back to the operation phase via the self-renewal/soft fork. Hard forks generate a new blockchain incompatible with the original blockchain system, while soft forks generate a change of rules that creates blocks recognized as valid by the original system [5].

Blockchain governance needs a dynamic, evolutionary viewpoint for several reasons. First, while blockchain governance is typically considered decentralized, an evolution pattern can be observed that a central authority makes the first design decisions, and the system becomes more decentralized when maturing [76]. Second, the level of automatizing governance also evolves over time: while ad-hoc decisions cannot be automatized, the planned decisions can be implemented later using technical means [20]. Third, crises situations, such as the Ethereum's DAO crisis hack shows that during crises, the on-chain governance means are often suspended, and the developers use off-chain governance for critical decision-making [85]. Thus, questions of temporality and change over time should be considered when designing the governance of blockchain systems [78].

4.2.5. Outputs of blockchain governance

The outputs of blockchain governance can be *tangible* (e.g., cryptocurrency returns) or *intangible* (e.g., construction of alliances, developers' attention, and network effects) and *intended* or *unintended* [55,72]. Effective, "good" governance can be defined in several ways, such as effectiveness in decision making, providing incentives, managing conflicts, protecting the actors' investments, coordinating the adaptation and changes, trustworthy information, and fostering a common identity [36,44,71,86,87]. Effectively governed blockchain systems are reliable, resilient, and adaptive [87].

Success is highly context-dependent and can be measured *internally* (i.e., a process-oriented viewpoint: how effectively internal governance decisions are made in the given context) or *externally* (i.e., an objective-oriented viewpoint: how well the goals are achieved) [72]. Different systems use different metrics to measure the effectiveness of governance, such as indicators for cost overruns, delays, quality control, the number of users, and partner satisfaction [43,77].

Blockchain systems are polycentric, and as such, "their governance outcomes are also shaped by the larger and smaller associations that are part of the same governance network, as well as other similarly sized governance units with which a given network competes" ([77], p. 19). Further, competitive jurisdictions shape governance outcomes [77]. That is, blockchain governance is subject to the constraints of market structure and competition because of the possibility of the users to move to a better-governed network easily. Finally, superior governance forces, such as private and public institutions, shape governance outcomes [77].

4.3. Future research avenues

Several further research avenues are identified that are listed in form of research questions in Table 5. The research questions presented in the table are based on the literature review results and the proposed conceptual model. These questions are not addressed in recent work adequately, and answering them is crucial for understanding blockchain governance.

4.4. Illustrative case studies for applying the system-based model of blockchain governance

To illustrate the application of the proposed framework, in the following subsections, we describe the governance of a public permissionless blockchain and a private permissioned blockchain system using the system-based model of blockchain governance. For our analysis, we integrated insights from the literature describing these case studies and the results of empirical analysis based on publicly available data.

4.4.1. Case study: governance of Ethereum

Ethereum is a public permissionless blockchain infrastructure launched in 2015 based on Vitalik Buterin's vision for a fully Turing-compete programming language that supports smart contracts and blockchain [13]. Ethereum has a wide open-source community. Ethereum acts as a platform for many important blockchain-based innovations, such as decentralized applications, DeFi services, DAOs, NFTs, stablecoins, etc. In September 2022, Ethereum plans to merge from the Ethereum Mainnet to Beacon Chain PoS system to reduce Ethereum's energy consumption by more than 99%. After the merge, Ethereum will use PoS consensus mechanism instead of PoW. The details of Ethereum governance are described in Table 6.

4.4.2. Case study: governance of IBM Food Trust

IBM Food Trust was founded in 2017 to connect actors across food supply chains through a permissioned blockchain system provided by IBM [76]. IBM Food Trust enables nearly real-time data sharing and data reconciliation. The details of the governance of IBM Food Trust are described in Table 7.

5. Discussion

Blockchain has been considered as "trustless" or "trust-fee" technology because of its potential to dismiss the need to trust traditional institutions and online intermediaries [17,89]. According to this viewpoint, trust in the authority of institutions can be replaced by trust in technology. However, technology-based trust entails shared expectations on how the system operates, and instead of a trusted authority, a low level of trust is required towards a set of actors for maintaining and securing the system. This underlines the importance of governance in gaining trust: trust towards a blockchain system depends on the decisions on how the system is functioning, and the rules, norms and strategies that guide the behavior of the actors. Thus, governance plays a key part in blockchain technology to gain trust and achieve its full potential.

In our work, we integrated insights from recent work that studied the phenomenon from the viewpoint of different theories. Instead of building our definition on one specific theory (such as IT governance, open-source software governance, or corporate governance), we defined blockchain governance from a holistic, system-based perspective that was missing from the current literature. System models' pragmatic value relies on the opportunity to identify which factors are the most crucial to understand how the system functions [26]. Based on the literature

Table 5
Further research areas.

Research area	Example research questions
Inputs	• What factors influence the choice of governance mode? • What are the factors that lead to effective governance? • What are the conditions under which blockchains are the most efficient mode of governance relative to market, hierarchy, or hybrid forms?
Outputs	• How to define and measure the success of blockchain systems? • What is effective governance? • What are suitable performance indicators for blockchain systems in different contexts? • How can the outputs be defined at different levels, such as individual, group, organization, or the blockchain system?
Technical and social means of blockchain governance	• What kind of trade-offs between the technical and social means of governance lead toward effectively governed blockchain systems in different contexts? • How do the technical and social means of governance become intertwined in a complementary and substitutional way in various contexts?
Actors and their roles	• How to identify the key actors, roles, and potential new actors in a blockchain system? • Which actors can be the most effective in using blockchains to govern collaborations? • Who is impacted by the blockchain systems?
Rights, rules, and responsibilities	• How can a leader have an impact on the system without having authority?
Incentives	• What incentives are successful in achieving the sustainability of blockchain systems? • What incentives drive the mass adoption of blockchain systems? • How does incentive alignment work during the different lifecycle phases of a blockchain system?
Technological aspects	• How do different technological characteristics (e.g., scalability, interoperability, privacy, transparency) affect the effectiveness of blockchain systems?
Business aspects	• How and to what degree can business-related decisions be automatized? • What are the benefits and the cost factors of implementing governance mechanisms into a blockchain system? • How do changes in a blockchain system affect the current business models?
Legal and regulatory aspects	• What is the role of standards in the process? How should these standards be developed, and by whom? • How do the laws and regulations enable and limit blockchain systems? • How do pre-existing social norms and agreements between parties influence the governance mechanisms of blockchains? • To what extent the blockchain-based, distributed systems can operate outside of laws when governments cannot legitimately exert pressure upon not identifiable actors?
Congruence/ fit/ interactions between different aspects	• Do the different aspects fit, and does their congruence lead to effective governance? • How could the business goals be aligned among different actors? • To what extent, and under which conditions can blockchain systems be considered hyper-political tools capable of governing social interactions on large scale, and dismissing traditional central authorities?
Interdependence and conflicts	• What are the dependencies between the actors and the different aspects? • How do the interdependencies between the different aspects mutually influence each other

(*continued on next page*)

Table 5 (*continued*)

Research area	Example research questions
	over time?
Equilibrium	• What causes conflicting behavior? When and why do forks occur? • What are actions crucial to achieving sustainability? • Which governance mechanisms would be more effective in encouraging equilibrium and consensus?
Capacity for feedback	• What performance measures could be used to improve governance? • Which aspects of a blockchain system would benefit from decentralization, and which components require centralization in effectively governed systems?
Adaptation principle	• How should the governance of blockchain systems adapt to changing inputs, such as economic conditions?
Equifinity	• What are the various configurations of governance components that lead to a particular desired system output?
Lifecycle stages	• What actions lead to a crisis? • What patterns does the governance of different blockchain systems follow throughout its lifecycle?

review, we found that the key building blocks of blockchain governance are the social and technical means of decision making, actors, roles, rules, rights, responsibilities, incentives, and business, technological, legal, and regulatory aspects.

A system-based perspective enables us to perceive in more detail the multi-faceted and complex aspect of blockchain governance [76]. Incorporating on-chain and off-chain governance, governance *of* the infrastructure, and governance *by* the infrastructure in one model facilitates the investigation of how the technical and social governance means substitute for and complement each other [43]. Furthermore, based on our work, we emphasize the dynamic, evolving nature of blockchain governance [76]: decisions should consider the lifecycle stage of the system. For example, governance might be more centralized in the formation phase but evolve towards decentralized governance structures. The complexity and ad-hoc nature of the governance decisions also differ in different lifecycle stages.

Applying the systems lens enables us to conceptualize governance as a system where the input parameters (e.g., the starting conditions, the context, such as the role of culture, user preferences, and legitimacy), the output parameters (e.g., the key objective and measures of success), and the interactions and interdependencies of the components need to be considered as well. In this work, we applied our proposed model to two real-world blockchain systems: Ethereum and IBM Food Trust. As visible from these case studies, the governance of blockchain systems may differ substantially in the case of private permissioned and public permissionless systems; however, the proposed system-based model can accurately describe how these systems are governed.

Based on our review, we emphasize three important gaps in the literature that need further investigation. First, the literature lacks studies that provide contextual details on how the context and environment affect the effectiveness of different governance structures. For example, why some blockchain systems are more successful in some countries while not in others? Second, there is a need for studies on how different component configurations can lead to the same outcome. For example, analyzing the data from decentralized voting systems (e.g., DAOAnalyzer) could identify patterns for successful blockchain governance. Third, we call for future longitudinal research to understand how blockchain systems adapt to changes in the environment and to changes in the systems' objectives. For example, Ethereum's transition from PoW consensus mechanism to PoS will provide valuable insights into many aspects of blockchain governance.

Table 6
Governance of Ethereum.

Building block	Ethereum
Inputs	Global context. High level of uncertainty.
Outputs	The Ethereum's network value follows the Metcalfe's law fairly well, which identifies a network's value as proportional to the square of the number of its nodes, or end users.
Technical means of blockchain governance	Proof of Work and Proof of Stake consensus mechanisms. Potential forks. Potential governance tokens.
Social means of blockchain governance	Reddit, Twitter, Slack, Discord, Gitter, The Ethereum Community Forum, the Ether Forum, local meetups, podcasts, events, comments via Github, scheduled developer calls.
Actors and their roles	Token holders, miners, stakers, developers, Ethereum Foundation, industry organizations, fellowships, community figureheads, online moderators, contributors, maintainers, Ethereum Improvement Proposal editors, full nodes, lightweight nodes, Ethereum Enterprise Alliance, etc.
Rights, rules, and responsibilities	Open access rights. Joining industry organization groups requires an application process and a license fee. The Ethereum Foundation manages some community infrastructure, employs teams working on Ethereum software such as testing frameworks, and runs official developer conferences.
Incentives	Financial benefits in the form of a potential increase of Ether. The benefits of Ethereum applications. Fun and social recognition. Salary paid by the Ethereum Foundation. Block rewards. Transaction fees. Network support. Security incentives.
Technological aspects	Ethereum Virtual Machine. Ethereum Stack. Programming languages (e.g., Solidity, Vyper). APIs. Oracles (e.g., via Chainlink, Witnet, Probale, Paralink, Dos. Network services). JSON-RPC middleware, etc. IDEs: Remix, EthFiddle, Gitter, ChainIDE, Replit, Visual Studio Code, Atom, JetBrains IDEs, etc.
Business aspects	Miners are rewarded in Ether. The Ecosystem Support Program allocates resources to builder tools, infrastructure, research, and public goods. The Ethereum Foundation got some initial funding from the pre-minded native coins at the launch of the Ethereum.
Legal and regulatory aspects	Standards are introduced as Ethereum Improvement Proposals (EIPs), which community members discuss through a standard process. Ethereum is banned in some countries such as Afghanistan, Pakistan, and Algeria. Ethereum has been restricted in some countries such as China, India and Egypt.
Congruence/ fit/ interactions between different aspects	There are many challenges related to the congruence of different aspects, such as immature legal context and, lack of standards for technical architecture, disputes within the community.
Interdependence and conflicts	There are several conflicts within the community, such as the dispute around migration from PoW to PoS consensus mechanism.
Equilibrium	Ethereum aims to achieve equilibrium by adapting a democratic governance model, influence from the benevolent dictator, and a possibility for forks.
Capacity for feedback	Feedback is encouraged, especially by social means for governance. The community can signal its opinion through Carbon votes and Twitter polls.
Adaptation principle	The system adapts to the changing environment for example, by forks and changes in the consensus mechanism.
Equifinity	

(*continued on next page*)

Table 6 (*continued*)

Building block	Ethereum
	Ethereum provides an infrastructure to develop various governance models (e.g., governance tokens, and voting systems) that might provide the same results.
Lifecycle stages	The governance of Ethereum has been evolving from having a benevolent dictator (Vitalik Buterin), through oligarchy (Buterin co-founded Ethereum with several individuals) towards democracy (ensured by the miners' voting mechanism). There are crisis stages in Ethereum's history, such as Ethereum's split into Ethereum and Ethereum Classic after The DAO crisis.

5.1. Implications for theory

This research has several theoretical and empirical contributions. First, the work contributes to system engineering literature by providing a unique, holistic view of blockchain governance and its multi-faceted, complex, and dynamic nature. In particular, the holistic definition of blockchain governance advances theory by integrating the different theoretical viewpoints and can serve as a reference definition for further studies. Furthermore, researchers can use the model as a reference framework in future work, such as empirical and comparative case studies. This integrative framework is significant since it balances the benefits and drawbacks of a single blockchain governance model and intends to cover all relevant components. Moreover, the proposed framework is novel as compared to the blockchain governance framework proposed by Van Pelt et al. [13] because the model introduced in this paper incorporates the legal and regulatory aspects of blockchain governance, it emphasizes the dynamic, evolving nature of blockchain systems and their lifecycle, and in this model, also the business aspects get more attention.

Second, systems theory has been applied in systematic literature review methodology in several research fields (e.g., natural sciences and management; [27,90]); however, we are unaware of its use in the software engineering literature. Thus, with this work, we aim to raise the attention of software engineering researchers to the choice of advancing theory by applying systems theory in systematic literature reviews.

5.2. Managerial implications

For practitioners, such as the actors of blockchain systems, the definition and the model provide a structured foundation and a shared language to understand, analyze and communicate blockchain governance decisions. The need for such a framework is underlined by DuPont [[91], p.198]: "there is no one right approach to [blockchain] governance [. . .] there are risks and opportunities for each". That is, similarly to Business Model Canvas [92] which has been commonly used in business model development, this model can serve as a tool for identifying the gaps and questions, and provides a systematic way of documenting governance decisions throughout the whole lifecycle of the system, such as formation/design, operations, and crisis. We describe some important questions in Table 8, that practitioners might need to consider while designing and operating related to the governance of their blockchain systems.

5.3. Limitations

The work has several limitations. First, due to the phenomenon's complexity, the conceptual model cannot encompass all the details but rather aims to give an overall picture of blockchain governance. We acknowledge the importance of research investigating different parts of blockchain governance in various contexts. While this study aimed to build a holistic view, we encourage future research to address detailed questions related to this complex phenomenon. Second, the study could be extended with findings from gray literature following the guidelines on carrying out a multi-vocal literature review [93]. To mitigate this limitation, the authors followed the gray literature (news, blogs, videos, etc.) related to the topic during the study and conducted several searches to address specific issues related to the phenomenon. Third, future research could provide more details on current blockchain governance mechanisms. For example, analyzing DAO activities using the web tool

Table 7
Governance of IBM food trust.

Building block	Governance of IBM Food Trust
Inputs	Standards and regulations. Data availability. Market needs.
Outputs	Success could be measured by the number of customers, the magnitude of the profit, and the satisfaction of the supply chain actors.
Technical and social means of blockchain governance	Smart contracts for decision-making within the supply chain. Practical Byzantine Fault Tolerance consensus algorithm. Trust anchors receive a full copy of the encrypted ledger but can only view the hashes of the transaction unless data owners grant access. Traditional social means between IBM and other actors in IBM Food Trust system.
Actors and their roles	IBM, producers, suppliers, manufacturers, retailers, port and terminal operators, customs authorities, restaurant owners, consumers, waste disposal actors.
Rights, rules, and responsibilities	IBM owns and is responsible for the Food Trust Platform, but other service providers may build applications or services on top. Data is owned and controlled by the registered actors that own it before it is uploaded to Food Trust. A council of industry representatives (IBM Food Trust Advisory Council) sets the engagement rules. Trust anchors are responsible for resource ownership, verification, endorsement, and data extractions.
Incentives	Real-time, trustworthy information on the food ingredients and provenance data. Increased supply chain efficiency. Competitive advantage. Better customer relationship. Identifying gaps in the transportation networks. Efficiency in logistics. Less food contamination.
Technological aspects	The IBM Blockchain Platform is built on HyperLedger Fabrik. IBM Cloud.
Business aspects	Large enterprises and SMEs in the food industry pay a subscription fee for some services.
Legal and regulatory aspects	Global Standards One (GS1). EPC Information Services (EPCIS) Standard. ISO-8601. National, international and regional laws concerning the actors (e.g., Food Safety Modernization Act). Agreements between IBM and registered actors.
Congruence/ fit/ interactions between different aspects	The IBM Food Trust solves a real problem by providing a technological solution and complementing incentives for various actors.
Interdependence and conflicts	Different actors are interdependent within the same supply chain that rely on each other's data.
Equilibrium	The key pillar of ensuring equilibrium is the Advisory Council and the Practical Byzantine Fault Tolerance consensus algorithm.
Capacity for feedback	Actors have the opportunity to influence, guide, and provide expertise to the system's operations.
Adaptation principle	"The Food Trust Governance Model is continually re-evaluated and updated based on the expansion of the solution, member needs, technology innovation, and regulatory changes." [88]
Equifinity	There is no data on how other governance models might affect the success of IBM Food Trust system.
Lifecycle stages	The system has gone through the design phase and is currently in the operating phase.

Table 8
Some key considerations related to the governance of blockchain systems.

Building block/system principle	Questions
Inputs	• What are the key factors affecting the success and sustainability of the system? • What is the scope of the system?
Outputs	• How can we measure the success of the system?
Technical and social means of blockchain governance	• What decisions should be automatized? What decisions require human interventions?
Actors and their roles	• Who are the key actors, and what roles do they have? Who are the customers and the infrastructure providers? Who are the collaborative partners? Who are the end users? Are the actors individuals, organizations, or other entities?
Rights, rules, and responsibilities	• What rights and rules exist in the system? (e.g., access rights/rules, control rights/rules, development rights/rules, voting rights/rules, decision rights/rules, ownership rights/rules) • What responsibilities exist in the system? (e.g., responsibility for maintaining the infrastructure, developing an application, etc).>
Incentives	• What are the incentives for the actors or roles? Why would they join the system, and why would they continue contributing? (e.g., monetary motivations, non-monetary incentives such as reputation, visibility, shared norms, gaining experience, networking, collaborating)
Technological aspects	• What smart contracts, oracles, frameworks, and data the system requires for off-chain governance? • How do the actors communicate and collaborate?
Business aspects	• What is the key value the system provides? • What is the value proposition? • What is the revenue model? • What are the greatest cost factors and the key activities for value creation and capture? • Does the system benefit from launching an Initial Coin Offering?
Legal and regulatory aspects	• What standards (e.g., industry or technological standards) does the system comply with? • What laws, acts, directives, or regulations the system complies with?
Congruence/ fit/ interactions between different aspects	• Do the different components fit?
Interdependence and conflicts	• Where are the greatest tensions in the system? • What are the greatest dependencies in the system?
Equilibrium	• What are the mechanisms that ensure that the system operates sustainably?
Capacity for feedback	• What are the channels for feedback?
Adaptation principle	• How the system adapts to unexpected changes?
Equifinity	• Could the system achieve the same outcome using different governance models?
Lifecycle stages	• How will the governance of the systems change according to their lifecycle stage?

DAOAnalyzer could provide meaningful insights into the governance of public blockchain systems. One great example of such an analysis is provided by Faqir-Rhazoui et al. [32], who found large differences among the DAO platforms related to growth, activity, and voting results. Fourth, the articles were collected in spring 2021; thus, including articles published after that in the systematic literature review process is left for future research.

6. Concluding remarks

Governance decisions in decentralized systems cannot be made solely by focusing on the key components from one specific theory (e.g., decision rights, accountability, and incentives from IT governance theory). Instead, making governance decisions needs a comprehensive analysis of the system. We define blockchain governance from a holistic perspective by integrating insights from recent work. That is, blockchain governance encompasses technical and social means to make decisions on the individual, community, organizational, inter-organizational, national, international levels related to actors, roles, rights, incentives, responsibilities, rules, and the business, technological, legal, and regulatory aspects of a blockchain system during its whole lifecycle. This definition is novel due to its comprehensive characteristic. It provides a systematic viewpoint on the governance decisions that must be made during designing, operating, and managing blockchain systems during crises.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

[1] V. Chang, P. Baudier, H. Zhang, Q. Xu, J. Zhang, M. Arami, How blockchain can impact financial services – the overview, challenges and recommendations from expert interviewees, Technol. Forecast. Soc. Change 158 (2020), 120166, https://doi.org/10.1016/j.techfore.2020.120166.
[2] Panin, A., Kemell, K.-K., & Hara, V. (2019). Initial Coin Offering (ICO) as a fundraising strategy: a multiple case study on success factors. In S. Hyrynsalmi, M. Suoranta, A. Nguyen-Duc, P. Tyrväinen, & P. Abrahamsson (Eds.), Software Business (Vol. 370, pp. 237–251). Springer International Publishing. 10.1007/978-3-030-33742-1_19.
[3] M. Zachariadis, G. Hileman, S.V. Scott, Governance and control in distributed ledgers: understanding the challenges facing blockchain technology in financial services, Inf. Circ. - Aust., C. S. I. R. O., Min. Dep., Univ. Melbourne, Ore Dressing Invest. 29 (2) (2019) 105–117, https://doi.org/10.1016/j.infoandorg.2019.03.001.
[4] A. Razzaq, M.M. Khan, R. Talib, A. Butt, N. Hanif, S. Afzal, M. Razeen, Use of blockchain in governance: a systematic literature review, Int. J. Adv. Comput. Sci. Appl. 10 (2019), https://doi.org/10.14569/IJACSA.2019.0100585.
[5] B.D. Trump, E. Wells, J. Trump, I. Linkov, Cryptocurrency: governance for what was meant to be ungovernable, Environ. Syst. Decis. 38 (3) (2018) 426–430, https://doi.org/10.1007/s10669-018-9703-8.
[6] Wang, M. Singgih, J. Wang, M Rit, Making sense of blockchain technology: how will it transform supply chains? Int. J. Prod. Econ. 211 (2019) 221–236, https://doi.org/10.1016/j.ijpe.2019.02.002.
[7] P.D. Filippi, C. Wray, G. Sileno, Smart contracts, Internet Policy Review 10 (2) (2021). https://policyreview.info/glossary/smart-contracts.
[8] M. Poblet, D.W.E. Allen, O. Konashevych, A.M. Lane, C.A. Diaz Valdivia, From Athens to the blockchain: oracles for digital democracy, Front. Blockchain 3 (2020). https://www.frontiersin.org/articles/10.3389/fbloc.2020.575662.
[9] O. Rikken, M. Janssen, Z. Kwee, Governance challenges of blockchain and decentralized autonomous organizations, Inform. Polity 24 (4) (2019) 397–417, https://doi.org/10.3233/IP-190154.
[10] T. Kolehmainen, G. Laatikainen, J. Kultanen, E. Kazan, P. Abrahamsson, Using blockchain in digitalizing enterprise legacy systems: an experience report, in: International Conference on Software Business, 2020, pp. 70–85.
[11] V. Shermin, Disrupting governance with blockchains and smart contracts, Strategic Change 26 (5) (2017) 499–509, https://doi.org/10.1002/jsc.2150.
[12] R. Beck, C. Muller-Bloch, J.L. King, Governance in the blockchain economy: a framework and research agenda, J. Assoc. Inform. Syst. 19 (10) (2018) 1020–1034, https://doi.org/10.17705/1jais.00518.
[13] R. van Pelt, S. Jansen, D. Baars, S. Overbeek, Defining blockchain governance: a framework for analysis and comparison, Inform. Syst. Manage. (2019), https://doi.org/10.1080/10580530.2020.1720046.
[14] P. De Filippi, B. Loveluck, The invisible politics of Bitcoin: governance crisis of a decentralised infrastructure, Internet Policy Rev. (2016). https://hal.archives-ouvertes.fr/hal-01382007.
[15] W. Reijers, I. Wuisman, M. Mannan, P. De Filippi, C. Wray, V. Rae-Looi, A. Cubillos Vélez, L. Orgad, Now the Code Runs Itself: On-Chain and Off-Chain Governance of Blockchain Technologies, Topoi, 2018, https://doi.org/10.1007/s11245-018-9626-5.

[16] P. Tasca, C.J. Tessone, Taxonomy of Blockchain Technologies. Principles of Identification and Classification, 1708, ArXiv, 2018, p. 04872 [Cs], http://arxiv.org/abs/1708.04872.
[17] P. De Filippi, M. Mannan, W. Reijers, Blockchain as a confidence machine: the problem of trust & challenges of governance, Technol. Soc. 62 (2020), 101284.
[18] Van Deventer, M.O., Brewster, C., & Everts, M. (2017). Governance and business models of blockchain technologies and networks.
[19] Atzori, M. Blockchain Technology and Decentralized Governance: Is the State Still Necessary? Available at SSRN 2709713 (2015). https://associazioneblockchain.it/wp-content/uploads/2015/12/SSRN-id2709713.pdf.
[20] R. Ziolkowski, G. Parangi, G. Miscione, G. Schwabe, Examining gentle rivalry: decision-making in blockchain systems, in: Hawaii International Conference on System Sciences, 2019, https://doi.org/10.24251/HICSS.2019.550.
[21] O. Nilsson, D. Garagol, Public blockchain communities A study on how governance mechanisms are expressed within blockchain communities. https://www.semanticscholar.org/paper/Public-blockchain-communities-A-study-on-how-are-Nilsson-Garagol/28820f279360f9a5111fb89062f238fa7616d241?p2df.
[22] P. De Filippi, G. Mcmullen, Governance of blockchain systems: governance of and by distributed infrastructure [Research Report], Blockchain Res. Instit. COALA (2018). https://hal.archives-ouvertes.fr/hal-02046787.
[23] G. Laatikainen, T. Kolehmainen, P. Abrahamsson, Self-sovereign Identity ecosystems: Benefits and Challenges, Scandinavian Conference on Information Systems, 2021.
[24] G. Laatikainen, T. Kolehmainen, M. Li, M. Hautala, A. Kettunen, P. Abrahamsson, Towards a Trustful Digital world: Exploring self-Sovereign Identity Ecosystems, arXiv Preprint arXiv, 2021, 2105.15131.
[25] G. Laatikainen, M. Li, P. Abrahamsson, Blockchain governance: a dynamic view, in: X. Wang, A. Martini, A. Nguyen-Duc, V. Stray (Eds.), Software Business, Eds., Springer International Publishing, 2021, pp. 66–80, https://doi.org/10.1007/978-3-030-91983-2_6.
[26] D.A. Nadler, M.L. Tushman, A model for diagnosing organizational behavior, Organ. Dyn. 9 (2) (1980) 35–51, https://doi.org/10.1016/0090-2616(80)90039-X.
[27] C. Post, R. Sarala, C. Gatrell, J.E. Prescott, Advancing theory with review articles, J. Manage. Stud. 57 (2) (2020) 351–376, https://doi.org/10.1111/joms.12549.
[28] M. Andoni, V. Robu, D. Flynn, S. Abram, D. Geach, D. Jenkins, P. McCallum, A. Peacock, Blockchain technology in the energy sector: a systematic review of challenges and opportunities, Renew. Sustain. Energy Rev. 100 (2019) 143–174, https://doi.org/10.1016/j.rser.2018.10.014.
[29] A. Cohn, T. West, C. Parker, Smart After All: Blockchain, Smart Contracts, Parametric Insurance, and Smart Energy Grids, April 24, Georgetown Law Technology Review, 2017, https://georgetownlawtechreview.org/smart-after-all-blockchain-smart-contracts-parametric-insurance-and-smart-energy-grids/GLTR-04-2017/.
[30] Wang, P De Filippi, Self-sovereign identity in a globalized world: credentials-based identity systems as a driver for economic inclusion, Front. Blockchain 2 (2020), https://doi.org/10.3389/fbloc.2019.00028.
[31] Y. Chen, C. Bellavitis, Blockchain disruption and decentralized finance: the rise of decentralized business models, J. Bus. Ventur. Insights 13 (2020) e00151, https://doi.org/10.1016/j.jbvi.2019.e00151.
[32] Y. Faqir-Rhazoui, J. Arroyo, S. Hassan, A comparative analysis of the platforms for decentralized autonomous organizations in the Ethereum blockchain, J. Internet Serv. Appl. 12 (1) (2021) 9, https://doi.org/10.1186/s13174-021-00139-6.
[33] Jensen, J.R. (2021). Empirical evidence from four governance token distributions. 9.
[34] Hsieh. (2017). The internal and external governance of blockchain-based organizations: evidence from cryptocurrencies. 26.
[35] J. Schmeiss, K. Hoelzle, R.P.G. Tech, Designing governance mechanisms in platform ecosystems: addressing the paradox of openness through blockchain technology, Calif. Manage. Rev. 62 (1) (2019) 121–143, https://doi.org/10.1177/0008125619883618.
[36] Y. Chen, I. Pereira, P. Patel, Decentralized governance of blockchain platforms (SSRN Scholarly Paper ID 3553382), Soc. Sci. Res. Netw. (2020). https://papers.ssrn.com/abstract=3553382.
[37] J. Pereira, M.M. Tavalaei, H. Ozalp, Blockchain-based platforms: decentralized infrastructures and its boundary conditions, Technol. Forecast. Soc. Change 146 (2019) 94–102, https://doi.org/10.1016/j.techfore.2019.04.030.
[38] Allen, & Berg. (2020). Blockchain governance: what we can learn from the economics of corporate governance. 14.
[39] M. Lacity, Addressing key challenges to making enterprise blockchain applications a reality, MIS Qu. Exec. 17 (3) (2018). https://aisel.aisnet.org/misqe/vol17/iss3/3.
[40] Carter, N. (2017). A cross-sectional overview of cryptoasset governance and implications for investors. 61.Available at https://niccarter.info/wp-content/uploads/dissertation_UoE_1617.pdf.
[41] J. Mattila, T. Seppälä, Distributed governance in multi-sided platforms: a conceptual framework from case: bitcoin, in: A. Smedlund, A. Lindblom, L. Mitronen (Eds.), Collaborative Value Co-Creation in the Platform Economy, Eds., Springer, 2018, pp. 183–205, https://doi.org/10.1007/978-981-10-8956-5_10.
[42] N.M. Brennan, N. Subramaniam, C.J. van Staden, Corporate governance implications of disruptive technology: an overview, Br. Account. Rev. 51 (6) (2019), 100860, https://doi.org/10.1016/j.bar.2019.100860.
[43] F. Lumineau, W. Wang, O. Schilke, Blockchain governance—A new way of organizing collaborations? Organization Science 32 (2) (2021) 500–521.
[44] B. Arruñada, L. Garicano, Blockchain: the birth of decentralized governance (SSRN Scholarly Paper ID 3160070), Soc. Sci. Res. Netw. (2018), https://doi.org/10.2139/ssrn.3160070.
[45] B.E. Lee, D.J. Moroz, D.C. Parkes, The Political Economy of Blockchain Governance (SSRN Scholarly Paper ID 3537314), Soc. Sci. Res. Netw. (2020), https://doi.org/10.2139/ssrn.3537314.
[46] P. Hacker, Corporate governance for complex cryptocurrencies? A framework for stability and decision making in blockchain-based organizations, in: Regulating Blockchain (Ed.), Ioannis Lianos, Georgios Dimitropoulos, and Stefan Eich, Edited by Philipp Hacker, Oxford University Press, 2019, pp. 140–166, 2019, Pp, https://www.academia.edu/34762203/Corporate_Governance_for_Complex_Cryptocurrencies_A_Framework_for_Stability_and_Decision_Making_in_Blockchain-Based_Organizations.
[47] W. Reijers, F. O'Brolcháin, P. Haynes, Governance in blockchain technologies & social contract theories, Ledger 1 (2016) 134–151, https://doi.org/10.5195/ledger.2016.62.
[48] Y.-.C. Hsieh, K.-.Y. Lin, C. Lu, K. Rong, Governing a sustainable business ecosystem in Taiwan's circular economy: the story of spring pool glass, Sustainability 9 (6) (2017) 1068, https://doi.org/10.3390/su9061068.
[49] C.L. Reyes, N.G. Packin, Distributed governance, SSRN Electronic Journal (2016), https://doi.org/10.2139/ssrn.2884978.
[50] M. Ertz, É. Boily, The rise of the digital economy: thoughts on blockchain technology and cryptocurrencies for the collaborative economy, Int. J. Innov. Appl. Stud. 3 (4) (2019) 84–93, https://doi.org/10.1016/j.ijis.2019.12.002.
[51] G. Benedict, Challenges of DLT-enabled scalablegovernance and the role of standards, J. ICT Standard. 7 (3) (2019) 195–208, https://doi.org/10.13052/jicts2245-800X.731.
[52] van Deventer, O., Berkers, F., Vos, M., Zandee, A., Vreuls, T., van Piggelen, L., Blom, A., Heeringa, B., Akdim, S., van Helvoort, P., van de Weem, L., & van de Ruit, D. (2018). Techruption Consortium Blockchain – what it takes to run a blockchain together. https://doi.org/10.18420/BLOCKCHAIN2018_06.
[53] Smit, K., el Mansouri, J., Saïd, S., van Meerten, J., & Leewis, S. (2020). Decision rights and governance within the blockchain domain: a literature analysis.
[54] M. Crepaldi, Why blockchains need the law: secondary rules as the missing piece of blockchain governance, in: Proceedings of the Seventeenth International Conference on Artificial Intelligence and Law, 2019, pp. 189–193.
[55] M. Campbell-Verduyn, Bitcoin and beyond: Cryptocurrencies, Blockchains and Global Governance, 2017. Taylor & Francis.
[56] S. DiRose, M. Mansouri, Comparison and analysis of governance mechanisms employed by blockchain-based distributed autonomous organizations, in: 2018 13th Annual Conference on System of Systems Engineering (SoSE), 2018, pp. 195–202, https://doi.org/10.1109/SYSOSE.2018.8428782.
[57] M. Baudlet, F. Doudou, Y. Taenaka, Y. Kadobayashi, The best of both worlds: a new composite framework leveraging pos and pow for blockchain security and governance, 2020 2nd Conference on Blockchain Research & Applications for Innovative Networks and Services (BRAINS) (2020) 17–24.
[58] D. Katz, R.L. Kahn, The Social Psychology of Organizations, 2, Wiley New York, 1978.
[59] D.J. Schleicher, H.M. Baumann, D.W. Sullivan, P.E. Levy, D.C. Hargrove, B. A. Barros-Rivera, Putting the system into performance management systems: a review and agenda for performance management research, J. Manage. 44 (6) (2018) 2209–2245, https://doi.org/10.1177/0149206318755303.
[60] S. Kraus, M. Breier, S. Dasí-Rodríguez, The art of crafting a systematic literature review in entrepreneurship research, Int. Entrepr. Manage. J. (2020), https://doi.org/10.1007/s11365-020-00635-4.
[61] J.F. Wolfswinkel, E. Furtmueller, C.P. Wilderom, Using grounded theory as a method for rigorously reviewing literature, Eur. J. Inf. Syst. 22 (1) (2013) 45–55.
[62] N. Bakkalbasi, K. Bauer, J. Glover, L. Wang, Three options for citation tracking: google scholar, scopus and web of science, Biomed. Digit. Libr. 3 (1) (2006) 1–8.
[63] K.R. Mckeown, Challenges and solutions for libraries in serving entrepreneurship needs: findings from ProQuest research, J. Bus. Finance Librarianship 15 (3–4) (2010) 253–260.
[64] ATLAS.ti. (2022). https://atlasti.com/product/windows/.
[65] Locke, K. (2002). The grounded theory approach to qualitative research.
[66] D.A. Gioia, K.G. Corley, A.L. Hamilton, Seeking qualitative rigor in inductive research: notes on the Gioia methodology, Organ. Res. Methods 16 (1) (2013) 15–31, https://doi.org/10.1177/1094428112452151.
[67] A. Strauss, J. Corbin, Grounded theory methodology: an overview. Handbook of Qualitative Research, Sage Publications, Inc, 1994, pp. 273–285.
[68] G. Schwabe, The Role of Public Agencies in Blockchain consortia: Learning from the Cardossier, Information Polity, Preprint, 2019, pp. 1–15.
[69] D. McCurdy, The Role of collaborative governance in blockchain-enabled supply chains: a proposed framework, Bus. Admin. Dissert. (2020). https://scholarworks.gsu.edu/bus_admin_diss/131.
[70] D. Meijer, J. Ubacht, The Governance of Blockchain Systems from an Institutional perspective, a Matter of Trust Or control? Dgo, 2018, p. 18, https://doi.org/10.1145/3209281.3209321.
[71] A. Diaz-Valdivia, M. Poblet, Connecting the Grids: A Review of Blockchain Governance, Distributed Energy Transitions, 2020. Available at SSRN 3777293.
[72] U. Gasser, R. Budish, S.M. West, Multistakeholder as Governance Groups: observations from Case Studies, SSRN Electr. J. (2015), https://doi.org/10.2139/ssrn.2549270.
[73] B.J. Bushee, J.E. Core, W. Guay, S.J. Hamm, The role of the business press as an information intermediary, J. Account. Res. 48 (1) (2010) 1–19.
[74] A. Dyck, N. Volchkova, L. Zingales, The corporate governance role of the media: evidence from Russia, J. Finance 63 (3) (2008) 1093–1135.
[75] T. John, M. Pam, Complex adaptive blockchain governance, MATEC Web Conf. 223 (2018) 01010.

[76] M. Lacity, Z. Steelman, P. Cronan, Blockchain Governance models: Insights for Enterprises, University of Arkansas, 2019.

[77] Alston, E., Law, W., & Murtazashvili, I. (2020). Can permissionless blockchains avoid governance?.

[78] Hofmann, A., Schatz, F.J., & Winkelmann, A. (2020). Uncovering the mining behaviour in proof-of-work blockchains. In Proceedings of the 28th European Conference on Information Systems (ECIS) An Online AIS Conference, June 15-17, 2020. https://aisel.aisnet.org/ecis2020_rp/203.

[79] V. Midha, A. Bhattacherjee, Governance practices and software maintenance: a study of open source projects, Decis. Support Syst. 54 (1) (2012) 23–32.

[80] Karjalainen, R. (2020). Governance in decentralized networks. Available at SSRN 3551099.

[81] P. Wells, Economies of scale versus small is beautiful: a business model approach based on architecture, principles and components in the beer industry, Organ. Environ. 29 (1) (2016) 36–52.

[82] B. Demil, X. Lecocq, Business Model Evolution: in Search of Dynamic Consistency, Long Range Plann. 43 (2010) 227–246.

[83] Smith, Crown, 2019 Review: Distributed Governance, Smith + Crown, 2019. https://smithandcrown.com/research/2019-review-distributed-governance/.

[84] P.D. Filippi, A. Wright, 4. smart contracts as legal contracts. In 4. Smart Contracts As Legal Contracts, Harvard University Press, 2018, pp. 72–88, https://doi.org/10.4159/9780674985933-005.

[85] M. Hütten, The soft spot of hard code: blockchain technology, network governance and pitfalls of technological utopianism, Glob. Netw. 19 (3) (2019) 329–348.

[86] D.W. Allen, C. Berg, S. Davidson, J. Potts, Property rights, knowledge commons, and blockchain governance, Govern. Markets Knowl. Commons (2021) 159.

[87] Howell, B.E., Potgieter, P.H., & Sadowski, B.M. (2019). Governance of blockchain and distributed ledger technology projects. Available at SSRN 3365519.

[88] IBM Food Trust. (2022). https://www.ibm.com/blockchain/solutions/food-trust.

[89] K. Werbach, Trust, but verify: why the blockchain needs the law (SSRN Scholarly Paper ID 2844409), Soc. Sci. Res. Netw. (2017), https://doi.org/10.2139/ssrn.2844409.

[90] J. Schad, P. Bansal, Seeing the forest and the trees: how a systems perspective informs paradox research, J. Manage. Stud. 55 (8) (2018) 1490–1506.

[91] Q. DuPont, Experiments in algorithmic governance: a history and ethnography of "The DAO," a failed decentralized autonomous organization, Bitcoin Beyond (2017) 157–177.

[92] A. Osterwalder, Y. Pigneur, C.L. Tucci, Clarifying business models: origins, present, and future of the concept, Commun. Assoc. Inform. Syst. 16 (1) (2005) 1.

[93] V. Garousi, M. Felderer, M.V. Mäntylä, Guidelines for including grey literature and conducting multivocal literature reviews in software engineering, Inf. Softw. Technol. 106 (2019) 101–121, https://doi.org/10.1016/j.infsof.2018.09.006.