DECISION-MAKING IN BLOCKCHAINS

Research Paper

Abstract

Blockchain platforms are a new technology that allow for innovative business models. However, due to the decentralized aspect of blockchains, new organizational challenges arise. Blockchains require intricate governance mechanisms to align all interests of the involved stakeholders. A crucial part of blockchain governance is decision-making, i.e., the way how a community of a blockchain platform is able to reach decisions. While blockchain governance as a whole has received considerable interest of academia, blockchain decision-making has not yet been sufficiently addressed. Through an exploratory multiple case study, we create a framework to analyse blockchain decision-making and identify five different archetypes of decision-making. Even though blockchains are decentralized platforms, we can show that there are central elements for every archetype. The degree of this centralization varies across archetype and might be connected to the business cases of the different platforms. Furthermore, many factors of decision-making process are still off-chain and only a few factors are truly on-chain. We arrived at these insights through a first stsuctured approach for decision-making in blockchains. Thus, we provide new tools for researcher and practitioners and pave the way to novel blockchain applications with sound decision-making mechanisms.

Keywords*: Blockchain, Decision-Making, Governance, Framework, Archetypes*

1 Introduction

David Chaum (1983) already introduced the idea of a digital cash system which should be anonymous but still capable to provide a proof of payment. Later, the computer scientist Nick Szabo suggested a mechanism for a decentralized digital currency called 'Bit Gold' (Szabo, 2005), However, all the proposed digital currency systems couldn't solve one essential problem in a decentralized way: making spending the same digital token more then once impossible. To overcome this 'double-spending problem' all digital cash systems need to have some sort of a central authority to keep records of the individual account balances. It was only in 2008, when Satoshi Nakamoto (2008) could finally porpose a solution to the double-spending problem by timestamping transactions in a purely peer-to-peer network through hashing them into an ongoing chain of hash-based proof-of-work. This 'chain of blocks' would thereby build a public verifiable record that cannot be changed without redoing the proof-of-work. Based on this idea, a disperse group of cryptographers and software developers started in 2009 to build 'Bitcoin', the first purely decentralized peer-to-peer cryptocurrency network based on the later called 'blockchain' technology.

However, blockchain is not merely the technology that underpins cryptocurrencies and other decentralized applications. Rather, blockchains form complex socio-economic systems allowing for the creation and exchange of digital values in a decentralized fashion. In the last few years, a wide variety of these systems have emerged (Spychiger et al., 2021). These systems include many different stakeholders such as token holders, network validators, core and application developers, founders and many more (Allen & Berg, 2020). It remains a challenge how these stakeholders collectively take decisions that are needed to evolve a blockchain platform (Rikken et al., 2019). In other words, a solid blockchain governance is needed to make sure that a decentralized blockchain platform may be governed in a way that guarantees its ability to adjust to future change and assure its prospering.

Having said this, what exactly is blockchain governance? Several authors have tried to provide a framework to define blockchain governance. Beck et al. (2018) define blockchain governance along three dimensions: *decision rights, accountability* and *incentives.* The interplay of these three dimensions determines blockchain governance. Compared to traditional IT governance, blockchain governance has more decentralized decision rights, accountability is rather technically enabled than institutionally set, and incentives alignment becomes more important. The dimensions *decision-making* and *incentives* are also identified by van Pelt et al. (2021) among *roles, membership, communication,* and *formation and context.* Along these dimensions, they also differ between *on-chain* and *off-chain* to refer to elements that are situated within and outside of the blockchain platform. This differentiaton has also been made by Reijers et al. (2018) who point out a potential tension between a strictly *on-chain* governance and *off-chain* governance mechanisms. Especially in exeptional situations, *off-chain* governance may play a crucial role and blockchains become vunerable to private interest exerted through this mechanisms. As a consequence, *off-chain* governance needs to be considered in the design of blockchain governance.

A particular important pillar of blockchain governance is decision-making. As Ziolkowsi et al. (2020) show, blockchain systems are full of decision problems. They identify four main decision areas in blockchain governance: membership considerations, balance between internal and external legitimaton, reduction of human interventions, and management of flexibility and adaptility of blockchain systems. Also Leewis et al. (2021) emphasize the importance of decision-making in blockchains. They focus on decision rights and show that it is important to define decision rights early on as otherwise it becomes more complex to introduce blockchain governance. Liu et al. (2021a) even argue that the purpose of blockchain governance consists of supporting the decision-making process in blockchains. Within a systemic literature review on blockchain governance, Liu et al. (2021b) investigated the word count in the definition of

blockchain governance in 34 primary studies and the most frequent word that they found was *decision.*

While there are frameworks that study blockchain governance, no such frameworks are out there that allow for the categorization of decision-making in blockchain platforms. However, decision-making is a pivotal part of each blockchain platform and differs among the various platforms. Therefore, we answer the following research questions with this work:

RQ1: How can blockchain decision-making be categorized?

RQ2: What kind of decision-making approaches are used in blockchain platforms?

The remainder of the paper is structured as follows: in the next section, we explain our methodology. Section 3 elaborates on the related work of blockchain governance and decision-making. Section 4 presents the blockchain decision-making framework and the identified archetypes. Section 5 discusses the implications of the results. Section 6 concludes.

2 Methodology

In the following, we will detail this research's methodology along the overall applied methodology, how the analytical lens has been built, and how data has been gathered and subsequently analyzed.

2.1 Main Methodology

This research follows the main methodological approach of an exploratory multiple case study proposed by Yin (2009). As we argue in the related work section, this case study is motivated by the lack of existing literature to provide a lens to study the decision-making within public and permissionless blockchain systems from a governance perspective, which has led to numerous decision-making conflicts within existing systems and to the halt of many more. To study this phenomenon, namely decision-making within blockchain systems, we utilize several sets of data to 1) create a lens to study decision-making within blockchain systems, 2) apply

this lens to a set of chosen blockchain systems based on available information on these, and 3) derive insights and critically reflect on the developed lens to inform future research. In the following, this research will detail the aforementioned steps.

2.2 Data

After our lens was built, we searched for mature blockchain cases to which our lens could be applied. The blockchain domain brought forward thousands of alike projects, counting in forks of major blockchains. For the sake of this research, we focused on five, primarily public and permissionless blockchain systems, which are 1) publicly well-documented, 2) have existing scientific material, and 3) run for several years, which proves their maturity, namely: Bitcoin, Tezos, Stellar, Decred, and Ripple. We believe, that different information sources, academic and non-academic, are especially important as research on blockchain systems can be considered in its infancy. Especially these system's maturity is an important characteristic to study their decision-making, as it can be argued that governance matters evolve over time, when technical choices are made.

To retrieve data on these systems, we initiated a keyword search on various search engines covering the keywords of "(<project>) Governance", "(<project>) Whitepaper", "(<project>) Stakeholder", and variations of these. In addition, because research on these platforms can be considered relatively young, also other websites have been considered, such as websites, fora, specialized blogs, or social media posts and videos to triangulate our findings. In total, our data search yielded 159 documents, of which 34 are academic papers and 125 are complementary files, with the most (15) academic papers being found on Bitcoin and Ripple (8), and the complementary files being evenly distributed.

2.3 Towards a Lens for Decision-Making within Blockchain Governance

We utilized the framework of van Pelt et al. (2021) for general blockchain governance as the starting point to analyse the data collected from the five blockchain platforms. The framework of van Pelt (2021) suits well to study different blockchain governance approaches, but it it can be further specified with respect to decision-making processes. The data collected allowed us to identify different key elements of the blockchain decisions-making process. With the help of additional literature, we iteratively adapted van Pelts (2021) lens to better capture specific characteristics of blockchain decision-making. The resulting framework was then used to identify five different archetypes for blockchain decision-making.

3 Related Work

3.1 Blockchain Governance

The focus of this papers lays on blockchain governance, therefore technical details are only of interest to the extend that they are relevant to understand the most important aspects of this new technology. In line with Ziolkoski et al. (2020), we understand blockchain systems as blockchain technology-based applications and their organizational embedding. Blockchain technologie relies thereby on several very specific principles, which have be summarized by Zheng et al. (2017) as (i) decentralization (no central authority), (ii) persistency (transaction immutability), (iii) auditability (traceability of events), and (iv) anonymity (key pair authentication). From an application perspective blockchain can therefore be understood as a "general-purpose programmable infrastructure with a public ledger that records the computational results" (Xu et al., 2017) or as Vitalik Buterin (2016), the founder of Ethereum coined it: blockchain systems can be seen as 'shared world computing platforms' or 'world computer', "(…)where anyone can upload and run programs that are guaranteed to be executed exactly as written on a highly robust and decentralized consensus network consisting of thousands of computers around the world."

According to Peters and Panayi (2015) blockchain system can be classified along two axes: access to transactions and transaction validation rights, which leads to either public (public transactions, everyone can validate), permissioned (public transactions, restricted validation), or private (private transactions, restricted validation) blockchains. In practices we can find mainly a difference between the application based on public blockchains and permissioned/private blockhain. Established enterprises are thereby mainly investigating the use of permissioned/private blockchain together with other business in consortia (therefore we can call them also 'consortium blockchains') (Rauchs et al., 2019; Vadgama & Tasca, 2021). However, especially if it is about cryptocurrency and digital asset (e.g. non-functional tokens) applications, the most common type to date are public blockchain systems, such as Bitcoin (DuPont, 2017).

The governance of these two different blockchain types is thereby very different. As the main objective of permissioned/private blockchain applications are mainly efficiency, collaboration, and competitive advanges, their approach to governance can be described as 'consortial' with more traditional hierarchical and centralized decision-making processes (Zavolokina et al., 2020). In contrast, the public blockchains are emphasising more the typical blockchain aspects of decentralization and anonymity, which makes their approach to governance more 'tribal', where actors coordinate in loosely defined groups with shared values and interests (Miscione et al., 2018). With the effect that when interests diverge, members of a tribe branch out (forking) and create their own tribe (fork) (Ziolkowski, 2021).

Looking in to the literature, we can find two further distinctions in blockchain governance: *first*, the investigation of blockchain governance can be approached from the perspectives of governance ***through*** or governance ***of*** blockchains (Olnes et al., 2017; De Filippi & Mcmullen, 2018; Miscione et al., 2018), and *second*, can blockchain governance be ***on***-chain or ***off***-chain (De Filippi & Mcmullen, 2018; Reijers et al., 2018). In respect of the first distinction our

research is clearly focusing on the governance of blockchains and is not considering aspects from the governance through blockchain discussion. However, when it is about the second distinction, we can see from the literature that the on-chain/off-chain differntation is very much a question if the governance is directly encoded 'on-chain' into the blockchain system or if governance procedures are arrange 'off-chain' outside of the blockchain system itself (Reijers et al. 2018). The main issue with 'off-chain' governance is thereby, that it is inherently vague and can lead to centralization in areas once thought to be decentralized (De Filippi & Mcmullen 2018; Ziolkowski, 2021).

3.2 Decision-Making in Blockchains

If it comes to a common understanding of 'governance', Bevir (2012) provides a useful general definition by stating that "governance refers (…) to all processes of governing, whether undertaken by a government, market, or network, whether over a family, tribe, formal or informal organization, or territory, and whether through laws, norms, power or language." And further Hufty (2011) defines governance as "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions." Based on these definitions we can state that governance is mainly characterized as a decision-making process between the involved actors of a (social) system. For the purpose of our research, we will therefore define blockchain governance as the processes among the actors involved in a blockchain system to provide decisions for collectively accepted so far unsolved system issues.

The focus on the decision-making process in our research on blockchain governance can thereby be justified by earlier research. As Ziolowski et al. (2019) demonstrated there are a wide range of how decision rights and power can be distributed between the different actors in blockchain system and in many cases these distribution can even evolve and change over time. A dezentralized decision-making process is one of the most important reason why actors like

e.g. application developers, users or investors are choosing a certain blockchain system over another system in the first place (Arruñada & Garicano, 2018). However, as the technologies behind blockchains are rapidly developed further (e.g. proof-of-stake protocols, sharding and cross-chain bridges (King & Nadal, 2012; Luu et al., 2016; Kannengießer et al., 2020), there is an inherent need for blockchain systems to make decisions about adaption and changes in their protocol in a efficient and fast way (Rauchs et al., 2019). Additionally, as the The Dao hack in 2016 showed (Mehar et al., 2019), flaws in codes on blockchain system can be very costly and wrong decisions can lead to security breaches. How decisions are made is therefore a crucial aspects for the long-term endurance of blockchain system (van Deventer et al., 2017).

In their study, Ziolkowski et al. (2019) analysed different blockchain system by looking at decision-making processes in respect to demand management, data authenticity, system architecture development, membership, ownership disputes, and transaction reversals. The authors could thereby identify four main aspects in the decision-making process that characterize in their opinion the different blockchain governance approaches: *first*, the dependance on an external legitimation; *second*, the degree of restrictions imposed on the discretionary power; *third*, the extent of an explicit system access control; and finally *fourth*, the extend of a temporal management of the system by core stakeholders.

4 Results

4.1 Blockchain Decision-Making

Based on the analysis of the related work, a morphological box constructed (Table 1). The factors are split into two groups, off-chain and on-chain. On-chain covers all the activity that is governed by the protocol itself whereas off-chain refers to all factors that are not governed by the protocol. The five decision-making parameters on the first column describe the blockchain platforms along its attributes:

- **Decision-Maker:** the stakeholders involved in the decision-making process of the blockchain platform. The off-chain decision-makers are the developers that contribute to the code base of the platform (Protocol developer), if existing, the legally registered entity behind the protocol (Legal insititution), the parties responsible for verifying transactions on the blockchain (Validators), the owners of the native token of the blockchain platform (Token holders), educational insitutions that research topics related to the blockchain platform (Universities), developers who build applications on the blockchain platform (Application developers) and regulatrory bodies who are interested in regulating activities on the blockchain platform or the platform itself (Regualtors). On-chain decisions can be made by decentralized autonomous organizations (DAO) (Decred, 2022).
- **Incentives/Motivation:** are the rewards that one gets for participating in activities regarding the blockchain platform. Off-chain, some parties don't expect nothing in return for their work and do it in order to foster the common good (Altruism) or to increase their soft power (Reputation). Other participants expect something in return, for example tokens of the native currency of the blockchain platform (Gifts (Airdrops)), financial gains payed by an employer (Salary) or the community of the platform (Community rewards). On-chain the incentives consist of rewards for block production (Block rewards) and transaction processing (Transaction fees) (Carlsten et al., 2016; Nakamoto, 2008). As transaction origins on most blockchains are public, decision-making activities are publicly visible (Accountability), for some actors, the opposite can be the case as they don't have to reveal their true identity in order to cast their vote (Anonymity).
- **Access:** describes the ways that one can participate in the decision-making process and the barriers of entry. Access to decision-making Off-chain can be open to

anyone (Open), but there are also different categories to restrict acces: Access can be granted only to a certain group of of original contributors and enitites that have been recommended by a current decision-maker (Closed-aristocratic) (Walch, 2019; Ethereum, 2022), only employees of a certain legal institution (Closed-employed) (Ripple, 2022) or only entities that have received votes (Closed-elected). On-chain access to the decision-making process can be open to anyone (Public), restricted to parties that pay a fee to access the platform (Semi-Permissioned) or only by admission (Permissioned) (De Angelis et al., 2018).

- **Communication/Coordination:** describes the platforms on which communication and coordination in the decision-making process happens. Off-chain, discussion can happen in the public realm between parties on a multitude of platforms such as social media, vcs and messaging services (Public decentralized). Communication can also take place in press releases or updates provided by a central party (Public centralized) or be published by academic institutions (Academic literature). Off-chain decisions do not have to be openly accessible and can take place in a Non-publicized environment (Private centralized). On-chain communication and coordination can be done by observing and/or placing bets on the outcome of the decision-making process (Prediction markets) (Hanson, 2013; Gnosis, 2020) and the block producers can place information in the blocks that signals readiness for a certain version of the node software (Block information (Signaling)).
- **Voting:** describes the way that decision-makers are determined and how voting power is distributed. Votings power can be obtained by gathering (tokenized) influence (Repuation-based) (De Filippi et al., 2021) or by producing blocks for the blockchain (Validator voting) (Nakamoto, 2008). Voting power can also be determined by the amount of tokens that a party holds (Token-based) or by

delegating voting power to other parties that vote on the behalf of the delegator (Delegated voting) (Tezos, 2021). In certain cases, the voting proces is hidden from the public (Unclear). On-chain, the voting process can either be determined by the protocol itself (Consensus-based) or by smart contracts that sit on top of the platform (Smart contract-based).

Table 1: Blockchain Decision-Making Framework

Decision-maker	*Off-chain*	Protocol developer	Legal institution	Validators	Token holders	Universities	Application developers	Regulators
	On-chain	DAO						
Incentives / Motivation	*Off-chain*	Altruism	Reputation	Gifts (Airdrops)	Salary	Community rewards		
	On-chain	Block rewards	Transaction fees	Accountability	Anonymity			
Access	*Off-chain*	Open	Closed - aristocratic	Closed – employed	Closed - elected			
	On-chain	Public	Permissioned	Semi-permissioned (Buy-in)				
Communication / Coordination	*Off-chain*	Public decentralized	Public centralized	Private centralized	Academic literature			
	On-chain	Prediction markets	Block information (Signaling)					
Votings	*Off-chain*	Repuation-based	Validator voting	Token-based voting	Delegated voting	In-person meetings		
	On-chain	Consensus-based	Smart contract-based					

4.2 Blockchain Decision-Making Archetypes

To identify different blockchain decision-making archetypes, the empirical data allowed us to identify patterns through the direct instantiation of the decision making mechanisms along the parameters in the morphological box. These patterns are understood as combinations of parameters from our morphological box. They represent different approaches for decision-making in blockchain platforms. Table 2 shows the five identified archetypes.

Table 2: Blockchain Decision-Making Archetypes

Archetype	Description
Aristrocratic (Bitcoin)	*The decision-making is mainly decentralized, but still organized in a loose hierarchical manner.* (Protocol developer / Validators ; Altruism ; Block rewards / Transaction fees / Anonymity ; Closed-aristocratic ; Public ; Public decentralized / Academic literature ; Block information (Signaling) ; Validator voting ; Consenus-based)
Foundation – Delegation-based (Tezos)	*A foundation coordinates the decision-making for a decentralized community.* (Protocol developer / Legal institution / Validators / Token holders ; Altruism / Salary ; Block rewards / Transaction fees / Accountability ; Open / Closed-employed ; Semi-permissioned (Buy-in) ; Public decentralized / Public centralized / Academic literature ; Token-based voting / Delegated voting ; Smart contract-based)
Foundation – Validator-based (Stellar)	*The decision-making is organized by a foundation for a few central participants of the platform.* (Protocol developer / Legal institution / Validators ; Altruism / Salary / Community rewards ; Accountability / Anonymity ; Closed-employed / Closed-elected ; Permissioned ; Public decentralized / Public centralized / Academic literature ; Validator voting / In-person meetings ; Consensus-based)
DAO (Decred)	*A DAO coordinates the decision-making for the decentralized community.* (Protocol developer / Legal institution / Validators ; DAO ; Altruism / Gifts (Airdrops) / Salary ; Block rewards / Transaction fees ; Open ; Public / Semi-Permissioned. (Buy-in) ; Public decentralized ; Token-based voting ; Smart contract-based)
Centralized (Ripple)	*A centralized company coordinates the platform and takes the decisions for the network.* (Protocol developer / Legal institution / Validators ; Salary ; Block rewards / Transaction fees / Accountability / Anonymity ; Closed-employed ; Permissioned ; Private centralized ; Unclear)

5 Discussion

Our research suggests important factors to capture decision-making in decentralized blockchain platforms. While there are many applications that can be governed ***through*** blockchains, we focus on the governance ***of*** blockchains (Olnes et al., 2017; De Filippi & Mcmullen, 2018;

Miscione et al., 2018). To understand the decision-making process in blockchains, it is crucial to determine who the actual decision-makers are. This also influences attributes in the other factors of blockchain decision-making. If there is no legal institution backing the governance process, the incentives for participating differ as no salary will be payed. The involvement of different decision-makers determines also the degree of decentralization in the decision-making process. The more the community is involved, the more decentralized the decision-making process.

With respect to ***on***-chain and ***off***-chain governance chain (De Filippi & Mcmullen, 2018; Reijers et al. 2018), we could observe that most of the decision-making elements are placed *off-chain.* Consequently, many decision-making mechanisms (votings) are similar to mechanisms in non-blockchain organisations with the difference being in the inclusiveness of the decision process. In blockchains, the participants are usually anonymous which means that the platforms need to have means to make anonymous participation possible. This in turn also has implications on the voting: An inclusive decision-making process requires mechanisms that allow every vested party to participate. As such, token-based votings are quite common.

A major characteristic of blockchains is that no central authority controls the system (Zheng et al., 2017). This means that no single party has the power to control a blockchain platform. While this might be true for the consensus mechanisms in blockchains, this has to be at least re-evaluated for the decision-making in blockchains. By looking at the five archetypes, we can identify central parties in each of them. Starting with the most obvious, in a *Centralized* decision-making approach (such as in Ripple), the decision-making is completely taken over by a central party – similarly in the *Foundation Validator-based* setting where the decision-making is split across a few central validators. For the *Foundation Delegation-based* model, a central foundation is responsible to coordinate the decision-making. Therefore, no central authority (or group) controls the decision-making mechanism, but there is a foundation that at

least exerts a certain influence and shapes the decision to some extent. Similary, in the *Aristocratic* archetype where no institutionalized organization guides the decision-making, but an informal group of historically connected core members. Eventually, the *DAO* comes closest to decision-making without a central authority.

The decision-making in a platform might be connected to the purpose of the platform. Ripple and Stellar both target banks as their customers. The financial system is a highly regulated sector that requires simplified approaches. Therefore, a rather centralized decision-making approach that can be easily controlled might be more adequate. Tezos wants to provide a platform to build all kind of decentralized applications. They want to include an active community which is also reflected in their delegation-based decision-making mechanism. Bitcoin and Decred want to be a decentralized currency. As a consequence, decentralization is important for both platforms. While Bitcoin has avoided to create any institutionalized setting, Decred has opted for a decentralized autonomous organization.

6 Conclusion

We identified a gap in the current research on blockchain governace. While there are several frameworks looking at blockchain governace, the decision-making in blockchains has been neglected so far. We have collected data on five major blockchain platforms to build a lens for blockchain decision-making. Our blockchain-decision framework contributes to the identified research gap by providing a tool to categorize decision-making in blockchain platforms. We applied our framework to showcase its utility and to extract different archetypes of blockchain decision-making.

Our results suggest that decision-making in blockchains has different degees of decentralization. It can be fully centralized, i.e., in the hand of one company, or rather decentralized and led by a DAO. However, some kind of central element is always needed.

Furthermore, the off-chain aspect is still crucial in understanding decision-making in blockchain platforms.

Whils these are some first insights into the decision-making in blockchain platforms, our work comes with a few limitations. We only looked at a subset of the blockchain ecosystem. To improve our framework and to identify more archetypes, a larger dataset would be helpful. However, we emphasize our contribution to this novel field. Our study is a first step to better understand the decision-making in blockchain platforms. From a methodological standpoint, we admit that interpretation of the collected data might had an influence on the framework development. However, we also stress the equal treatement of the blockchain platforms. Further reproducibility and expert involvments could help to strengthen our approach.

We hope that the developed framework provides a first step to better understand decision-making in blockchains. It can be a starting point for researchers and practioners alike to design and evaluate decision-making approaches in blockchain platforms. This should improve conditions and lead the way to blockchain-based applications and business models.

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