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Non-algorithmic governance mechanisms of blockchain-based decentralized applications: Evidence from multiple cases☆

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ABSTRACT

The rise of Decentralized Applications (DApps) represents a significant shift in how digital services are developed and governed, utilizing blockchain technology to eliminate central oversight and facilitate peer-to-peer interactions. While blockchain's algorithmic governance mechanisms are designed to enforce transparency and decentralization, human-driven processes—such as leadership roles, community engagement, and social norms—continue to play a pivotal role in shaping governance outcomes. This study investigates how these non-algorithmic factors influence the decentralization of DApp governance. Through a multiple case study of seven Decentralized Finance DApps, we analyze the governance structures, decision-making processes, and power dynamics at play. Our findings reveal that, despite the technological promise of decentralization, human-driven processes can reintroduce centralization risks, impacting inclusivity and decision-making. We propose an integrated governance framework that emphasizes human-driven mechanisms, contributing to the discourse on the practical realities of decentralized governance in DApps. The study offers theoretical and empirical insights into how decentralization is enacted and challenged in blockchain-based ecosystems.

1. Introduction

Decentralized Applications (DApps) have emerged as a transformative frontier in blockchain technology, offering the potential to revolutionize how digital services are developed, distributed, and consumed by eliminating centralized control and fostering peer-to-peer interactions (Angelis and Silva, 2019). By leveraging blockchain's inherent features of transparency, security, and immutability (Nakamoto, 2008), DApps aim to democratize digital ecosystems and empower users through enhanced autonomy and ownership (Xu et al., 2019; Zheng et al., 2018). They represent a shift toward decentralized models where users have direct control over their data and transactions, reducing reliance on intermediaries (Chen and Bellavitis, 2020).

Despite these technological advancements, human-driven processes continue to play a significant role in shaping decision-making within DApps (Lumineau et al., 2021; Hassan and De Filippi, 2021). While blockchain technology provides algorithmic governance mechanisms—automated decision-making processes enforced through code—to maintain decentralization and trust (Voshmgir, 2019), these mechanisms alone may not suffice. The rigidity of code and its inability to adapt to unforeseen circumstances highlight significant limitations (Werbach, 2018; Reijers et al., 2016). Conflicts arising from unpredictable events, evolving community values, or the need for protocol upgrades often require human judgment and intervention beyond what algorithmic mechanisms can provide (De Filippi and Loveluck, 2016; Beck et al., 2018). For instance, the infamous DAO hack in 2016 exposed vulnerabilities in smart contracts and necessitated human intervention to resolve the crisis, leading to a contentious hard fork in the Ethereum blockchain (Siegel et al., 2018; DuPont, 2019). This incident underscores the need for flexible governance structures that can respond to emergent issues not pre-programmed into the system (Jentzsch, 2016).

This raises critical questions about the true nature of decentralization in DApps. If human-driven factors influence decision-making processes, to what extent are DApps genuinely decentralized? Evidence suggests that non-algorithmic factors significantly impact governance outcomes (Beck et al., 2018; De Filippi, 2019; Xu et al., 2018), introducing power imbalances, centralization risks and challenges to inclusivity and transparency (Jensen et al., 2021; De Filippi and Loveluck, 2016; Kittur

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et al., 2013). Leadership and core development teams, for instance, often wield significant influence over the direction of DApps, making critical decisions about updates and protocol changes (Davidson et al., 2018; Azouvi et al., 2019). Moreover, if community engagement is crucial for the legitimacy and adaptability of DApps, achieving meaningful participation is challenging due to technical complexities and information asymmetries (Hsieh et al., 2018; von Hippel, 2017). Also incentive structures, which are designed to encourage stakeholder participation, can sometimes lead to unintended consequences such as the concentration of tokens among few participants, thereby undermining decentralization (Atzori, 2015; Lee et al., 2021). Legal and regulatory frameworks also play a role, as compliance requirements can influence the governance structure and operational decisions of DApps (Finck, 2018; Yeung, 2019). Social norms and cultural factors significantly influence governance effectiveness in blockchain ecosystems. Community values and informal practices, in fact, shape decision-making and conflict resolution (Rozas et al., 2021; Ostrom, 1990) and these elements, though not codified, are powerful in maintaining cohesion and guiding actions within the community. Finally, reputation systems also serve as governance mechanisms by influencing stakeholder behavior based on social feedback and trustworthiness (Hassan and De Filippi, 2021; Liu et al., 2022). Participants with higher reputations may wield more influence or be more trusted in governance processes.

If current literature acknowledges all these challenges, often it treats non-algorithmic governance mechanisms in isolation or as peripheral concerns (Lumineau et al., 2021; Wright and De Filippi, 2015). Actually, there is a lack of comprehensive understanding of how human-driven processes shape governance in DApps without necessarily interacting directly with algorithmic mechanisms (Howell et al., 2019; Xu et al., 2018). This gap is particularly pronounced at the application level, where the unique dynamics of individual DApps can lead to varied governance structures and outcomes (Goldsby and Hanisch, 2022; Luu et al., 2016).

This study aims to investigate the following research question: how do non-algorithmic factors influence the decentralization of DApp governance? By addressing this question, we seek to uncover the complexities and nuances of governance in DApps, focusing on the human-driven mechanisms that may reinforce or undermine decentralization (Rozas et al., 2021; Ostrom, 2010). We problematize the notion that DApps are inherently decentralized simply by virtue of their underlying technology and, instead, explore the extent to which human elements impact their governance structures (Buterin, 2017; Tsoukas, 1994). To explore this research question, we focus on DApps in Decentralized Finance (DeFi)—a sector that exemplifies both the potential and the challenges of blockchain-based decentralization (Schär, 2020). DeFi DApps offer financial services without traditional intermediaries, operating in a domain where trust, security, and regulatory compliance are critical (Auer and Claessens, 2018). The high stakes and complexity of DeFi make it an ideal context for examining how non-algorithmic factors influence governance and decentralization. We conduct a multiple case study of seven representative DeFi DApps, selected based on active user metrics to ensure relevance and impact. Through qualitative analysis of their governance structures, decision-making processes, and stakeholder interactions, we identified the human-driven factors at play and assessed their implications for decentralization.

Our research contributes to the academic discourse by highlighting the significant role of non-algorithmic factors in DApp governance, challenging the assumption that technological mechanisms alone suffice for decentralization. We provide empirical evidence on how human-driven processes influence governance outcomes, offering insights into the practical realities of decentralization in DApps. Additionally, we propose a more integrated governance framework that emphasizes human-driven mechanisms, addressing the gap in existing literature and contributing to more effective governance models. Understanding how non-algorithmic factors influence the decentralization of DApp governance is crucial for several reasons. First, it sheds light on potential vulnerabilities and centralization risks that may undermine the goals of decentralization. Second, it informs the design of governance structures that balance technological efficiency with human adaptability and inclusivity. Third, it offers practical guidance for developers, users, investors, and policymakers seeking to navigate and shape the evolving landscape of blockchain-based applications.

In the following sections, we dig deeper into the complexities of blockchain governance (Section 2), focusing on human-driven mechanisms and identifying gaps in current understanding. We then describe our methodology (Section 3), explaining the selection of cases and data collection methods. Our findings (Section 4) reveal the non-algorithmic factors influencing governance in the selected DeFi DApps and their impact on decentralization. In the discussion (Section 5), we analyze these findings in the context of existing theories and propose implications for practice and future research. Finally, we conclude (Section 6) by summarizing our contributions, acknowledging limitations, and suggesting avenues for further investigation.

2. Theoretical background

2.1. The complexity of blockchain governance

Blockchain governance is a multifaceted and evolving field, marked by both convergent and divergent views within academic discourse (Lumineau et al., 2021). While there is general agreement on the intricate nature of governing blockchain systems, scholars offer diverse interpretations and approaches to understanding its complexities (Beck et al., 2018).

A central theme in the literature is the challenge of balancing the ideals of decentralization with practical governance needs. Several studies (De Filippi and Loveluck, 2016; De Filippi and McMullen, 2018; Petersen, 2022) explore the tensions that arise when implementing decentralized autonomy within blockchain networks. These works recognize that, while blockchain technology aspires to eliminate centralized control, achieving true decentralization in practice is fraught with difficulties. The rigidity of predetermined rules and protocols can hinder adaptability to unforeseen and dynamic scenarios (Beck et al., 2018). This limitation reflects a deeper conceptual challenge in reconciling the fixed nature of code with the fluidity of human contexts and needs (Petersen, 2022).

The literature diverges in its emphasis on the role of human elements in blockchain governance. For instance, De Filippi et al. (2020) focus on blockchain as a "confidence machine," highlighting the trust generated through distributed consensus and cryptographic security. This perspective emphasizes the technological strengths of blockchain but may downplay the critical role that human actors play in shaping and directing governance processes. In contrast, Werbach (2018) advocates for a more balanced view that acknowledges the indispensability of human judgment and intervention, especially in resolving disputes and making adaptive decisions. Moreover, De Filippi (2019) highlights the pitfalls of considering blockchain as a "trustless" technology. She argues that, despite the potential for decentralized governance, blockchain networks have, in practice, become increasingly centralized, with significant control exerted by a few large corporations, such as major exchanges and wallet providers. This centralization mirrors the trajectory of the Internet, where decentralized infrastructures did not prevent the concentration of power. De Filippi (2019) emphasizes the urgency of shaping blockchain governance to preserve the distribution of power within these infrastructures.

Scholars also present varied perspectives on the role of centralization in blockchain systems. Halaburda and Mueller-Bloch (2019) argue for the benefits of some degree of centralization, particularly in the early stages of blockchain development. They assert that centralized control can be crucial in steering and stabilizing nascent blockchain networks. This viewpoint is especially relevant in the context of permissioned blockchains, where greater control over the network is achievable

through off-chain agreements. In contrast, Ziolkowski et al. (2020) and Trump et al. (2018) delve into governance implications based on data access and ledger control, suggesting a more nuanced approach to understanding decentralization across different blockchain applications. Balcerzak et al. (2022) contribute to this discourse by conducting a systematic review of decentralized governance systems, integrating insights on blockchain technology and smart contracts. They highlight the importance of smart urban governance and suggest that future research should investigate the governance of blockchain applications using decision-making tools and spatial cognition algorithms. Their work underscores the need for comprehensive frameworks to understand decentralized governance in various contexts.

The contributions of Goldsby and Hanisch (2022) and Lumineau et al. (2021) add depth by providing frameworks for understanding diverse governance mechanisms. However, they also reveal a significant gap in the literature regarding the specific governance needs of DApps. The majority of existing studies focus predominantly on blockchain infrastructure, often overlooking the distinct governance challenges and dynamics at the application level. This oversight signals a need for more detailed research that explores the intricate governance structures within individual DApps, particularly emphasizing the human-driven processes that influence decentralization.

2.2. The pivotal role of non-algorithmic governance mechanisms

While blockchain governance has often centered around algorithmic mechanisms—automated processes enforced through code—the critical role of human-driven, non-algorithmic factors in shaping governance outcomes is increasingly recognized (Beck et al., 2018). These non-algorithmic governance mechanisms encompass human processes, interactions, and social structures that significantly influence decision-making within blockchain ecosystems (Reijers et al., 2016). They include leadership roles, community engagement, communication channels, incentive structures, social norms, legal frameworks, reputation systems, and stakeholder coordination.

Non-algorithmic governance mechanisms play a pivotal role in shaping blockchain ecosystems, addressing complexities that cannot be managed by code alone (Werbach, 2018). One prominent example is the influence of leadership and core development teams. Despite blockchain's aspiration for decentralized control, core developers often wield significant power over a project's direction (Davidson et al., 2018). Their expertise and authority over the codebase enable them to make critical decisions regarding protocol changes, feature implementations, and security updates. Reijers et al. (2016) argue that these developers function as de facto leaders, guiding the technical roadmap and mediating among diverse stakeholder interests. This concentration of influence can undermine decentralization by creating power imbalances and limiting broader community participation in governance (Azouvi et al., 2019).

Building upon the influence of core developers, community engagement emerges as another crucial facet of non-algorithmic governance. The legitimacy and adaptability of blockchain systems hinge on the extent of user and stakeholder involvement in decision-making processes (Kassen, 2023; Liu et al., 2022). Mechanisms such as off-chain discussions, forums, and social media platforms facilitate community input and deliberation (Renwick and Gleasure, 2020). However, challenges like voter apathy, information asymmetry, and technical complexity can impede meaningful engagement (De Filippi and Loveluck, 2016). Consequently, governance processes may be dominated by a small subset of participants, further exacerbating centralization.

Effective communication channels are essential for coordination and decision-making in decentralized systems. Information asymmetry between core teams and other stakeholders can hinder participation and lead to power imbalances (Chen et al., 2021). Stakeholders lacking access to pertinent information are less able to contribute to governance discussions or challenge decisions. By fostering transparent and accessible communication platforms, the community can reduce information gaps, promote inclusivity, and support decentralization (Scholten et al., 2020).

Well-designed incentive structures are fundamental in motivating stakeholder participation and contributing to the ecosystem's health (Beck et al., 2018). Properly aligned incentives encourage behaviors that support decentralization, such as active voting, proposal submissions, and collaborative development. Conversely, misaligned incentives can lead to stakeholder apathy, concentration of power, or even malicious activities (Atzori, 2015). The careful design of token economies, reward mechanisms, and penalty systems plays a critical role in shaping stakeholder behavior and sustaining decentralized governance (Saurabh et al., 2024).

Beyond these mechanisms, off-chain governance processes address issues requiring human judgment or complexities too intricate for smart contracts (Bettini de Miranda et al., 2024). These include discussions, meetings, and voting mechanisms not recorded on the blockchain. While off-chain governance allows for flexibility and adaptability, it can introduce centralization risks if certain groups or individuals disproportionately influence decisions. The lack of transparency and accountability in off-chain processes can exacerbate these risks, potentially undermining decentralization efforts (Wright and De Filippi, 2015).

Interwoven with governance processes are social norms and cultural factors that significantly influence blockchain ecosystems. Community values, shared beliefs, and informal practices shape decision-making and conflict resolution (Rozas et al., 2021). These elements, though not codified, are powerful in maintaining cohesion and guiding actions within the community. They can either reinforce decentralization by promoting collaborative behaviors or hinder it if they foster exclusionary practices (Nguyen Long et al., 2023). Furthermore, the external legal and regulatory environment plays a crucial role in shaping blockchain governance. Compliance with laws and regulations influences governance structures, operational decisions, and the degree of decentralization (Yeung, 2019). Legal frameworks may necessitate certain governance mechanisms to ensure accountability and protect stakeholder interests, impacting how blockchain systems are designed and managed. Adding another layer to governance dynamics, reputation systems serve as mechanisms influencing stakeholder behavior based on social feedback and trustworthiness (Hassan and De Filippi, 2021). Participants with higher reputations may wield more influence or be more trusted in governance processes. While reputation can encourage positive contributions and deter malicious actions, it may also lead to power imbalances if not carefully managed, potentially centralizing influence among a select few (Han et al., 2022).

Overall, these non-algorithmic governance mechanisms are deeply interconnected and create a complex governance landscape in blockchain ecosystems. This complexity underscores the need for a comprehensive framework that emphasizes human-driven processes. Current literature remains fragmented in this sense (Lumineau et al., 2021). This piecemeal approach hinders the development of effective governance models capable of addressing the multifaceted challenges associated with non-algorithmic factors. Consequently, there is a pressing need for systematic research that explores these human-driven governance mechanisms, assessing their influence on governance outcomes and decentralization in blockchain ecosystems.

3. Methodology

3.1. Research design

This study investigates how non-algorithmic, human-driven factors influence the decentralization of DApp governance. Given its nascent and evolving nature, this peculiar literature stream presents a landscape rich in complexity and contextual specificity. Consequently, exploring

such a domain demands a research approach sensitive to the nuances and granular realities of the setting. As the scholarship on non-algorithmic governance mechanisms within DApps is still limited, there exists a pressing need for empirical richness and contextual immersion to uncover the human elements influencing governance outcomes. To this end, we adopt a multiple case study method as our research design.

According to Yin (2018), the multiple case study approach is particularly effective when addressing 'how' and 'why' questions, as it allows for in-depth exploration within the real-life contexts where these phenomena manifest. This method is well-suited for our study since it enables us to delve deeply into the specific human-driven processes that shape governance in DApps. The selection of a multiple case study method is further justified by the emergent nature of our research focus. As noted by Eisenhardt and Graebner (2007), when the phenomenon under scrutiny is new and not well understood, case studies are particularly valuable for theory building. They provide rich, empirical descriptions that can reveal underlying patterns and relationships that are essential for developing a nuanced understanding of complex social phenomena. By examining seven representative Decentralized Finance (DeFi) DApps, selected based on active user metrics, we identified common themes and differences in how human-driven governance mechanisms operate across different contexts. The multiple case study approach facilitates a comprehensive examination through replication logic, where each case serves as a distinct experiment that confirms or contradicts emerging findings, thereby enhancing the robustness and generalizability of our insights (Yin, 2018).

This methodological choice aligns with the exploratory nature of our research question, which seeks to understand the human elements influencing the decentralization of DApp governance. The multiple case study method allows for a holistic and multifaceted examination of DApp governance, accommodating the complexity and dynamism that characterize this field. By disentangling various instances of governance structures across different DApps, we endeavor to uncover patterns, derive insights, and build a nuanced understanding that quantitative methods may not reveal. In focusing on qualitative data and rich contextual analysis, this approach enables us to capture the subtleties of human interactions and social structures that quantitative methods might overlook. It allows us to explore how non-algorithmic factors impact governance outcomes and potentially reintroduce centralization risks. By adopting a multiple case study approach, this research contributes to the academic discourse by providing empirical evidence on the non-algorithmic factors influencing DApp governance. The insights gained from our case studies can inform the development of more effective governance models that prioritize human-driven mechanisms. Additionally, our findings offer practical guidance for practitioners involved in designing and implementing governance frameworks in the realm of DApps.

The detail provided by this method affords will serve as a foundation upon which more predictive theories and models can be constructed as the field matures. By enhancing our understanding of how human-driven processes impact decentralization in DApp governance, we aim to contribute to the development of governance structures that balance technological efficiency with human adaptability and inclusivity.

3.2. Sampling and setting

To establish the foundational criteria for case selection and to pinpoint the target population of DApps for our analysis, we utilized DappRadar,[1] a comprehensive DApp database. Our initial analysis, executed in February 2022, leveraged variables such as balance, user count, and transaction volume, available on the platform. This enabled us to identify a subset of DApps demonstrating notable activity within a specific timeframe. Specifically, we focused on the top 150 DApps ranked by the number of Unique Active Wallets (UAW) engaging with the smart contracts of these DApps in the 30 days leading up to our data extraction. The decision to limit the timeframe to thirty days was due to the constraints imposed by the data availability from the sources we consulted.

From this initial dataset, we proceeded with a theoretical sampling approach as *per* Eisenhardt (1989), guided by criteria aimed at rigorous case selection. Our primary filter targeted DApps that exhibited a certain level of decentralization in their governance structures, as evidenced by secondary sources. Furthermore, we concentrated on those projects that had progressed beyond the initial development phase to ensure the robustness and integrity of the evidence collected. Subsequent to this filtration, we reached out to the management teams or founders of these DApps to gauge their willingness to participate in interviews. This selection process culminated in the identification of 7 distinct cases for our study. Table 1 provides with the details of the selected DApps.

The scope of this research is particularly centered on those DApps that offer financial services, categorically positioned within the sphere of Decentralized Finance (DeFi).[2] The rationale behind this specific focus is twofold. Firstly, the DeFi sector represents one of the most mature and rapidly advancing applications of DApps, as evidenced by a range of reports and academic papers that highlight its significant market growth and developmental strides (e.g., Schär, 2020; WEF, 2021; Blockchain & Web3 Observatory, 2023). Such maturity not only provides a robust context for examining governance structures but also ensures that the findings are grounded in a relatively stable and established subset of the DApp ecosystem.

Secondly, the inherent complexities and challenges that accompany the decentralized financial systems make DeFi a fertile ground for governance research. DeFi is emblematic of the promise and perils of decentralization – presenting unique challenges in terms of regulatory compliance, security, and user protection (Auer and Claessens, 2018). Studying governance within DeFi applications thus offers critical insights into how decentralized models can operate under the strain of high stakes and stringent requirements, which are less pronounced in other domains of DApp deployment.

Moreover, the choice of DeFi is driven by considerations of accessibility and familiarity. DeFi's growing integration with traditional financial systems has catalyzed a higher degree of public and academic awareness, making it a pertinent and accessible area for study. This sector has garnered significant scholarly attention, providing a substantive body of literature to build upon and contextualize our findings (Aramonte et al., 2021; Gudgeon et al., 2020).

3.3. Data collection

To mitigate potential biases and enhance the robustness of our insights, we employed a multifaceted evidence-gathering strategy (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). Our data sources were twofold: primary and secondary. Primary data were gleaned from semi-structured interviews, while secondary data comprised reports, whitepapers, posts on social networks, online news articles, and DApp-related websites.

The primary data corpus was built from 7 semi-structured interviews to members of core teams developing each Dapp. These interviews corresponded to distinct Dapps and were executed over the period from May to September 2022. Each interview began with a brief overview from the informants, where they described the DApp in question and their role within its ecosystem. This was followed by a set of semi-

[1] https://dappradar.com/.

[2] Decentralized finance (DeFi) is a blockchain-based financial infrastructure that has recently gained a lot of traction. The term generally refers to an open, permissionless, and highly interoperable protocol stack built on public smart contract platforms (Schär, 2020).

Table 1
Sample characteristics.

Investigated DeFi DApps	Website	Description
1Inch Network	https://1inch.io	The 1Inch Network, founded in 2020 by Sergej Kunz and Anton Bukov, is a decentralized exchange (DEX) aggregator aimed at optimizing decentralized trading. It sources liquidity from various DEXs to provide users with the best possible trading rates.
Bancor	https://bancor.network	Bancor, established in 2016 by Guy Benartzi, Eyal Hertzog, and Galia Benartzi, is a decentralized liquidity protocol allowing users to convert between different tokens without a traditional order book. Bancor uses automated market makers (AMMs) to reduce slippage and enhance liquidity.
Curve Finance	https://curve.fi/#/ethereum/swap	Curve Finance, established in 2020 by Michael Egorov, is a decentralized exchange optimized for stablecoin trading. It concentrates liquidity in stablecoin pairs to offer low slippage and low fees, facilitating efficient and low-risk trades among different stablecoins.
Furucombo	https://furucombo.app	Furucombo, founded in 2020 by Tony Ma, is a decentralized platform allowing users to create and execute custom DeFi strategies without extensive coding knowledge. It streamlines complex actions and optimizes decentralized finance strategies by combining various DeFi protocols in a single transaction.
Maker Protocol	https://makerdao.com	The Maker Protocol, established in 2015 by Rune Christensen, underlies the decentralized stablecoin Dai and the governance token MKR. Operating on the Ethereum blockchain, it enables users to generate Dai by locking up collateral in a smart contract, with MKR holders governing the system.
SpookySwap	https://spooky.fi/#	SpookySwap, initiated in 2021 (community-driven), is a decentralized exchange and automated market maker (AMM) on the Fantom Opera blockchain. Users can swap and trade tokens, and the community plays a significant role in its development and governance.
Yearn Finance	https://yearn.fi	Yearn Finance, founded in 2020 by Andre Cronje, is a decentralized yield aggregator automating yield farming strategies to optimize returns. It has expanded beyond yield farming to include vaults and other DeFi services.

structured questions grounded in prior research on community roles, governance, incentives, and participation in decentralized systems (see Appendix A). We delved into specifics of DApp governance, examining hierarchies, accountabilities, and decision-making mechanisms, including community input, voting, and conflict resolution. Governance structures were further explored through questions on the DApp's purpose, ideology, and change protocols. The research adopted an iterative data collection approach, allowing us to uncover emerging patterns by adapting subsequent interviews based on insights gathered from earlier conversations (Gioia et al., 2013). This flexible and responsive method helped us refine the interview protocol continuously, capturing relevant and evolving insights as they emerged from informants.

Each interview spanned at least 1 h, utilizing online communication platforms such as Microsoft Teams, Zoom, or Google Meet. All sessions were conducted by the authors, meticulously recorded, and then transcribed word for word to preserve the integrity of the data. To ensure rigor in our analysis, the initial data were cross-validated by the first two authors, who then shared their preliminary interpretations (Bourgeois and Eisenhardt, 1988). Subsequent evaluations by the extended research team served as a mechanism for critical scrutiny. This collaborative and reflective process enabled us to maintain a broad yet detailed analytical perspective (Gioia et al., 2010).

3.4. Data analysis

To align with the established protocols for multiple case study theory development, we engaged in both within-case and cross-case analyses, as advised by Eisenhardt (1989) and Eisenhardt and Graebner (2007). Initially, the primary data were meticulously examined by two authors of the team, who also incorporated secondary data to triangulate findings, a method recommended by Jick (1979). Following this, we applied an inductive approach to our analysis (Saldana, 2009). This entailed a rigorous coding of the interview transcripts, during which we surfaced preliminary concepts. With these initial insights, we advanced to a cross-case examination. By applying a replication logic, we sought to detect patterns across different cases. This step facilitated the aggregation of individual codes into higher-level, second-order themes.

Once we engaged in cross-case analysis, our process became iterative: we oscillated between examining case details, refining our understanding of emerging concepts and dimensions, and consulting relevant academic literature to hone the definitions of our constructs, determine appropriate levels of abstraction, specify construct measurements, and elucidate theoretical linkages (Gilbert, 2005). To ensure the development of a refined and parsimonious theoretical framework, the research team concentrated on the most substantial and consistent findings across cases, following the guidance of Andriopoulos and Lewis (2009). This disciplined focus allowed us to distil a robust set of constructs that held up under rigorous analysis.

4. Findings

4.1. Core team influence

As noted in the literature, while blockchain governance has often focused on algorithmic mechanisms, human-driven, non-algorithmic factors significantly influence decision-making within blockchain ecosystems (Reijers et al., 2016; Beck et al., 2018). These factors, which occur outside algorithmic mechanisms and therefore off-chain, play a crucial role in shaping Dapp governance by addressing complexities that cannot be managed solely by code (Werbach, 2018).

Off-chain decisions are usually overseen by a central entity, often the company or core team behind the application. This is because off-chain decisions, unlike those executed through smart contracts on the blockchain, involve interactions with the outside world. Matters requiring engagement beyond the blockchain sphere cannot be solely governed by code. Compliance with national and supranational regulations, such as registering intellectual property rights and brand ownership, may necessitate the involvement of a legal entity or another business organization in these decision-making processes. Partnerships with entities external to the blockchain also necessitate an organized entity to engage in well-defined and successful collaborations. Establishing arrangements and reaching business agreements with a diverse community would be challenging without official representatives.

Even in DApps that lack a legal entity representing them, it is typically the core team that handles relationships with external organizations, both outside the blockchain and with other blockchain protocols, unless the partnership explicitly involves the governance token. However, although off-chain governance is not a formal process and does not directly impact the DApp, it remains foundational to the decision-making process:

"Today the Maker Foundation is currently no longer in control of the treasury of the project and other things like that. But it still owns some intangible assets like IP and such, and some trademarks" (MakerDAO)

"Basically, 1Inch Foundation is the entity that you can make business with; it's the legal entity that has the rights to the pathfinder proprietary algorithm, that has bank accounts that pays core contributors money. It's really important to understand that fully decentralized organizations cannot do business with non-crypto firms, it's just impossible." (1Inch)

"Partners and actors external to the DAO are controlled by team members. […] I talk almost daily to protocols both within Fantom and outside of it. This would be big things like Chainlink, Anchor, maybe other layer 1s like Optimism or Arbitrium […]. There's constantly talking to protocols that want to partner with us, that want to do coordination, or want to get their tokens whitelisted." (SpookySwap)

"Well, there is an external company which is developing the code of the application." (Curve)

While smart contracts on public blockchains are universally accessible and can be triggered by sending blockchain transactions, a user interface significantly enhances accessibility for non-technical users and improves the overall user experience. Dapps' front-ends are typically provided on traditional web interfaces and require hosting on servers, which involves the need for someone to operate them—a task not easily undertaken by a group of token holders. Additionally, front-end development requires designers and developers to create the interface with which users interact, further emphasizing the dependence of DApps on core teams. It could be possible, however, to build parallel front ends interacting with the same set of smart contracts, but if users were not capable of understanding what is written in the transactions and smart contracts, they would need to trust that the operations performed are those they intended to produce:

"The frontend is hosted by the company" (Curve)

"Upgrades and changes to the website, logos, all that concerns the front end is managed by the team and done without necessarily confronting with the community. We are working to make it the most user friendly as possible and have a great UI and UX." (SpookySwap)

"Several contributors host the front end" (Yearn)

"Dinngo develops features for the Furucombo website. […] we haven't released the front end publicly yet, so only our engineer can develop it" (Furucombo)

"We have a 1Inch foundation. It's made of engineers, business developers, marketing people, legal team, that are necessary to actually build products because, otherwise in a decentralized fashion you would not be able to build products. You need to have this organization type of structure and people working." (1Inch)

The governance mechanisms employed by DApps to distribute decision-making powers often rely on voting systems to determine the acceptance or rejection of a given policy or change. Voting power is contingent on the amount of governance tokens an individual holds or locks into a contract for a specified period. Consequently, wealthier token holders can wield more influence on decisions, and the community, usually entitled to a significant share of the tokens, would ostensibly play a substantial role, especially in the voting process. However, the execution of decisions and the implementation of desired changes into executable "spells" are primarily carried out by the core team. Despite the potential for anyone to develop a contract, token holders often lack the capacity to develop features themselves and lack the authority to compel the development team to do so:

"Only a member of the Foundation, our chief or one of the lead engineers, deploys the smart contracts. After the code has been run through several audits." (1Inch)

"Voting happens on Snapshot, so after a vote has passed the proposal needs to be encoded by the developers of the team. […] it is the team that enforces the decisions." (SpookySwap)

"We want to open the smart contract side and invite all kinds of external builders, but currently after they build the contract, our team members still need to help them to merge the codes into the code base and then to allow users to use it on the Interface." (Furucombo)

"Well, there is a company which is developing the code. There are employees of that company and we typically discuss things with them […]" (Curve)

Indeed, even if a proposal were to be ratified through a DApp vote, without executable code or smart contracts ready to be deployed and enforced, it would not bring immediate change and would merely serve as a signaling system. The same logic applies to off-chain voting as well. This is why, in on-chain governance, proposals are typically voted on only after the code has been written and, in some cases, audited, ensuring that they automatically translate into effective protocol advancements. Depending on the scope and complexity of the decision being taken, either prior to or after the voting process, the core teams may be needed to develop the code, greatly emphasizing their importance in the ecosystem. Most of the time, token holders can contribute to changes that only alter a few parameters of existing contracts. The development teams also function as the workforce of the applications, managing operational responsibilities, administering groups, developing the code, setting the roadmap, and usually managing the budgets to achieve defined goals:

"We try to make sure that the proposal is as clear as possible before it goes to a vote. […] Then we work on whatever is written there and then deploy it." (Bancor)

"The DApp main development is still done by the team members. Those changes that regard the protocol operations are usually done without asking the community […] such as bug fixes, smart contracts maintenance." (SpookySwap)

"When proposals are made, they are not encoded yet. It some of the core team who write the code and deploy it on chain. (Yearn)

"But currently if we want to add a new feature, it is more about like how many development resources we have from the core team members. We will just schedule it and we will just tell the community when we are going to release it and then when we are ready then we will just release it …" (Furucombo)

"The people that are in charge of development, doing the actual work and that are making the road maps and stuff are the Core Units people." (MakerDAO)

The implementation of decisions and executive power are often concentrated in the hands of the core teams, which are also in charge of overseeing operational tasks. De facto, the community has the ability to influence outcomes and have an impact on policy-making, but the involvement of the token holders in governance systems does not necessarily imply that they are able to execute decisions or participate in maintaining the code base, defining and performing operating tasks and routines, as well as core business activities. We also found that in DApps with a higher degree of decentralization, token holders delegate authority and responsibilities to core teams to run the operations and take autonomous action on behalf of the community, whereas in less decentralized DApps, the team retains direct control of the execution and does not necessarily need to confront token holders with their work. Thus, we conclude that:

Proposition 1. *Core development teams maintain significant influence over DApp governance decisions, which impacts the extent of decentralization.*

4.2. Communication channels

As stated in the literature, developing specific proposals and establishing effective communication channels is essential to fostering transparency and inclusivity in DApps (Scholten et al., 2020). To include a wide range of stakeholders in governance, off-chain mechanisms such as discussions and social media platforms are necessary. These tools facilitate community input but are also challenged by issues that may lead to centralized governance (De Filippi and Loveluck, 2016).

Governance processes typically begin off-chain on various communication channels, allowing community members and development teams to interact freely. These discussions serve various purposes, including exchanging ideas, seeking consensus on DApp improvements, gauging community sentiment, and approving or rejecting formal processes. Once discussion topics are refined, some DApps move motions to off-chain voting platforms, where token holders can cast their votes for or against proposed changes. Since the voting happens off-chain, the outcome primarily serves as a signaling system, as there is no code execution involved:

> *"For the governance, what the community can do is post something in the forum, and then it can eventually be turned into a proposal. It needs a three-day discussion period, then it goes to Snapshot for voting. But first it's a non-binding discussion on the forum, because we need, and we want to promote the debate first."* (Yearn)

> *"If someone submits a proposal, it could potentially go to a vote. However, we're not obligated to follow through … If the DAO tries to push us into committing an illegal act, we definitely won't comply."* (Bancor)

> *"There are some coordination tools, like a forum, where governance discussions happen. […] People really need to know what the proposals they see are about. […] there is also an independent group that assesses the risks of different proposals to keep the governance informed."* (Curve)

> *"Currently, I think everyone can make a proposal on the forum. […] You have to follow certain formats to make it easy for people to understand what you are talking about. You have to post on the forum and gather some discussion for a certain period of time to make sure that you collect some feedback from others, and if you reach some kind of consensus on the forum, then you can go to Snapshot to propose it."* (Furucombo)

Decisions regarding the operational structures and development of the DApp must align with the interests of various stakeholders. However, these decisions, although they can often come from anyone's proposals, often involve specific knowledge and proprietary information held by development teams. This knowledge gap can create a disparity between the development teams and the broader community. Many decisions necessitate specialized technical or economic expertise that may not be possessed by the average token holder:

> *"Token holders can raise proposals, however, the technology itself, which is the core of 1Inch, is too complicated for essentially anyone from the community to understand. So, the core things that are driving 1Inch forward, hopefully to success, are happening within the foundation only, because all the engineers are contributors to the 1Inch foundation."* (1Inch)

> *"Usually when it comes to some interesting mathematically deep things, it's something either myself or somebody else in the company proposes"* (Curve)

> *"To participate in Maker governance, it takes a lot of time and expertise. The things that you need to vote on and the things that you need to engage in, the discussions, they're quite complex. So, it's not something that you can expect a regular MKR holder to do."* (MakerDAO)

> *"It's impossible to expect community members to write only things that are compliant with the regulation. […] They will write something, we kind of work with them to try and bring the proposal closer to something that is acceptable and then implement it afterwards."* (Bancor)

With a few exceptions, the information asymmetry often leads the community to primarily focus on elementary aspects or those related to a few specific areas, such as token allocations and protocol fees, in its discussions. What frequently occurs is that the community suggests ideas without first organizing them into a problem or identifying viable, data-driven solutions. These factors, in turn, tend excluding community members from the process of formulating complex decisions:

> *"We also need to understand what the main thing that bothers the community is or that actually they care about. Essentially what 99 % of the community care about is the price of the token. So, when they care about 1Inch token price, they don't really care about the technology because it's already good for them, since they are already using it. I would say that 90 % of the proposals from the community are heavily 1inch token oriented."* (1Inch)

> *"Most of the time the proposals are only changing parameters, which for us it's super easy […] or concern organizational things like the Y teams."* (Yearn)

> *"[…] a user could indeed write on the governance forum, and then multiple people can discuss over there, but it's just a user expressing an idea. It's nothing formal; it's not that there is some vote necessary or somebody has to follow it; nothing like that. It is more like people interacting with each other, coming up with suggestions […]."* (Curve)

Despite being scattered, unstructured, and non-binding, ideas arising from various stakeholders are often taken into consideration by the core teams. However, in most cases, they just serve as inputs for their decisions. Development units typically engage in separate conversations from the rest of the community to identify necessary changes and determine how addressing the issues experienced:

> *"In the Foundation, we have our internal chats, tons of them, for different departments and across departments"* (1Inch)

> *"If the proposal comes from the community, it usually happens on Discord. But if the new proposal comes from the contributors that are part of the yTeams it's going to happen in Telegram. The yTeams have groups where they talk about stuff, and they decide."* (Yearn)

> *"The community can ask for new features, of course. […] we listen to users and develop things, but that's not formally required by the DAO. It's not necessarily going on the governance forum; it's just expressed in how could be expressed when talking to users in chats. […] formal things with the DAO come when you actually connect the newly developed things to the Curve DAO ecosystem."* (Curve)

Consequently, what is observed is that token holders are primarily presented with yes-or-no proposals such as: "Should we list token X?" "Should we set parameter X in way Y?" "Should we pay for X?" "Should we add X feature?" etc. Alternatively, they are faced already drafted solutions and policies provided by core teams. The community is generally excluded from the problem identification and strategy formulation processes, as well as the determination and assessment of the alternatives that could be pursued to address an issue. In most cases, before the community has the chance to express their views or while they do so in unstructured ways, the core teams have already determined the policy details, what the improvements should look like, and why the proposed solution would benefit the ecosystem:

> *"What we did is we sent a proposal to the forum. There was some discussion and then it was voted. So, what we do is propose something we worked a lot to make, like a proposal that makes sense, and it gets voted."* (Yearn)

> *"There are two or even three people at 1Inch Foundation who are community managers, who try to help and guide the 1inch DAO participants*

in their voting. However, again we come back that they are people who essentially are working for a centralized entity which is 1Inch Foundation. Within 1Inch Network there is no hierarchy, there's just a wonderful bunch of people with 1inch tokens. Sometimes they offer something themselves without intervention of community managers but then it's extremely hard for them to reach the quorum for the vote." (1Inch)

"When it comes to the DAO, it controls things on chain, where the code is already developed and deployed. […] It's really all about getting a gauge, getting CRVs. What the DAO actually does is decide which smart contract will get CRVs streamed into it or and which does not and also how much CRVs it gets." (Curve)

"Currently, there are not many proposals made by the community on the forum. Most of the community members we talk a lot to are Furucombo fans, but they hope the developer team has ideas and proposes things […] I haven't seen many of them wanting to initiate something new. We haven't had formal proposals initiated from the community." (Furucombo)

Given the current governance structures, token holders and DApps participants tend having a decision-making power that they are unable to fully exercise. Instead, they often rubber stamp centrally made decisions or exercise veto power when granted by the governance system in place.

To fully involve the community and the token holders in the governance of DApps, proper processes need to be implemented to encourage constructive and transparent discussions. This enables stakeholders to coordinate and identify necessary or desired changes. The governance debate should transition into a consensus-seeking exercise aimed at achieving an optimal compromise. Communication channels should compel participants to focus on the underlying reasoning, causes, theories, and data rather than engaging in polarizing contests over specific token integrations, creation of new pools, setting of fees, or other parameters that may divert attention from the big picture and important issues.

Proposition 2. *Information asymmetry between core teams and other stakeholders limits effective participation in governance, leading to reduced decentralization.*

4.3. Incentives

In DApps, it is particularly important to introduce incentives for the core teams so that they benefit from the improvement and growth of the DApp, given that they are the primary contributors to its development and hold a higher influence in governance. The cases demonstrate that incentives for the core team are well-structured. They primarily consist of monetary rewards of two types: salaries paid by the DApp treasuries, which collect fees charged to users, or directly receiving a portion of the app revenues, and tokenomics. To distribute decision-making power, the DApp founders mint governance tokens and then distribute them through various mechanisms and initiatives. A share of native tokens is usually kept by the core team, and eventually, a portion can be sold to external investors to raise capital:

"A big chunk of tokens would be distributed to the people who at some point in time are or were parts of the Foundation. The investors are also getting lots of it." (1Inch)

"Contributors get economic incentives like monthly grants or one-time grants, depending on how they want to contribute." (Yearn)

"The developers are typically employed by the company, and they get a combination of Fiat and CRVs depending on their preference. The company gets code developed and when it is deployed it hopefully helps Curve ecosystem to grow. The company has a little bit of CRV so this is the incentive of the company." (Curve)

"Developers received an initial token allocation and have reserved a percentage of the future token emissions. It is not all distributed initially so that they do not lose the incentive to work on the project; the incentives are made to ensure the core team keeps developing" (SpookySwap)

"The people in the core units are all paid out by the protocol. They have a salary that can differ per Core Units and then there's also an MKR bonus." (MakerDAO)

Members of core teams frequently hold a considerable portion of the governance tokens, thus wielding significant voting power. To reduce risks of conflict of interest, the incentive systems are designed to ensure that teams are engaged in developing and growing the DApp in a way that aligns with the interests of the entire ecosystem. Salaries guarantee that core teams continue contributing code and maintaining the DApp, while token allocation ensures their interest in growing the value of the entire ecosystem and the demand for the governance token, which largely determines its price.

In contrast, the community is often not strongly incentivized to actively contribute to governance and development; rather, they may have incentives to simply hold or stake the tokens. Consequently, token holders may retain tokens as speculative investments without necessarily being motivated to participate in the governance of the DApp. In addition to their financial value, appreciation, and potential staking returns, native tokens can also be supplied in standard liquidity pools for other users to swap, allowing providers to earn trading fees. The absence of incentives directed toward governance activities could be one of the reasons explaining the general lack of community participation and engagement in governance discussions and decision-making procedures:

"We are not planning any incentives to increase participation in governance, because if you don't have the information or the knowledge, you shouldn't participate. Participation depends on the topic. If the topic is controversial, there is more participation in governance. But if the change is small, there is some voting apathy." (Yearn)

"We don't have any incentives. In fact, I think incentives are the fastest way to kill a DAO. […] People need to be self-motivated. the reason that they decide to do things it might even be transcendent, and that's okay." (Bancor)

"Unfortunately, the community engagement is quite low and, as the core team, we are trying to engage the community to vote and recommend doing so through our official channels. […] We also thought about implementing an NFT for people who vote but it is expensive and takes time. […] Participation also depends on market trends; in bull markets the community tend to participate more while in bear markets to participate less." (SpookySwap)

"Recently what we've seen is that you actually have to make a lot of effort for the users to actively participate in DAO and this is super understandable because token holders have also other things to care about and might not understand clearly why should they bother and spend time and do some voting" (1inch)

Certain DApps, like Curve, incentivize users who lock their tokens to gain voting power and enforce penalties for early unlocking. This approach tends fostering a more engaged community, even though the incentive is not directly linked to participation itself. Once users have locked their tokens and have limited alternatives, they may be more inclined to actively engage in the governance system. On the other hand, MakerDAO does not provide incentives for passive token holders; instead, it compensates contributors actively involved in governance, promoting a dynamic exchange of ideas and discussions:

"The 50 % of trading fees going to the DAO gets distributed to those who have voting power. So it's not sitting in treasury for voting for different purposes. It's just going to those who have voting power. (Curve)

> *"I think there are quite many proposals from the community, and I don't even track all of them. Sometimes for me it's a surprise to see some something getting voted on. And sometimes I cannot even really affect whether it gets accepted or not because a voting power higher than mine has already voted and reached the quorum."* (Curve)

> *"If you are a delegate, you basically commit to spending more time on becoming knowledgeable and becoming an informed voter. […] Recognized delegates that have gone through a KYC process and have committed to the code of conduct, are eligible for receiving a DAI compensation based on how many MKRs are delegated to them. Instead, when it comes to other participants, for example passive MKR holders, right now there is not really any incentive going on. There are not farming or other rewards."* (MakerDAO)

The community often lacks incentives to participate in governance beyond the opportunity to engage in the decision-making process. In cases where incentives are provided, token holders may be required to lock their assets for specified periods to access rewards and voting power. The absence of strong incentives can result in a concentration of influence among a few powerful token holders, as those with limited voting power may find the opportunity costs of engaging in governance too high. Delegation, especially when combined with disincentives for non-participation, could enhance community voice and influence. Time-locking tokens with penalties for early withdrawal serves a similar purpose, encouraging decision-makers to vote in the best interest of the ecosystem for long-term value appreciation. Overall, we can conclude that:

Proposition 3. *Misaligned incentives discourage stakeholder participation in governance processes, concentrating decision-making power and affecting decentralization.*

5. Discussion

The findings presented in this study unravel the multi-layered and dynamic nature of governance in DApps, challenging conventional paradigms and revealing the complex interplay between decentralized ideals and pragmatic necessities. In this section, we aim to illuminate the theoretical and practical implications of our research, specifically addressing how non-algorithmic factors influence decentralization in Dapp governance. We build on the foundational concepts established in our theoretical background and extending these ideas further, contributing to an evolving discourse that straddles the realms of technology, management, and organizational strategy.

5.1. Theoretical implications

First of all, our study introduces a nuanced perspective on blockchain decentralization, reframing it not as a binary state but as a continuum. This reconceptualization of decentralization aligns with the arguments presented by De Filippi and Wright (2018), who contend that the governance structures of blockchain systems are often more complex and less deterministic than the idealized, fully decentralized models. This complexity in decentralization is also reflected in the work of Catalini and Gans (2019), Gervais et al. (2016), and Wang et al. (2022), who explore how different degrees of decentralization in blockchain networks impact their efficiency and security. They argue that the optimal level of decentralization in blockchain settings is contingent on its specific use case and the trade-offs between various factors such as speed, security, and governance.

Building on the notion of decentralization as a spectrum, this research extends this framework by examining the significant role that off-chain, non-algorithmic decision-making by core teams plays in Dapp governance. This finding necessitates a reevaluation of blockchain governance models, where the strategic importance of off-chain decision-making is recognized alongside on-chain mechanisms. The complexities and unpredictability inherent in real-world applications of blockchain, where algorithmic governance may not suffice, highlights the necessity for human judgment and discretion in decision-making processes. For this reason, core teams, often armed with specialized knowledge and expertise, are pivotal in managing the complex aspects of DApp development and operations that transcend the capabilities of coded protocols.

The critical role of core teams in off-chain decision-making in our study echoes the insights provided by Bech and Garratt (2017) regarding the governance of digital currencies. They highlight the indispensability of leadership in navigating the complexities of blockchain-based systems, a perspective often overshadowed in the dominant blockchain literature. This oversight is addressed in Morkunas et al.'s (2019) work, which underscores the importance of human intervention in blockchain governance. In their study, Morkunas et al. (2019) delve into the interplay between technological protocols and human oversight in shaping blockchain applications.

The integration of the human component into DApp governance, while necessary, introduces significant challenges that, if not properly managed, could undermine decentralization and render algorithmic governance mechanisms redundant. Our findings identify these challenges revealing their implications for the decentralization of governance. Despite the foundational goal of blockchain technology to distribute control, our study reveals a persistent centralization of influence within core development teams. This observation aligns with concerns raised in existing literature, where core developers often wield significant power over a project's direction due to their expertise and control over the codebase (Davidson et al., 2018; Reijers et al., 2016). Such concentration of authority can unintentionally undermine decentralization by restricting community participation, both its breadth and the level of active engagement.

The first critical barrier to meaningful stakeholder engagement that may arise from the role of the core team in off-chain decision-making is information asymmetry. When core teams limit access to essential information, stakeholders find themselves ill-equipped to effectively participate in governance processes (Chen et al., 2021). However, the issue is not solely about actively restricting access to information; it also involves the inherent complexity of the topics being discussed, which requires a concerted effort to "translate" these matters in ways that make them accessible and comprehensible to a wider range of stakeholders. Our findings suggest that this lack of transparency not only discourages active involvement but also reinforces the dominance of the core team. This scenario echoes the observations of Hsieh et al. (2018), who noted that technical complexities and information gaps can lead to governance being dominated by a small group of participants.

In parallel with the issue of information asymmetry, incentive structures significantly shape stakeholder behavior within DApp ecosystems. Well-crafted incentives can encourage active participation—such as voting and submitting proposals—thereby fostering a healthier and more decentralized environment (Beck et al., 2018). However, our research suggests that when core teams fail to distribute tokens in a way that promotes genuine stakeholder engagement, incentives become misaligned, favouring speculative behavior over meaningful participation and not encouraging stakeholders to actively inform themselves to reduce information asymmetry (Atzori, 2015; Lee et al., 2021). Moreover, if no measures are adopted to reduce conflicts of interest, members of core teams may be incentivized to retain a considerable portion of the governance tokens for themselves, thereby wielding significant voting power and increased influence. This misalignment, when present, reduces stakeholders' motivation to contribute meaningfully, exacerbating information asymmetry and consolidating power within the core team.

The interplay between core team influence, information asymmetry, and incentive misalignment creates a self-perpetuating cycle that undermines decentralization. As illustrated in Fig. 1, as the core team's influence grows—often as a result of diminished stakeholder

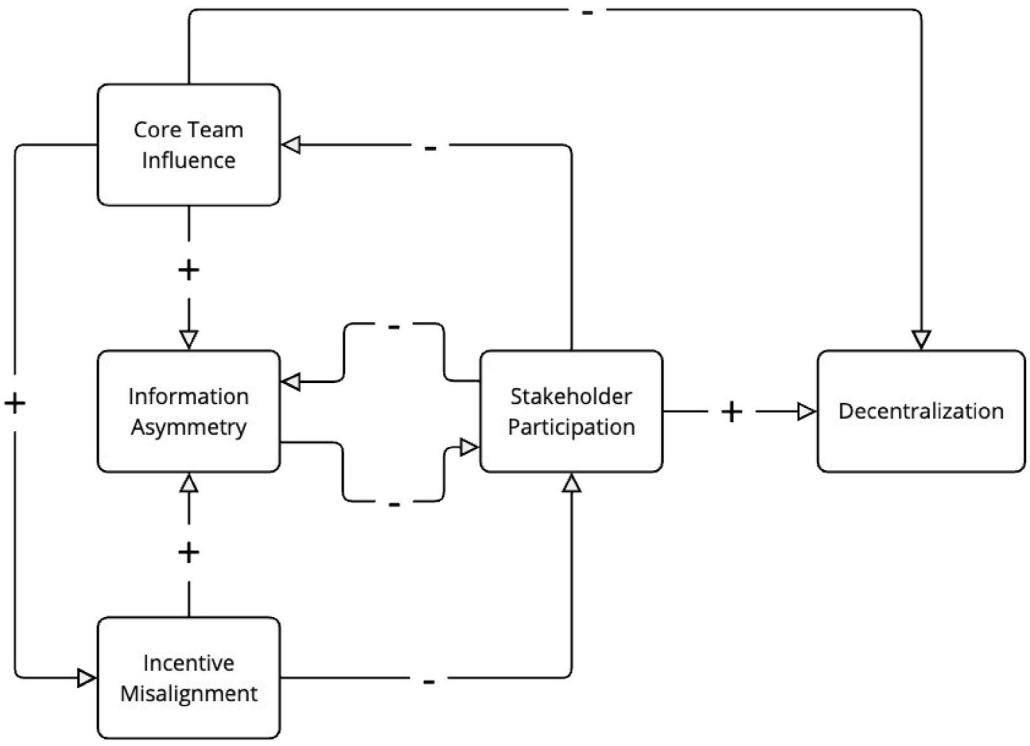

Fig. 1. The interrelationships between core team influence, information asymmetry, incentive misalignment, and their impact on stakeholder participation and the decentralization of governance.

participation—they may implement governance decisions that further misalign incentives and widen information gaps. This dynamic mirrors the concerns highlighted by De Filippi and Loveluck (2016), who discussed how voter apathy and technical complexity can impede meaningful engagement, leading to increased centralization. Our findings illustrate these interrelationships, emphasizing stakeholder participation as both an influencing factor and a consequence of the governance dynamics. Enhancing stakeholder engagement is crucial for redistributing decision-making power and promoting greater decentralization. Active involvement from stakeholders dilutes the dominance of the core team, leading to more balanced governance structures. This participation also enhances information sharing and aligns incentives with the broader interests of the community (Kassen, 2023; Liu et al., 2022).

To tackle the identified challenges, improving transparency and communication within DApp ecosystems is essential. By reducing information asymmetry, stakeholders become better equipped to engage effectively in governance processes (Scholten et al., 2020). Moreover, designing incentive mechanisms that reward active participation—rather than mere token holding—can motivate stakeholders to invest more deeply in the platform, aligning with Beck et al. (2018)'s emphasis on the importance of well-designed incentives. Our findings contribute to the broader discourse on the risks of centralization within systems that are intended to be decentralized. They underscore the necessity for a nuanced understanding of how human factors can influence technological ecosystems, reinforcing the observations of Azouvi et al. (2019) and Hsieh et al. (2018) regarding the challenges of achieving meaningful community engagement in the face of influential core teams.

5.2. Managerial implications

The practical implications of this study revolve around addressing the identified challenges in decentralized governance, especially in the context of DApp development. While blockchain promises distributed control and decision-making, the research demonstrates that human factors, such as the influence of core teams, continue to shape the outcomes of these systems.

A first takeaway from our study is highlighting the importance of hybrid governance models. Such models combine the efficiency and impartiality of algorithmic governance with the flexibility and nuanced understanding of human judgment. For practitioners, this means actively creating and participating in governance structures that can balance on-chain and off-chain governance mechanisms. As blockchain's algorithmic governance cannot fully replace human judgment and discretion in complex decision-making scenarios, organizations clearly outline which decisions can be implemented autonomously on-chain and which ones require off-chain deliberation and human input. This clarity is vital for managing stakeholder expectations and ensuring that complex decisions are given the attention they require.

Closely related to the previous takeaway is the issue of information asymmetry, highlighting the need for improved communication channels and increased transparency. There is a significant need for educating stakeholders about the platform's intricacies. Providing comprehensive information and data related to proposed changes is essential for informed decision-making by the community. Developers and organizations should focus on simplifying complex technical information and making it accessible to a wider range of stakeholders. This could involve creating educational tools or communication strategies that bridge the knowledge gap between the core team and other participants, ensuring that the governance process is genuinely participatory and inclusive. Addressing these gaps can lead to a more engaged community, which in turn can foster a more decentralized governance structure.

A third practical implication concerns the alignment of incentives. Several DApps have already put in place mechanisms to discourage speculative dynamics, such as time-locking, voting delegation mechanisms, or direct compensation tied to active participation. The study highlights the risks that could arise when such practices are absent or ineffective. Moreover, core teams may retain too much governance power by controlling a disproportionate share of tokens. To mitigate

this, token distribution and governance mechanisms should be structured to encourage meaningful participation rather than speculative behavior. Organizations should design governance frameworks that promote active participation from a diverse set of stakeholders, ensuring that the token economy supports long-term engagement and reduces conflicts of interest.

Finally, practitioners should consider implementing mechanisms for regularly auditing and assessing the distribution of power and influence within the DApp ecosystem, taking care not to view individual governance elements in isolation but rather acknowledging the connections and interdependencies that can subtly reinforce centralization dynamics. This approach can help identify areas where centralization might be unintentionally increasing, enabling timely corrective actions. Regular audits and assessments can promote transparency, highlight emerging disparities in governance power, and ensure the ecosystem stays aligned with decentralization goals.

Overall, the practice of governance in DApps is characterized by a nuanced blend of decentralized ideals and practical necessities. For practitioners, the challenge lies in creating governance models that are not only technologically innovative but also inclusive, responsive, and sustainable. By considering these insights, practitioners can contribute significantly to the evolution of DApps, ensuring they are governed effectively and poised for long-term success in the blockchain ecosystem.

6. Limitations and future research

This study provides substantial insights into the governance of DApps, yet it is not without limitations that open avenues for future research. One primary limitation lies in the focus on DeFi DApps, which, while offering a rich context, may not fully capture the governance dynamics in other blockchain application domains. The evolving nature of blockchain technology and the diversity of applications across various sectors suggest that findings in the DeFi context might not be universally applicable. Future studies should therefore explore governance mechanisms in a broader range of DApps, including non-financial applications, to provide a more comprehensive understanding of decentralized governance.

Additionally, the reliance on a case study approach, while providing depth, may limit the generalizability of the findings. Future research could employ quantitative methods to validate and extend the qualitative insights gained from this study. Large-scale surveys or experimental designs could offer statistical evidence to support or refine the conclusions drawn from these case studies.

Another notable limitation is the temporal scope of the study. Given the rapid evolution of blockchain technology and its applications, the findings represent a snapshot in time. Continuous longitudinal studies would be valuable in tracking the evolution of governance structures in DApps and how they adapt to technological advancements and changing regulatory landscapes. Moreover, this study primarily addresses governance from an organizational and technical perspective, leaving room for exploration of the socio-political implications of DApp governance. Future research should delve into how decentralized governance models impact broader societal and ethical considerations, such as inclusivity, power dynamics, and the digital divide.

Lastly, the current research predominantly focuses on internal governance mechanisms within DApps. An exploration of how these decentralized applications interact with external regulatory frameworks and traditional governance structures would provide critical insights into the integration and co-evolution of decentralized and centralized governance models. Such studies would be particularly pertinent for policymakers and regulators seeking to understand and engage with blockchain technologies.

CRediT authorship contribution statement

Giacomo Vella: Writing – original draft, Investigation, Conceptualization, Writing – review & editing, Methodology, Data curation, Formal analysis. **Luca Gastaldi:** Validation, Data curation, Writing – original draft, Methodology, Supervision, Formal analysis, Conceptualization. **Francesco Paolo Appio:** Supervision, Formal analysis, Writing – original draft, Investigation, Writing – review & editing, Methodology, Conceptualization.

Declarations of competing interest

None.

Appendix A. Interview questions

Decentralized application overview

1. What is the purpose of the decentralized application?
2. Who was in charge of the original design and deployment?
3. What was the launch style of the application?
4. Why was this mode of governance selected?

Roles and hierarchy

5. What roles are defined within the community?
6. Are there observable hierarchical structures between these roles?
7. Are there specific roles related to on-chain governance?
8. Who deploys off-chain decisions on-chain?

Incentives and rewards

9. What are the associated incentives for the available community roles?
10. Do these incentives include monetary or non-monetary rewards?
11. What are the associated incentives for development roles?
12. Are developers paid?
13. How is funding arranged for developers?
14. What are the associated incentives for the on-chain activities?

Community participation and access

15. Is the community open for anyone to join and participate?
16. Are there processes or rules for community management?
17. Who can join the development roles?
18. Is the developer community open for anyone to join and participate?
19. Is training necessary for developers?

Governance and decision-making

20. Who can take part in the governance?
21. How does the community have input on development decisions?
22. Are there any signaling systems, such as voting mechanisms, for the community?
23. How does generation of decision proposals work?
24. Are there clear guidelines for how the governance mechanisms and protocol can be changed?

Coordination and communication

25. What are the media used for community and development discussions?
26. How does the community achieve agreement and coordinate actions?
27. How do developers achieve agreement and coordinate actions?

28. How does communication among the available roles take place?
29. Are there processes for dispute resolution within the community?
30. What are the procedures to solve conflicts during development?

Data availability

Data will be made available on request.

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