Seminar Thesis

Analysis of Voting Mechanisms in Decentralized Autonomous Organizations

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Abstract

Decentralized Autonomous Organizations (DAOs) present a novel paradigm for organizational governance, leveraging blockchain technology to enable direct and transparent decision-making processes. This paper analyzes three prevalent voting mechanisms in DAOs — Quorum-Based Voting, Delegated Voting, and Quadratic Voting. Each system is evaluated qualitatively for its theoretical merits and quantitatively using real-world data from Uniswap and Gitcoin. Although each mechanism contributes valuable solutions to on-chain governance, the research reveals potential pitfalls like possible centralization and vulnerability to Sybil attacks. As no ideal system is found, this paper underscores the need for continuous research to develop a more effective on-chain governance model.

Keywords: DAO, governance, blockchain, on-chain governance, quorum-based voting, delegated voting, quadratic voting.

Contents

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1 Introduction

Emerging from its roots in cryptocurrencies, blockchain technology has proven itself as a disruptive force across a diverse range of applications. Initially used primarily for financial applications, blockchain's versatility has been increasingly recognized in recent years leading to the emergence of Decentralized Autonomous Organizations (DAOs) (Faqir-Rhazoui et al., 2021). DAOs can fundamentally alter how organizations operate. These organizations leverage blockchain technology as their fundamental infrastructure, enabling new organizational innovations. The rise of DAOs marks a significant step towards decentralized governance, redefining how organizations are structured and how they operate in an increasingly interconnected world (Bellavitis et al., 2023).

Central to these organizations' operation are voting mechanisms that allow token holders to contribute to the decision-making process (Hassan and De Filippi, 2021). These voting mechanisms play an essential role in the pursuit of decentralization and democracy, which are fundamental principles at the heart of DAOs. However, designing efficient voting mechanisms poses significant challenges, as issues related to decentralization, voter participation, efficiency, coordination, scalability, and security must be addressed (Nigam et al., 2023).

This research centers on understanding the operational dynamics of voting mechanisms in DAOs. Specifically, it addresses two key research questions: 1) What are the voting mechanisms used in DAOs, and how do they work? 2) Through qualitative and quantitative analysis, what are the unique challenges and advantages associated with these selected voting mechanisms in DAOs?

In the pursuit of answers, this paper investigates two commonly used voting mechanisms, Quorum-Based Voting and Delegated Voting, and one novel mechanism, Quadratic Voting. The study employs a comprehensive analysis of Uniswap's governance data to inspect the functioning of Quorum-Based and Delegated Voting and utilizes data from the Gitcoin Stewards Council to explore Quadratic Voting.

The structure of this paper is as follows: Chapter 2 delves into the concept of Decentralized Autonomous Organizations, detailing their characterization, governance mechanisms, and the integral role of voting. A practical examination of Uniswap's governance model is then offered, illustrating governance in action. The section further underscores the relevance of DAO governance and voting. Chapter 3 introduces and provides a thorough analysis of the core voting mechanisms: Quorum-Based Voting, Delegated Voting, and Quadratic Voting. Both qualitative and quantitative perspectives are employed in the analysis to uncover the intricacies of these mechanisms and their implications in DAOs. The discussion in Chapter 4 considers the research findings and their implications for on-chain governance, providing an interpretation of the results from the previous section. Finally, Chapter 5 concludes the paper by summarizing the key insights derived from the research and proposing directions for future research.

2 Decentralised Autonomous Organizations

The modern meaning of DAOs can be traced back to the earlier concept of Decentralised Autonomous Corporations (DAC), which emerged a few years after Bitcoin's inception in 2008. The term DAC was used informally by early cryptocurrency enthusiasts to describe a new form of corporate governance using tokenized tradable shares where anyone could become a stakeholder by buying or earning its stock (Hassan and De Filippi, 2021). However, it was not until 2013 that the term DAC gained wider acceptance and was publicly discussed on various websites (Larimer, 2013), including by Vitalik Buterin, the co-founder of Bitcoin Magazine (Buterin, 2013). Later in 2014, Buterin (2014*a*) introduced the term DAOs as a replacement for DACs, reflecting a broader vision for decentralized organizations that could go beyond traditional corporate governance structures (Hassan and De Filippi, 2021).

According to Buterin (2014*b*) in the Ethereum white paper, a DAO is a virtual entity with a group of members or shareholders who are authorized to expend the entity's funds and modify its code, with enforcement only through cryptographic blockchain technology. In addition, other scholars like Hassan and De Filippi have characterized a DAO as "a blockchain-based system that enables people to coordinate and govern themselves mediated by a set of self-executing rules deployed on a public blockchain, and whose governance is decentralized" (Hassan and De Filippi, 2021, p. 2). However, it is important to note that there exists multiple definitions of a DAO (Hassan and De Filippi, 2021) and it is still subject to some ambiguity (Pranata and Moslemzadeh Tehrani, 2022).

2.1 Characterization

Despite the lack of a universal definition, DAOs are generally characterized by a set of distinctive features (Hassan and De Filippi, 2021):

Self-Governing Organization DAOs serve as a framework for a group of people to collaborate and self-govern in the digital space (Singh and Kim, 2019). DAOs mediate the interactions of a group of people, typically an open community that joins as members (Faqir-Rhazoui et al., 2021). In most DAOs, members hold specific tokens that grant them participation rights, similiar to shares in a corporation (Faqir-Rhazoui et al., 2021; Fritsch et al., 2022). While there is no specified minimum group size, the term "organization" typically refers to a collective of individuals working together to achieve a shared objective (El Faqir et al., 2020).

Autonomy, Blockchain, and Smart Contracts A DAO is built arguably always upon a public blockchain with smart contract capabilities, such as Ethereum (Hsieh et al., 2018). The smart contract code serves as the foundation for specifying the rules governing interactions among participants (De Filippi and Hassan, 2016). Nonetheless, the extent to which other governance mechanisms may impact or supersede these rules remains uncertain. For instance, (Singh and Kim, 2019) define a DAO as an organization with automated operations based on code-assigned rules and principles without human involvement. However, Reijers et al. (2018) challenge this definition by differentiating between "on-chain" and "off-chain" governance in DAOs, suggesting a more nuanced governance structure. These self-executing smart contracts play a crucial role in a DAO's autonomy, operating independently from creators and central authorities. DAOs are autonomous entities, subject to their code, which dictates their operations alongside the human governance provided by members. By being deployed on a public blockchain, DAOs also gain censorship resistance, ensuring that no central authority can shut down the DAO or its services (Faqir-Rhazoui et al., 2021).

Decentralization DAOs, by relying on a public blockchain, inherit properties such as transparency, cryptographic security, and decentralization (Beck et al., 2018). This serverless, decentralized infrastructure forms the basis for their operations and represents the infrastructural layer of decentralization (Faqir-Rhazoui et al., 2021; Hassan and De Filippi, 2021). Additionally, DAOs can also implement decentralization at the governance level by utilizing decentralized governance mechanisms, ensuring that no central actor or group of actors controls the organization (Faqir-Rhazoui et al., 2021; El Faqir et al., 2020). These governance mechanisms enable decision-making processes to depend on the collective agreement of its members (Faqir-Rhazoui et al., 2021). Typically, this involves a voting system where members can actively participate, further reinforcing the decentralized nature of these organizations (Faqir-Rhazoui et al., 2021).

2.2 Governance

The term governance refers to the actions and procedures used by organizations to make decisions. Each of these organizations recognizes the need to establish decision rights, including who is responsible for making decisions, who will bear responsibility for their consequences, and how decisions are communicated to relevant stakeholders (Nigam et al., 2023). In other words, governance in DAOs is the act of managing collective decision-making (Chitra, 2021).

2.3 Voting

In DAOs, the decision-making process requires collective agreement from its members, typically through voting (Faqir-Rhazoui et al., 2021). Voting is a process that allows individuals or members of a group to express their preferences and make collective decisions (Elkind and Lipmaa, 2005). In the context of DAOs, voting is a central aspect that enables democratic and decentralized governance (Hassan and De Filippi, 2021). Due to the ease with which numerous pseudonyms (addresses) can be created at virtually no cost, decentralized governance systems are unable to rely on the "one person, one vote" approach (Goldberg and Schär, 2023). This challenge necessitates the use of alternative voting mechanisms in DAOs. Consequently, most DAOs employ token-based voting to facilitate the decision-making process (Bellavitis et al., 2023). This approach involves issuing governance tokens which represent stakeholders' voting rights. In this system, each token corresponds to one vote. Members can use these tokens to participate in the decision-making process, which typically involves creating proposals and casting votes on them (Fritsch et al., 2022). Proposals can address various topics, such as the allocation of resources, funding projects, payments to members, or changes in the DAO's code (Faqir-Rhazoui et al., 2021).

2.4 Governance in Action: A Practical Examination of Uniswap's Governance Model

So far, discussions of DAO governance and voting have been predominantly theoretical. This chapter will exemplify these concepts by showcasing the governance structure implemented by Uniswap. This preliminary examination, although not exhaustive, sets the foundation for a more comprehensive evaluation of voting procedures in subsequent chapters, with a special emphasis on the on-chain voting process employed by Uniswap.

Uniswap is one of the most popular decentralized exchange protocols for cryptocurrencies, operating within the Ethereum blockchain ecosystem (Schär, 2021). As of September 16, 2020, the Uniswap Protocol Token was launched, providing UNI token holders the ability to engage in the governance of the protocol (*Introducing UNI*, 2020). The governance procedure of Uniswap underwent a significant update on December 21, 2022, enacted through a voting process. Presently, it consists of three key phases: Request for Comment (RFC), Temperature Check, and Governance Proposal (Devin, 2023).

2.4.1 Request for Comment

In Uniswap's governance process, the RFC phase initiates a discourse on a proposal within the community. This off-chain procedure, lasting for a minimum of seven days, allows community members to review, comment on, and ask questions about a proposal via the Uniswap Governance Forum.

2.4.2 Temperature Check

Upon completion of the RFC phase, the governance process transitions into the Temperature Check phase, lasting five days. In this phase, an updated proposal incorporating community feedback from the RFC is developed and subsequently posted on the Uniswap governance forum. A Snapshot poll is initiated at this stage. Snapshot, an open-source and gasless voting platform for DAOs (Zuber, 2023), is utilized to assess the community's sentiment and secure a quorum of at least 10 million UNI votes before the proposal advances to the on-chain voting process. This systematic approach ensures that the community reaches a consensus before transitioning to the more resource-intensive on-chain voting phase.

2.4.3 On-Chain Governance Proposal

In Uniswap's final governance phase, the proposal — modified based on prior feedback — is presented for on-chain governance. It can be constructed via an interface like Uniswap, Tally, or Boardroom, or by scripting the calldata for proposals with more sophisticated logic. The proposer must have at least 2.5 million UNI delegated to them to submit a proposal. During a voting period of seven days, the proposal needs to gain more 'For' votes than 'Against' votes to be approved. Additionally, the total count of 'For' votes must surpass 40 million for the proposal to meet the quorum. Upon meeting these conditions, the proposal is queued in the Timelock and becomes executable after a minimum waiting period of two days. Uniswap's governance and protocol updates are guided by UNI token holders (*Uniswap Docs*, 2022). This system relies on three smart contracts: the UNI token, the governance module Governor Bravo, and the Timelock, details of which will be elaborated in chapter 3.2.1.

2.5 Relevance of DAO Governance and Voting

DAOs are gaining prominence and managing substantial amounts of money through their governance systems. For instance, Uniswap's treasury currently holds $2.6 billion[1]. As a result, the decisions made through these governance systems can have significant consequences. One such decision was Uniswap's allocation of $20 million from its treasury to a lobbying group called the "DeFi Education Fund" in July 2021, which generated some controversy (Fritsch et al., 2022). In essence, DAOs are now responsible for managing large sums of money and making critical decisions regarding their allocation.

[1] https://openorgs.info/

2.5.1 Decentralization and Power Distribution

A key value proposition of a DAO is its decentralized governance model, which contrasts with traditional organizations like corporations, where decision-making authority is typically held by a select group, such as board members, founder(s), or institutional shareholders (Nigam et al., 2023). However, achieving true decentralization in DAOs can be challenging, as it aims to distribute power and control across a wide range of stakeholders. One obstacle to decentralization is the concentration of voting power in the hands of a few large shareholders (Nigam et al., 2023). These shareholders, such as institutional investors or the project's initial developers, often own a substantial share of the tokens, giving them significant influence over the decision-making process (Defiant, 2021). This concentration of power can lead to dependencies and rent extraction behavior (Goldberg and Schär, 2023).

Historical examples have shown that voter manipulation can undermine the democratic nature of organizations, such as the corporate takeover of American political life (Kapferer, 2005) or the subversion of post-Soviet privatization by oligarchs through mass purchases of citizens' coupons (Burawoy, 1994). DAOs are also susceptible to similar threats of oligarchic power concentration among voter groups or influential individuals. The Build Finance DAO, for instance, experienced a coup when a single individual accumulated enough token concentration to pass a vote, assign themselves total control over the DAO, and siphon all its funds. This incident highlights the importance of horizontal accountability in preserving the democratic nature of DAOs, which aligns with the underlying cryptoanarchist philosophy (Chohan, 2017).

The success of a DAO in achieving a decentralized governance structure often depends on the design of its voting system and the readiness of the initial development team to cede power through this mechanism. Crafting an effective and fair voting system is a difficult task due to the lack of established models and the necessity to strike a balance between the decentralization philosophy of the DAO and other seemingly contradictory objectives, such as efficiency and scalability (Nigam et al., 2023).

The weak identity problem further complicates decentralized governance in DAOs (Goldberg and Schär, 2023). Due to the ease of creating multiple pseudonyms or addresses at minimal costs, DAOs cannot rely on 'one person, one vote' schemes, as they would be vulnerable to Sybil attacks (Douceur, 2002*a*; Tran et al., 2009). This issue hinders the enforcement of entity-specific voting power restrictions and traditional regulations, such as shareholder protection and reporting requirements (Goldberg and Schär, 2023), which may exacerbate centralization. Furthermore, users potentially splitting their voting power across multiple entities leads to an underestimation of the centralization problem (Goldberg and Schär, 2023).

2.5.2 Voter Participation

DAOs may face issues related to voter apathy due to the procedural nature of voting on DAO-related modifications. The labor required to consider each proposal can lead to a lack of voter engagement (Chohan, 2017). This challenge, along with the increased cost and effort required for active governance participation, can contribute to voter apathy and governance paralysis (Nigam et al., 2023). The design and implementation of a voting system can significantly influence these issues.

2.5.3 Efficiency, Coordination, and Scalability

While DAOs enable decentralized and democratic decision-making through smart contract-based, on-chain governance, this approach can also create challenges in terms of efficiency and coordination (Bellavitis et al., 2023). The time-consuming nature of the voting process, especially when a consensus is needed to address time-critical issues, can lead to coordination inefficiencies (Bellavitis et al., 2023). These inefficiencies may hinder the overall welfare generated by the decentralized organization (Momtaz, 2022). As Chitra (2021) argues, governance requires significant coordination costs arising from the need to have network participants involved in voting on every decision made. This becomes particularly challenging in situations requiring swift action. For instance, fixing bugs and security gaps in a DAO's code requires both the development of new code and an agreement to migrate funds, which can be a slow and potentially insecure process (Chohan, 2017).

Scalability is another aspect that can affect efficiency and coordination in DAOs. As the number of agents within a DAO increases, so does the need for more resource-allocation decisions regarding contributions. To grow effectively, a DAO's decision-making system must be able to process an increasing number of decisions in a fixed period of time. Scalability, in this context, refers to the DAO's ability to scale up the number of decisions it can effectively make within a given time frame as the organization expands (Field, 2018).

Moreover, DAOs can suffer from practical drawbacks when complex or elaborate governance models are implemented. In some cases, quick decision-making is essential, and a convoluted governance model can be more of a hindrance than a benefit, particularly when proposals are vague or open to interpretation (Nigam et al., 2023).

2.5.4 Participation Barriers and Technological Knowledge

One of the challenges DAOs face is the high barrier to entry for participation in governance due to the complexity of the underlying technology and various governance models. Blockchain technology, smart contracts, and the intricacies of DAO governance systems can be difficult to comprehend for individuals who lack technical expertise (Bellavitis et al., 2023). Participation costs, referring to the effort that individuals need to spend to understand and enter a market (Allen and Santomero, 1997), are relatively high for DAOs. This knowledge barrier can discourage potential participants from engaging in the governance process and lead to the segmentation of investors between those who possess the technical know-how and those who do not (Bellavitis et al., 2023).

In addition to the technological complexity, there are numerous governance modes, with the one token-one vote model being the most prevalent (Bellavitis et al., 2023). Familiarizing oneself with the technological and economic intricacies of DAOs, as well as the different governance modes, is associated with high costs (Cumming et al., 2023). This may lead to a potential need to reintroduce some degree of intermediation or hierarchy to lower barriers to entry (Bellavitis et al., 2023).

2.5.5 Security Risks and Vulnerabilities

DAOs face security risks and vulnerabilities that can significantly impact their governance and voting mechanisms. A notable example is "The DAO," an early attempt at creating a Decentralized Autonomous Organization launched in 2016 on the Ethereum blockchain (Bellavitis et al., 2023). It was designed to be an investment fund managed entirely by smart contracts, with no human intervention. However, a hacker exploited a vulnerability in the smart contract code, resulting in the theft of around $50 million from the organization (Cryptopedia, 2022; Chohan, 2017). This incident highlighted the importance of addressing security risks and vulnerabilities in DAOs and their governance mechanisms.
In line with the larger industry trend, many DAOs have been significantly impacted by hacks and theft of funds in recent years (Nigam et al., 2023). For instance, BadgerDAO suffered a loss of $150 million when attackers used a compromised Cloudflare API key to siphon off funds from user wallets. In addition to cybersecurity attacks, DAOs are also susceptible to 'governance attacks,' where actors or groups with misaligned objectives exploit weaknesses in governance procedures and deploy the treasury funds to their own ends (Nigam et al., 2023).
The rigidity of DAO code, which can be difficult to alter once the system is in operation, further complicates addressing security risks and vulnerabilities. This inherent inflexibility can be an ironic eventuality, considering that digital systems are meant to be flexible and decentralized systems are intended to be dynamic (Chohan, 2017).

3 Voting Mechanisms

Chapter 3 examines the various voting mechanisms used by DAOs to manage their decision-making processes. This exploration begins with an overview of the range of voting mechanisms used in the field. It then examines a selected set of these mechanisms in detail, both qualitatively and quantitatively, by delving into their inner workings using real-world cases. The aim of this in-depth analysis is to highlight the strengths and weaknesses of the selected voting mechanisms.

3.1 Overview

In the world of DAO governance, a range of voting mechanisms exist, each contributing to decision-making with unique features and functionalities. This chapter briefly introduces these different mechanisms. However, it is important to note that this paper will later delve into a detailed examination of a few selected voting mechanisms in order to provide an in-depth qualitative and quantitative analysis.

Quorum-Based Voting Quorum-Based Voting serves as one of the most basic yet crucial mechanisms in DAO governance, focusing on ensuring a certain level of participation for decision-making validity (Nigam et al., 2023).

Delegated Voting Another widely adopted mechanism is Delegated Voting, which is essentially a hybrid model of decision-making. This approach balances direct and representative democracy, allowing voters to either participate directly or delegate their votes to chosen representatives (Zhang and Zhou, 2017).

Quadratic Voting Moving on to Quadratic Voting, this mechanism captures not just voters' choices but also the intensity of their preferences. This is achieved by allowing individuals to purchase varying quantities of votes, with the cost of each additional vote increasing quadratically, thus highlighting the weight of each voter's conviction in their choice (Lalley and Weyl, 2018; Nigam et al., 2023).

Ranked Choice Voting Ranked Choice Voting, employed in platforms like Snapshot and Nouns DAO, allows voters to rank options sequentially. The initial round considers each voter's top choice, with subsequent rounds eliminating the least-preferred option and shifting votes until one option receives over half of the votes. Although it strengthens options with solid support, the complexity and inability to select multiple winners restrict its broader adoption (Nigam et al., 2023; *Snapshot Docs*, 2023).

Conviction Voting Conviction Voting is a continuous decision-making method where the weight of a vote increases over time (Faqir-Rhazoui et al., 2021). This approach, adopted by platforms like Aragon, Commons Stack, and 1Hive, empowers long-term community members, deters manipulative behavior, and mitigates vote volatility. However, it is a slow process, potentially discouraging change, and is still in an experimental stage in the DAO community (Emmett, 2019; Nigam et al., 2023; Bellavitis et al., 2023).

Holographic Consensus Holographic Consensus, implemented by DAOstack, addresses the scalability issue of absolute majority decision-making by introducing the concept of boosting. It requires an absolute majority to approve a proposal, but a relative majority is acceptable under certain conditions. The boosting process allows individuals to stake tokens on proposals, fast-tracking relevant ones and incentivizing alignment with the DAO's opinion. This mechanism combines prediction market dynamics with the participation of stakers, contributing to scalability and resilience in DAO governance (Field, 2018; Faqir et al., 2021).

Gasless Voting on Snapshot Snapshot is a prominent platform used for facilitating off-chain, or 'gasless,' voting in DAOs (Zuber, 2023). Snapshot's major innovation is that it enables DAO members to vote without incurring Ethereum gas fees. This is achieved by allowing users to sign votes with their private keys and submitting these digitally-signed votes directly to the Snapshot server or IPFS (InterPlanetary File System), bypassing the need for on-chain transactions. By creating spaces for each organization, Snapshot facilitates the creation and voting on proposals.

While the overview of voting mechanisms presented here is not an exhaustive list, it provides a brief introduction to some of the voting mechanisms utilized in DAOs. It is important to acknowledge that there are additional voting mechanisms available. However, for the purpose and scope of this paper, the focus will be on examining and analyzing in detail the selected mechanisms, namely Delegated Voting and Quorum-Based Voting, which are well-established and widely used in the context of on-chain governance. Additionally, Quadratic Voting, a novel approach in DAOs, will also be explored to understand its unique characteristics and potential benefits.

3.2 Quorum Based Voting and Delegated Voting

Quorum-based token voting is one of the earliest and most straightforward voting mechanisms adopted by DAOs to facilitate governance decisions (Nigam et al., 2023). Its primary purpose is to ensure that a minimum threshold of token holders participates in the voting process, promoting inclusiveness and democratic decision-making within the organization (Nigam et al., 2023; Grace, 2023). Once this quorum has been met, a proposal is accepted or rejected based on the recorded results of the token holder voting process (Arsenault, 2020; Grace, 2023).
Delegated Voting, also referred as liquid democracy, is a hybrid approach to decision-making that combines elements of direct democracy and representative democracy. In this system, voters can either participate directly in voting on issues or delegate their votes to representatives who vote on their behalf (Zhang and Zhou, 2017). This method of collective decision-making does not rely on electing fixed representatives (Paulin, 2020). Instead, any member of a group can delegate their voting rights,

including any powers delegated to them, to another member (Paulin, 2020). Similar to elected democracies, liquid democracy involves selecting representatives to make voting decisions for the larger population (Bellavitis et al., 2023). However, the key difference lies in the ability to revoke delegated voting power at any given time, offering more flexibility and adaptability in the decision-making process (Bellavitis et al., 2023). This governance mechanism is an integral part of many DAOs, as it allows for a more dynamic and responsive governance process, empowering token holders to actively participate by choosing representatives who are best suited to make informed decisions on their behalf (Nigam et al., 2023).

The following chapter examines the smart contracts of Uniswap's on-chain governance proposal phase, focusing on how delegated voting and quorum-based voting are implemented.

3.2.1 Uniswap: On-Chain Governance Proposal

As previously noted in earlier chapters, the final phase of the Uniswap governance process involves forming, voting on, and implementing proposals directly on-chain. This process is managed through three critical smart contracts: the UNI token, the Governor Bravo governance module, and the Timelock. The upcoming chapter will delve into a detailed exploration of the UNI token contract and Governor Bravo. This analysis follows the path laid out by the insights from "A Look at Smart Contract Voting with Compound" by Anchorage Digital (2022), who examined the smart contracts of Compound — the original model for the governance processes now used by Uniswap. The focus will be specifically on the intricacies of the delegation process and the mechanics of casting a vote.

3.2.1.1 Delegation

The process unfolds as follows: First and foremost, delegation takes place. To initiate a proposal, a certain number of Uni Tokens must be assigned to the proposing address. Specifically, the address must have at least 2.5

million Uni Tokens delegated to it by other holders of the token (*Uniswap Docs*, 2022). This forms the backbone of the delegation procedure, where the delegatees emerge as potential proposers. The delegation process is managed by the Uni Token contract[2]. The Uni Token holders, the token being an ERC20 Token, can delegate their voting power using the delegate function.

```
pragma solidity ^0.5.16;

contract Uni {
  /// Official record of token balances for each account
  mapping (address => uint96) internal balances;

  /// A record of each accounts delegate
  mapping (address => address) public delegates;

  function delegate(address delegatee) public {
    return _delegate(msg.sender, delegatee);
  }

  function _delegate(address delegator, address delegatee)
      internal {
    address currentDelegate = delegates[delegator];
    uint96 delegatorBalance = balances[delegator];
    delegates[delegator] = delegatee;
    emit DelegateChanged(delegator, currentDelegate,
        delegatee);
    _moveDelegates(currentDelegate, delegatee,
        delegatorBalance);
  }
}
```

Listing 1: delegate function from Uni Token contract

The balances mapping stores each account's token balance, while the delegates mapping keeps track of the last delegatee for each delegator. The delegate function is available to delegators (sender), enabling them

[2] Available at: https://github.com/Uniswap/governance/blob/master/contracts/Uni.sol

to assign their voting power to a chosen delegatee. In the internal _delegate function on Line 17 in Listing 1 the delegatee of the delegator is updated. The assignment of voting power from the current delegatee to the new one takes place in the downstream _moveDelegates function. The function also emits an event to log the change in the delegation relationship. Examining this code reveals that when a delegation occurs, it involves the entirety of the delegator's balance, implying that partial delegation of voting power is not supported. Thus, a delegator's entire balance gets transferred in terms of voting power to the delegatee.

```
1  pragma solidity ^0.5.16;
2
3  contract Uni {
4    // A checkpoint for marking number of votes from a given
       block
5    struct Checkpoint {
6      uint32 fromBlock;
7      uint96 votes;
8    }
9    // A record of votes checkpoints for each account, by
      index
10   mapping (address => mapping (uint32 => Checkpoint))
       public checkpoints;
11
12   /// The number of checkpoints for each account
13   mapping (address => uint32) public numCheckpoints;
14
15   function _moveDelegates(address srcRep, address dstRep,
       uint96 amount) internal {
16     if (srcRep != dstRep && amount > 0) {
17         if (srcRep != address(0)) {
18             uint32 srcRepNum = numCheckpoints[srcRep];
19             uint96 srcRepOld = srcRepNum > 0 ? checkpoints
                 [srcRep][srcRepNum - 1].votes : 0;
20             uint96 srcRepNew = sub96(srcRepOld, amount, "
                 Uni::_moveVotes: vote amount underflows");
21             _writeCheckpoint(srcRep, srcRepNum, srcRepOld,
                   srcRepNew);
22         }
23
```

```
        if (dstRep != address(0)) {
            uint32 dstRepNum = numCheckpoints[dstRep];
            uint96 dstRepOld = dstRepNum > 0 ? checkpoints[dstRep][dstRepNum - 1].votes : 0;
            uint96 dstRepNew = add96(dstRepOld, amount, "Uni::_moveVotes: vote amount overflows");
            _writeCheckpoint(dstRep, dstRepNum, dstRepOld, dstRepNew);
        }
      }
    }
}
```

Listing 2: Internal _moveDelegate function from Uni Token contract

The _moveDelegates function orchestrates the assignment of voting power from one delegatee to another. This function is triggered with parameters srcRep (source representative), dstRep (destination representative), and the amount of tokens involved in the delegation. In situations where the source and destination addresses for delegation are identical (self-delegation), the function bypasses further computation, thereby minimizing transaction costs. However, when the source and destination addresses differ, and the delegated token amount is greater than zero, the function executes additional operations to update the voting power of both addresses. This results in a transaction with higher gas costs, signifying that shifting voting power to a different address, compared to self-delegation, incurs a higher computational expense due to these additional operations (Feichtinger et al., 2023). Self-delegation occurs automatically upon token purchase or receipt within the context of this contract, enabling immediate control over the associated voting rights, although this functionality is not explicitly visible in the listed code.

3.2.1.2 Checkpoints

Complementing the mechanics of delegation and voting power transfer is the concept of "checkpoints." Checkpoints offer a snapshot of the number of tokens delegated to a specific blockchain address at a given block number (Anchorage Digital, 2022). This method ensures that a wallet address can only cast votes equivalent to the amount of tokens delegated to it at the time the proposal opens for voting rather than suddenly accumulating tokens to unfairly influence the voting process. This mechanism acts as a safeguard against potential manipulation, ensuring the integrity and fairness of the voting process in the Uniswap Governance framework (Anchorage Digital, 2022).

While checkpoints uphold the fairness of voting, they do come with increased computational demands. Each new checkpoint requires storing additional data on the Ethereum blockchain, raising the gas fee for the transaction. Further, querying the voting power involves traversing the checkpoint mapping, which can consume more gas as the number of checkpoints increases. Thus, while vital for maintaining voting integrity, checkpoints do contribute to higher transaction costs.

Returning to the _moveDelegates function, a deeper analysis of the code reveals a robust system for handling the transfer of voting power between addresses. If the source representative's (srcRep) address is not a null address, the function retrieves the number of historical checkpoints and the vote count from the most recent checkpoint for this representative. If no checkpoints exist, the function defaults to zero. The new vote count for the source representative (srcRepNew) is then calculated by subtracting the delegated amount from the current vote count, with a built-in safeguard against underflow. This process is paralleled for the destination representative (dstRep), but with an addition rather than a subtraction of the delegated voting count. This carefully tracked transfer of voting power is then recorded in a new checkpoint, capturing the changes in voting power distribution after each delegation by calling the _writeCheckpoint function.

```
pragma solidity ^0.5.16;

contract Uni {
  function _writeCheckpoint(address delegatee, uint32
      nCheckpoints, uint96 oldVotes, uint96 newVotes)
      internal {
```

```
        uint32 blockNumber = safe32(block.number, "Uni::_writeCheckpoint: block number exceeds 32 bits");

        if (nCheckpoints > 0 && checkpoints[delegatee][nCheckpoints - 1].fromBlock == blockNumber) {
            checkpoints[delegatee][nCheckpoints - 1].votes = newVotes;
        } else {
            checkpoints[delegatee][nCheckpoints] = Checkpoint(blockNumber, newVotes);
            numCheckpoints[delegatee] = nCheckpoints + 1;
        }

        emit DelegateVotesChanged(delegatee, oldVotes, newVotes);
    }
}
```

Listing 3: Internal _writeCheckpoint function from Uni Token contract

In the Uniswap governance mechanism, the _writeCheckpoint function serves as an essential component. This function records changes in the delegation of Uni tokens and maintains an indexed record of all delegations an address has been involved in (Anchorage Digital, 2022).

For instance, consider the following scenario, adapted from Anchorage Digital (2022). Alice, a Uni token holder, decides to delegate her 20 Uni tokens to Bob, resulting in the creation of Checkpoint B.1 which records Bob's voting power as 20 Uni tokens. Later, Rick, another Uni token holder, delegates his 40 Uni tokens to Bob as well. The system reacts to this new delegation by creating Checkpoint B.2, updating Bob's voting power to 60 Uni tokens. After some time, Alice chooses to redelegate her 20 Uni tokens from Bob to Rick. In response, the system creates two new checkpoints: Checkpoint B.3 and Checkpoint R.1. Checkpoint B.3 records a decrease in Bob's voting power to 40 Uni tokens, while Checkpoint R.1 notes an increase in Rick's voting power to 20 Uni tokens.

3.2.1.3 Voting

Once an address accumulates the necessary amount of delegation, it gains the capability to create a proposal through the Governor Bravo Contract, initially introduced by the Compound protocol [3]. Although the specifics of proposal creation are beyond the scope of this study, it is crucial to note that the proposed change is embodied in executable code. This characteristic ensures that, if approved, the proposal will be able to make tangible changes to the system.

After the proposal has been submitted, the next phase of the governance process begins. Delegatees, who have received voting power from delegators, are granted the opportunity to cast their votes. The manner and implications of this voting process are further investigated in the subsequent sections.

```
pragma solidity ^0.5.16;


contract GovernorBravoDelegate is GovernorBravoDelegateStorageV1, GovernorBravoEvents {
  /// The number of votes in support of a proposal required in order for a quorum to be reached and for a vote to succeed
  uint public constant quorumVotes = 40000000e18; // 40,000,000 = 4% of Uni

  function castVote(uint proposalId, uint8 support) external {
      emit VoteCast(msg.sender, proposalId, support, castVoteInternal(msg.sender, proposalId, support), "");
  }

  function castVoteInternal(address voter, uint proposalId, uint8 support) internal returns (uint96) {
       require(state(proposalId) == ProposalState.Active, "GovernorBravo::castVoteInternal: voting is
```

[3]Available at: https://github.com/compound-finance/compound-protocol/blob/master/contracts/Governance/GovernorBravoDelegate.sol

```
closed");
        require(support <= 2, "GovernorBravo::castVoteInternal: invalid vote type");
        Proposal storage proposal = proposals[proposalId];
        Receipt storage receipt = proposal.receipts[voter];
        require(receipt.hasVoted == false, "GovernorBravo::castVoteInternal: voter already voted");
        uint96 votes = uni.getPriorVotes(voter, proposal.startBlock);

        if (support == 0) {
            proposal.againstVotes = add256(proposal.againstVotes, votes);
        } else if (support == 1) {
            proposal.forVotes = add256(proposal.forVotes, votes);
        } else if (support == 2) {
            proposal.abstainVotes = add256(proposal.abstainVotes, votes);
        }
        receipt.hasVoted = true;
        receipt.support = support;
        receipt.votes = votes;
        return votes;
    }
}
```

Listing 4: castVote function from Governor Bravo contract

The castVoteInternal function is central to the Governor Bravo Contract's voting process. This function is tasked with validating and recording votes on proposals, taking in parameters that include the voters address, the proposal's identifier, and the type of vote.

After validating that the proposal is active and the vote type is valid, the function checks the delegatee's voting history to prevent double voting. It then calls the getPriorVotes function to fetch the number of votes the delegate held at the proposal's creation time, utilizing the checkpointing mechanism from the Uni token contract. This allows the contract to respect the voting power the delegatee held when the proposal was made

rather than at the voting moment.
The votes are then recorded based on the vote type - for, against, or abstain. The voting receipt is updated to reflect the delegatee's voting activity and the function returns the number of votes cast, effectively completing the voting process for that delegate on the given proposal.
The conclusion of the voting phase on a proposal does not immediately result in its implementation. Instead, it triggers a series of steps that ensure both the validity of the proposal's acceptance and a safeguarding period for the community.

3.2.1.4 Queuing, Execution and the Timelock Contract

Upon successful voting, the proposal enters the 'Queued' state. A requirement for this transition is the attainment of a quorum, which is set at 4% of the total UNI supply, signifying broad consensus (40 million UNI tokens) within the community. The quorum check is done in the state function, which is not listed in the code above.
The queuing procedure timestamps the proposal using the current block timestamp and includes a delay period set by the system's 'Timelock'. This delay mechanism, inherent to the Timelock contract, is a protective measure that permits the community to react or prepare for the upcoming changes before they take effect *Uniswap Docs* (2022).
After the delay period, the proposal reaches the 'Execution' stage, where the suggested changes can be enacted and system rules or parameters are potentially modified. An event signals successful execution, confirming the proposed changes have been put into effect. As part of the paper's scope, the focus remained on the primary aspects related to the voting mechanisms studied, rather than exploring every detail of the code.

3.2.2 Qualitative Analysis

Both quorum-based and delegated voting systems, common in DOAs, come with their advantages and drawbacks, often tied to their reliance on token-based voting power. Such models can inadvertently establish a plutocracy, where wealth, or in this case, token holdings, equates to voting power (Goldberg and Schär, 2023; Leech, 2013). This potentially allows token-rich individuals or entities to disproportionately influence decision-making, somewhat counteracting the decentralization ethos in DAO communities. (Nigam et al., 2023).

DAOs often face challenges relating to the 'weak identities problem.' The ease of creating multiple pseudonyms at minimal cost can make enforcement of entity-specific voting power restrictions challenging, opening doors to Sybil attacks (Goldberg and Schär, 2023; Douceur, 2002*b*; Tran et al., 2009). Such issues can further deepen the problem of plutocracy, as certain users may disperse their voting power across multiple addresses to consolidate their influence.

Delegates, at times, might be tempted to use financial incentives or other enticements to sway voters, a practice that could breed corruption and manipulation within the system (Marin, 2022). Further, as DAOs expand, factions often form based on shared beliefs, ideologies, or identities, which can create discord, conceal information, or harm the broader DAO community (Marin, 2022). Additionally, quorum-based voting is susceptible to specific types of attacks, such as flash governance attacks (Arsenault, 2020). Implementing a timelock is a common strategy to counteract this vulnerability (Qureshi, 2020).

When it comes to specifically quorum-based voting, this system presents a set of inherent advantages and challenges. One critical concern is the difficulty in setting the appropriate quorum threshold (Nigam et al., 2023). An excessively high threshold might cause most proposals to fail due to voter apathy, while an overly low threshold might enable the passage of low-quality proposals or open avenues for manipulation or governance attacks by malicious actors. Moreover, this system demands significant participation from members to approve proposals, a requirement that can be both expensive and time-consuming (Arsenault, 2020).

Delegated Voting, as previously discussed, fosters enhanced decision-making dynamics. This method allows for the transfer of voting power to knowledgeable delegates who are well-incentivized, enabling them to make valuable decisions on behalf of the collective. It effectively tackles issues that token holders may encounter due to time, resources, or knowledge constraints (Nigam et al., 2023). However, it's important to note that delegated voting can also intensify existing issues related to plutocracy that are common in token-based systems. Delegates, given their ability to hold a large number of tokens, might gain considerable influence in decision-making. This concentration of power can be even more pronounced when these delegates receive more voting power through delegation. To prevent such centralization and ensure accountability, most DAOs allow members to transfer or withdraw their delegation rights at any time, helping to balance power within the community (Nigam et al., 2023; Marin, 2022).

3.2.3 Quantitative Analysis

This section presents a quantitative analysis of delegated voting and quorum-based voting, focused specifically on Uniswap's governance model. The analysis aims to substantiate findings from the qualitative analysis related to potential risks such as plutocracy, high participation requirements, and the impact of delegation.

Guided by the insights gained in the qualitative examination, this analysis considers important aspects of Uniswap's voting dynamics, such as voting power distribution, participation rates, and the development of delegated voting power in relation to proposal participation.

The data used in this quantitative analysis was collected primarily from the Uniswap governor data available on tally.xyz. A Python script was used to fetch this data via tally.xyz's GraphQL API. The scripts are publicly available on a GitHub repository [4].

A total of 39 proposals were analyzed, with 26 of them having non-zero votes. Out of these 26 proposals, only three did not reach the quorum.

Data were gathered from 29,316 delegatee addresses, in addition to the proposals. For each address, the present delegated voting power and token balance were obtained using the Brownie framework and Web3 in

[4] `https://github.com/tuncpolat/seminar-fs23`

Python. Infura and the Etherscan API served as providers for this data collection process.
In order to gain a deeper understanding of the dynamics of delegated voting power over time, additional event data was collected for the 13 delegatee addresses with the highest voting power.

3.2.3.1 Voting Power Distribution

Following the methodology outlined by Goldberg and Schär (2023), figure 1 displays the relative voting power of the delegatee with the highest voting power share for each proposal, provided that the proposal reached quorum. Among the 23 proposals, the delegatee with the highest relative voting power share never exceeded 50% in any of the proposals. Therefore, no individual delegatee could single-handedly determine the outcome of a proposal. Problems associated with this method, as identified by Goldberg and Schär (2023), must be kept in mind while interpreting these results. For instance, the relative voting power of the dominant voter is a lower bound value. It doesn't consider the scenario where a voter could be using multiple pseudonyms to aggregate more voting power. This could potentially underestimate the actual influence of 'whales' or dominant voters on proposal outcomes.

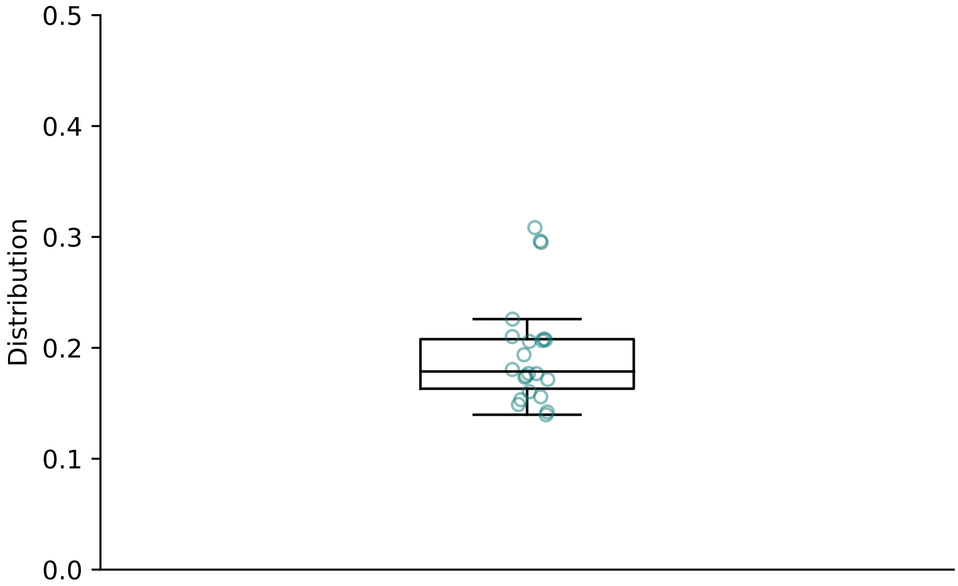


Figure 1: Relative voting power of voter with highest voting power share per proposal (quorum reached)

In line with the method adopted by Fritsch et al. (2022), Figure 2 illustrates the unequal distribution of voting power among delegatees in Uniswap. Their findings point towards a Gini coefficient close to one, signaling an intense disparity in the distribution of voting power in Uniswap's governance system, which operates on a liquid democracy model. The red line in the figure represents the 50% threshold; surpassing this mark could potentially enable a group of entities to determine the protocol. The figure reveals that a total of 14 addresses could attain such a level of influence, which closely aligns with the research of Fritsch et al. (2022). This is reflected in the Nakamoto Coefficient (Srinivasan and Lee, 2017), a metric used to measure decentralization, indicating the minimum number of entities required to control more than half of the resources or voting power within the system.

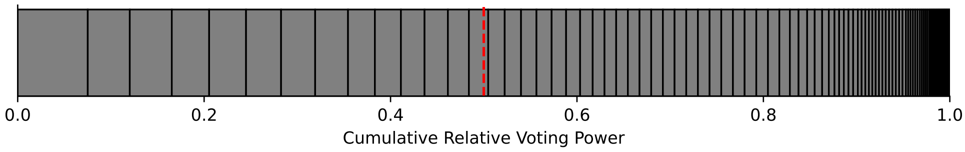


Figure 2: Voting power distribution among delegatees

Figure 3 presents the distribution of log-transformed delegated voting power per address. Given the skewed nature of the voting power distribution, a log10 transformation was employed for better visual clarity. The vertical green line in the figure marks the quorum threshold. An address with voting power above this line is theoretically capable of reaching the quorum on its own. However, the data shows that no single address is capable of exceeding the quorum on its own. However, it is important to interpret these results with caution, given the ease with which multiple addresses can be created in the ecosystem.

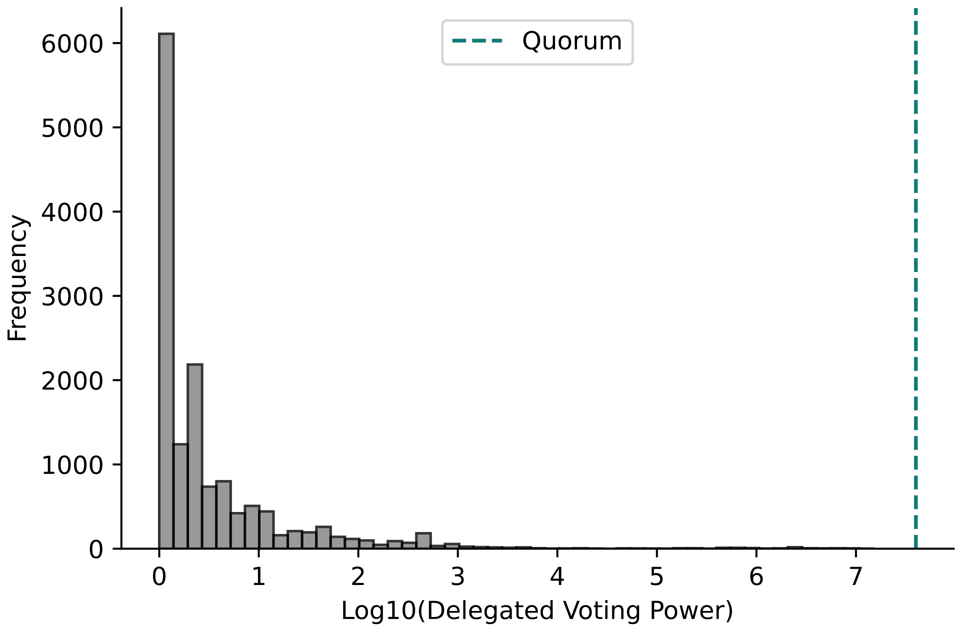


Figure 3: Log-transformed distribution of delegated voting power: evaluating the influence on quorum threshold

3.2.3.2 Voter Participation

The voting patterns of the 44 delegatees with over 1 million voting power are investigated in Figure 4. The delegatees are classified into three groups based on their voting power: over 5 million, between 2.5 and 5 million, and 1 to 2.5 million. 16 of these influential delegatees did not vote on any proposals. The average participation rate for these top delegatees is 24.18%. Delegatees with over 5 million and between 2.5 and 5 million voting power demonstrated slightly higher participation rates of 28% and 34% respectively. However, delegatees in the 1 to 2.5 million bracket had a notably lower participation rate of 8.28%, with eight not participating at all. Moreover, compared to other DAOs explored by Feichtinger et al. (2023), voter participation in Uniswap is on the lower end, suggesting possible inefficiencies in voting engagement, even among those with considerable delegated voting power.

3.2.3.3 Delegation

The temporal evolution of delegated voting power for a specific address, currently holding the highest delegated voting power within Uniswap DAO, is shown in Figure 5. Similar analyses for eight other delegatees, each with a voting power greater than 5 million and non-zero participation, are conducted as well and can be found in the appendix.

The graph tracks changes in delegated voting power over time, from the first block where delegation was received until the most recent block. Markers on the lines represent specific proposals, with green indicating a 'for' vote and red an 'against' vote.

An accompanying chart to the right displays a distribution of delegated voting power, demonstrating the number of delegators and the amount of voting power they've allocated. From this analysis, it can be observed that a multitude of delegators, each with small voting power, have contributed to the overall delegations. Yet, the delegated voting power for this delegatee is predominantly influenced by a single, substantial contribution. The large increase in voting power visible in the left graph

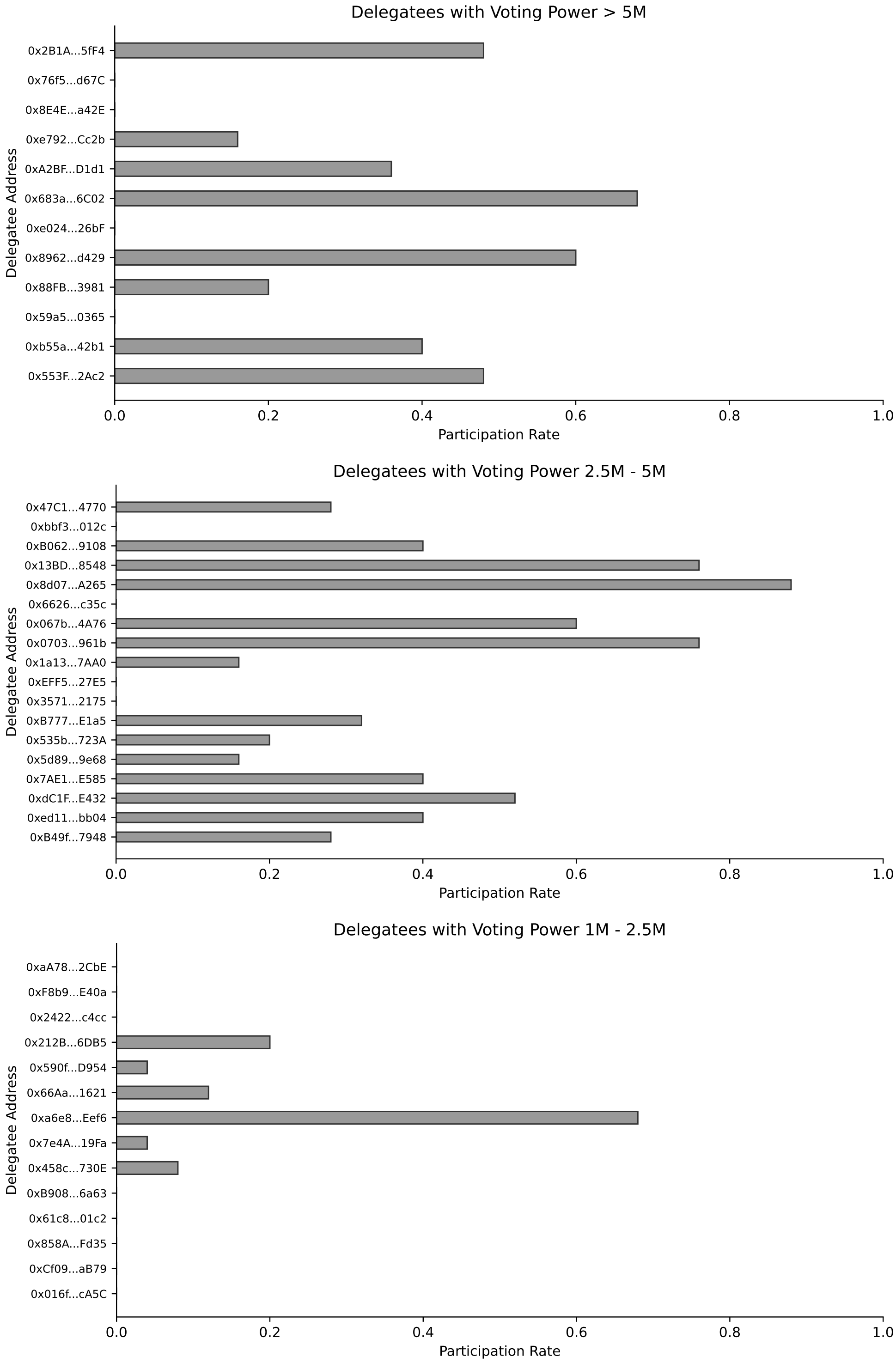


Figure 4: Participation rates of delegatees grouped by voting power

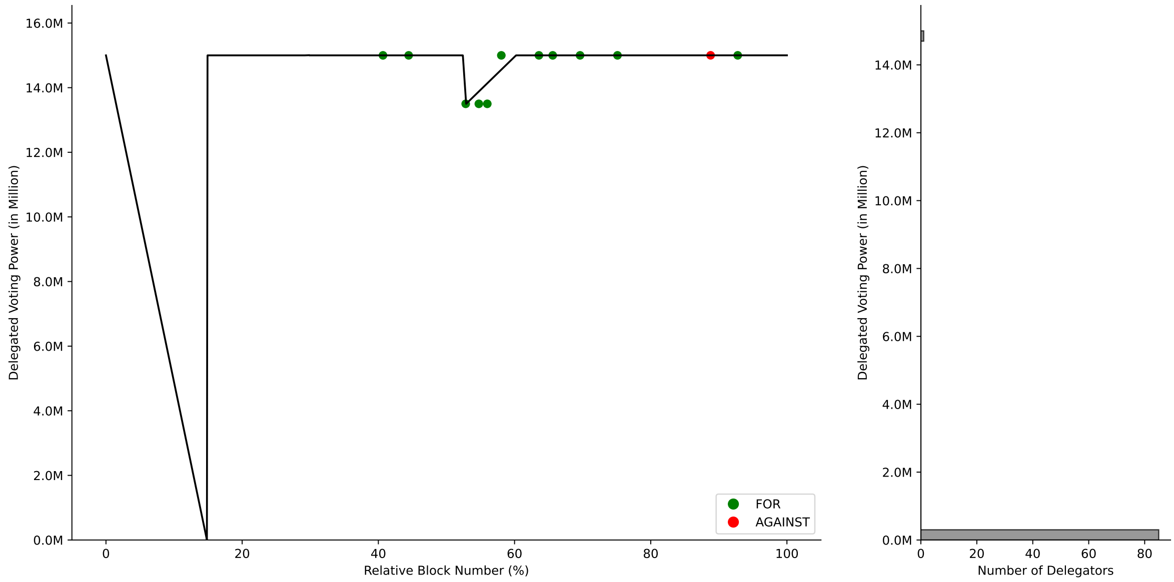


Figure 5: Progression of delegated voting power over time for the address holding the highest voting power, with individual proposals denoted ('for' vote in green, 'against' vote in red). Right: Distribution chart showing the number of delegators and their corresponding delegated voting power.

corresponds to this significant delegation.
This type of analysis was conducted for the top eight delegatees with more than 5 million voting power and non-zero participation rates. These additional evaluations can be found in the appendix of this document. The patterns exhibited were largely similar across all delegatees examined, suggesting a degree of centralization within delegation processes. This might imply that a representative's position is not significantly threatened by their delegators, particularly if self-delegation is a factor. In this context, the concept of re-delegation or withdrawal due to dissatisfaction may not hold as much weight as initially theorized.

3.3 Quadratic Voting

Quadratic voting (QV) presents a unique approach to capturing not only voters' choices but also the intensity of their preferences in the context of DAOs. Unlike conventional voting methods, which merely record the option selected by voters, QV accounts for the degree of preference by allowing individuals to purchase varying quantities of votes (Lalley and Weyl, 2018; Nigam et al., 2023).

In QV, voters may acquire any number of votes. However, the cost of each additional vote increases quadratically (Kurniawan and van der Werf, 2022). Figure 6 is an illustration of this relationship. This translates to a cost of one token for the first vote, four tokens for the second vote, and so on, thereby emphasizing the weight of each voter's conviction in their choice. Consequently, QV aims to efficiently incorporate the nuances of voters' opinions by permitting them to express strong support for particular proposals at an incrementally higher expense (Nigam et al., 2023).

Ongoing research and experimentation in the DAO community are actively exploring secure implementation methods for QV. Gitcoin, a platform dedicated to funding open-source digital public goods, has successfully employed quadratic funding to distribute substantial grants. Furthermore, Snapshot provides an option to incorporate quadratic voting with other voting methodologies, thereby enriching the decision-making processes within DAOs (Nigam et al., 2023). An instance of such integration was seen in the Gitcoin Stewards council election, which will be further analyzed in the upcoming chapter.

3.3.1 Gitcoins Stewards Council Election

Despite the theoretical interest in QV, its application in real-world scenarios, particularly in DAOs, has been limited (Nigam et al., 2023). However, one notable exception is the Gitcoin Stewards Council election held in December 2022 [5]. Gitcoin elected its Stewards Council using QV. The council, elected by the Gitcoin community, serves to refine governance and strategic decision-making within the platform. For the election, each registered steward received 99 tokens to distribute among 15 candidates

[5] https://gov.gitcoin.co/t/v2-of-the-steward-council-nomination-thread-and-election-results/12057

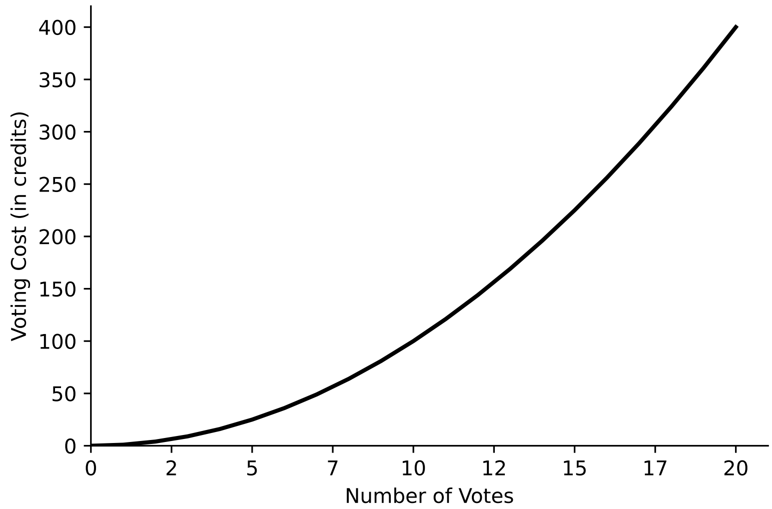


Figure 6: Quadratic voting function

using the QV method on the Snapshot platform. This approach aimed to balance influence among voters and enable a more expressive demonstration of preferences. The 15 candidates receiving votes are presented in Figure 7. The elected council, consisting of representatives from each workstream and externally active web3 leaders, is set to serve a term until June 3rd, 2023.

3.3.2 Qualitative Analsis

The qualitative analysis of QV reveals several noteworthy points. QV offers a unique avenue for individuals to express the intensity of their preferences (Nigam et al., 2023). One of the crucial aims of QV is to balance the influence of large token holders. It accomplishes this by increasing the cost of additional votes quadratically. This increase in cost makes it more difficult for wealthy individuals to dominate the voting process, effectively addressing the risks associated with simple and relative majority voting (Nigam et al., 2023; Bellavitis et al., 2023; O'Connor, 2022). However, the complexity of QV might pose challenges for average token holders, potentially skewing influence towards sophisticated and wealthy token holders (Nigam et al., 2023). Moreover, the cost of addi-

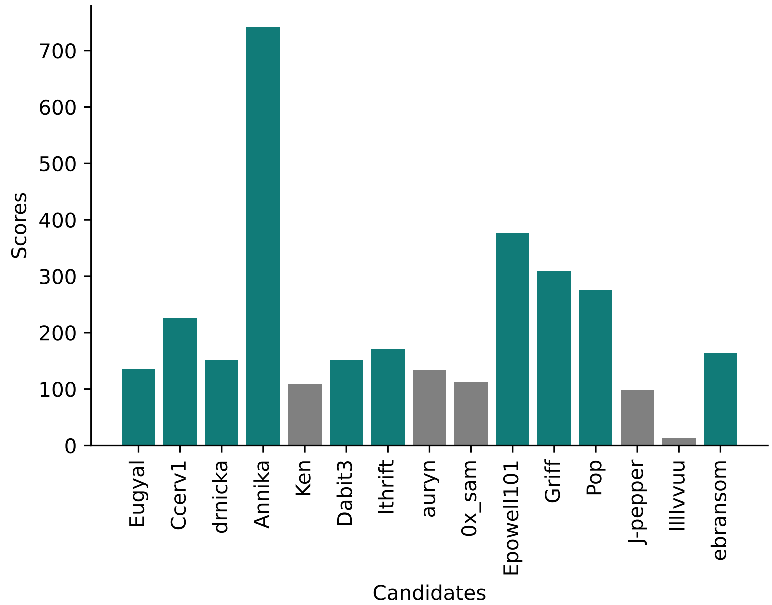


Figure 7: Scores per candidate

tional votes for wealthy token holders could be relatively less significant compared to minority token holders. Such a disparity could risk promoting a plutocratic governance system and distort the intended voting process (Nigam et al., 2023).

Just as with quorum-based and delegated voting systems, QV also faces the threat of Sybil attacks. This issue persists because these systems are fundamentally based on tokens, which makes them susceptible to users who create multiple pseudonymous identities to manipulate voting results. By sidestepping the quadratic cost function for buying more votes with each separate identity, these attackers can potentially distort the democratic process and undermine the core principles of QV (Nigam et al., 2023; Dimitri, 2022).

Moreover, QV encounters certain additional challenges. One of these involves the privacy of votes. QV necessitates a high degree of vote privacy to prevent vote-selling and collusion, a task which can be difficult to achieve in the digital context (Buterin, 2021). Furthermore, the system lacks an inherent mechanism for determining the proposals that make it to the ballot. This lack of built-in control can potentially open doors for malicious actors to exploit the system to their advantage (Buterin, 2019). It is important to note, however, that these are general issues that go beyond the realm of QV and persist in different voting models. Such challenges and potential solutions are discussed in more detail later in the discussion chapter.

3.3.3 Quantitative Analysis

QV's limited real-world application is one reason why this analysis pivots back to the elected stewards council members of Gitcoin. The data was sourced from Snapshot, which recorded voting activities of 32 registered stewards. In theory, QV provides voters with the capacity to express the intensity of their preferences, which contrasts with the binary options offered by other voting methods. Figure 8 showcases this feature by presenting the number of voters who distributed their votes to more than one candidate. In this figure, it is evident that only two voters selected a single candidate, while the remaining 30 voters distributed their tokens among two or more candidates. This data suggests that voters leveraged Quadratic Voting to express varying degrees of preference among multiple candidates.

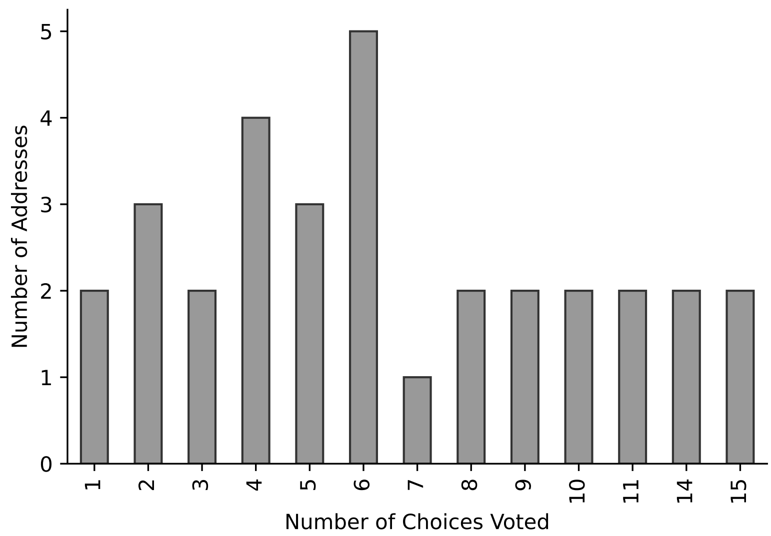


Figure 8: Addresses voting for different numbers of choices

4 Discussion

The primary focus of this research was on Quorum-Based Voting, Delegated Voting, and QV. The analysis initially looked at the qualitative aspects of these voting mechanisms, detailing their strengths and unique challenges. The data from Uniswap was then examined to confirm these challenges and benefits, as it uses Quorum-Based and Delegated Voting. Similarly, QV was examined using data from the Gitcoin Stewards Council election.

Voting within DAOs seeks to maintain democratic and decentralized governance. However, the fact that all examined mechanisms are built upon token-based voting raises valid concerns about potential plutocratic tendencies. These fears were underscored when data from the Uniswap protocol revealed possible centralization, contrary to the desired decentralization ethos within DAOs.

Regarding Delegated Voting, it aims to let voters delegate their votes to a representative of their choice, with the option to redelegate if unsatisfied at any time. However, the data uncovers some concerning trends. Primarily, it is evident that the voting power is highly centralized, with a minority of token holders commanding a considerable share of the overall voting power. More importantly, when examining the delegation of voting power, it emerges that the majority of delegated power often comes from a small number of token holders, with single, substantial delegations skewing the distribution. In other words, a significant portion of a delegatee's voting power tends to come from a single, large delegator regarding voting power, further intensifying the centralization. These findings suggest that the intended democratic and decentralized nature of this voting mechanism might be substantially diluted. One limitation to bear in mind, however, is that this analysis focused solely on Uniswap. Nevertheless, studies conducted by other researchers, such as Feichtinger et al. (2023), (Goldberg and Schär, 2023) and Fritsch et al. (2022), reveal similar centralization patterns across various other protocols, thereby validating the observed trends in this research.

Defining an appropriate quorum level poses a challenge in Quorum-

Based Voting. Setting it too low may invite malicious actors, while a high threshold might deter proposal passage due to lower voter participation. Yet, proposals in Uniswap frequently pass the quorum, likely attributed to its three-phase governance protocol where proposals discussed and accepted in earlier phases advance to on-chain voting. Data from Uniswap suggests that no single address can dictate proposal outcomes, although the 'weak identity problem' introduces some uncertainty. Voting participation is typically sufficient for passing the quorum. However, overall voter turnout, particularly among delegatees with significant voting power, is noticeably lower than in other protocols Feichtinger et al. (2023).

With Quadratic Voting, the limited data suggests that it allows voters to more effectively express their preferences. However, this limited dataset restricts comprehensive evaluation of its strengths and potential pitfalls. A notable concern is its vulnerability to Sybil attacks, where an entity could create multiple identities to bypass the quadratic cost function, effectively gaining an unfair influence. To address this issue, D3LAB has proposed the concept of Probabilistic Quadratic Voting, which aims to mitigate the impact of Sybil attacks through the incorporation of probabilistic elements (Chainlink, 2022). This ongoing development demonstrate the continuous efforts to address the vulnerability to Sybil attacks and enhance the fairness and robustness of voting mechanisms within DAOs.

While numerous voting mechanisms have been proposed and implemented to tackle the prevailing challenges of on-chain governance, each carries its own strengths and inherent limitations. Voting mechanisms introduced briefly in Chapter 3.1 such as Conviction Voting, which empowers long-term community members and deters manipulative behaviors, and Holographic Consensus, which enhances scalability to handle more decisions as a DAO expands, are tailored to address specific issues. However, an ideal system that flawlessly addresses the issues of decentralization, voter participation, efficiency, coordination, scalability, participation barriers, and security risks remains challenging. Buterin (2021), in his analysis, acknowledges the limitations of blockchain voting despite its potential.

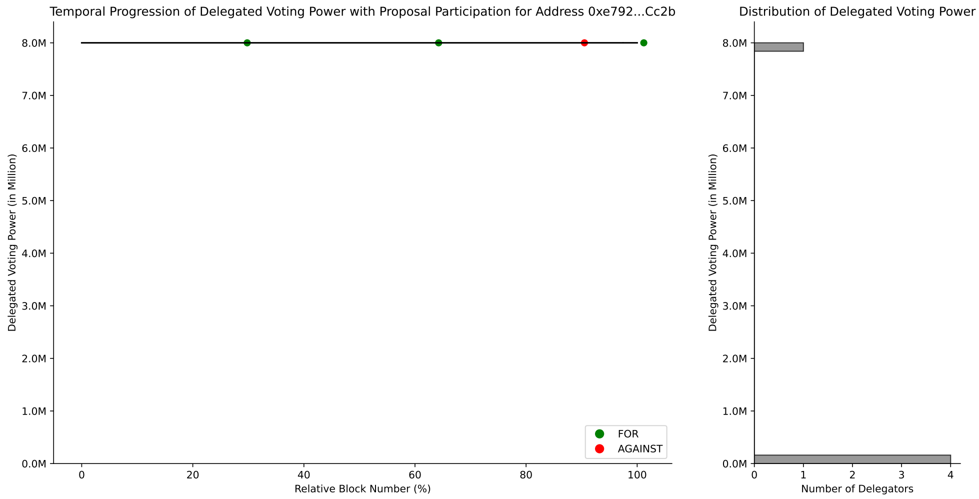
While blockchain technology ensures accurate execution and resistance against censorship, challenges persist in guaranteeing privacy and resistance against coercion. Therefore, he concludes that, in the short term, blockchain voting should be limited to small-scale experiments.

5 Conclusion

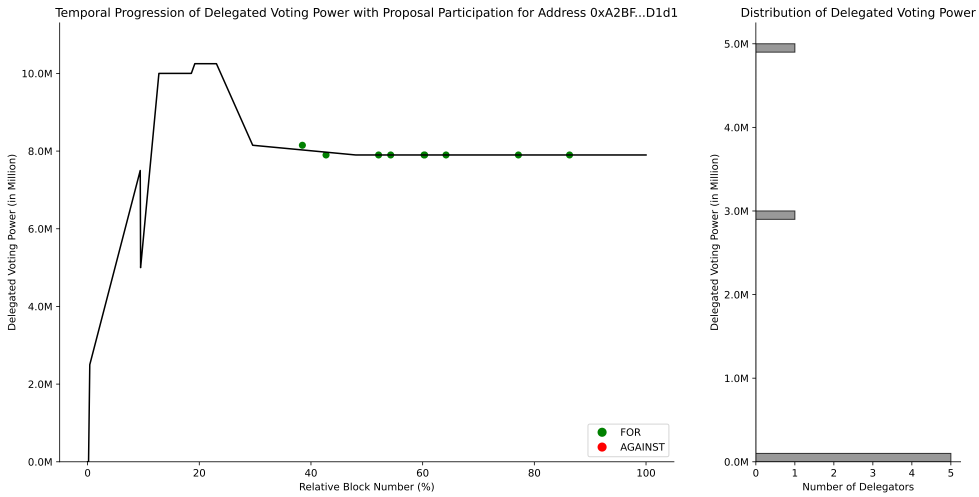
In conclusion, this paper examined the functioning of voting mechanisms within DAOs, with a specific focus on Quorum-Based Voting, Delegated Voting, and Quadratic Voting. The research aimed to meet two primary objectives: firstly, to identify and understand the working of these voting systems in DAOs, and secondly, to analyze these mechanisms and identify their distinct advantages and drawbacks in the DAO environment, both qualitatively and quantitatively.

The research conducted for this paper identifies potential centralization risks in token-based voting systems, notably evident in the Uniswap case study. Quadratic Voting, while promising as a tool for enhanced voter expression, also raised concerns due to its vulnerability to Sybil attacks. Despite various proposed voting mechanisms, an ideal solution that fully addresses the complexities and challenges of on-chain governance hasn't been developed yet. Future research in this area should focus on studying more new voting systems used in DAOs. Each novel method can reveal innovative ways to solve existing problems or offer insights into how to best balance important factors like decentralization, efficiency, participation, and security. By better understanding these systems, it is possible to improve upon their design, identifying and address issues, and maximizing their advantages.

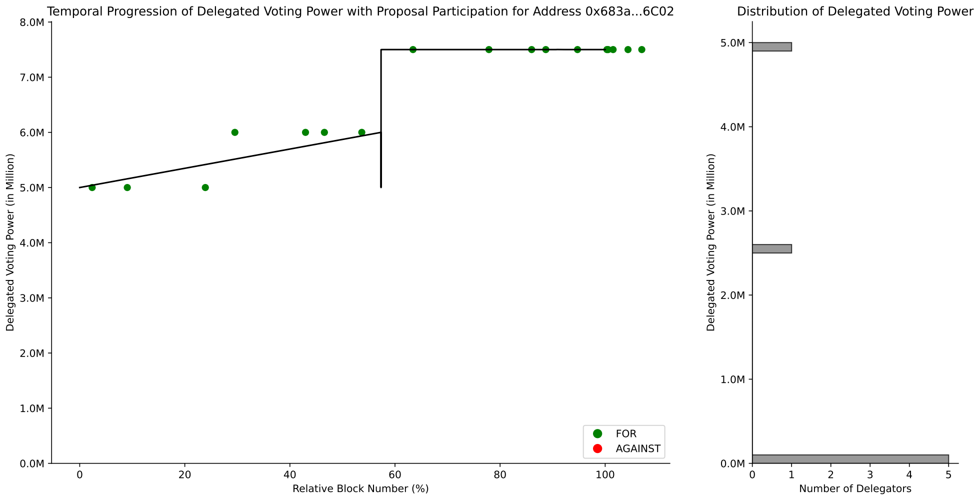
A Appendix

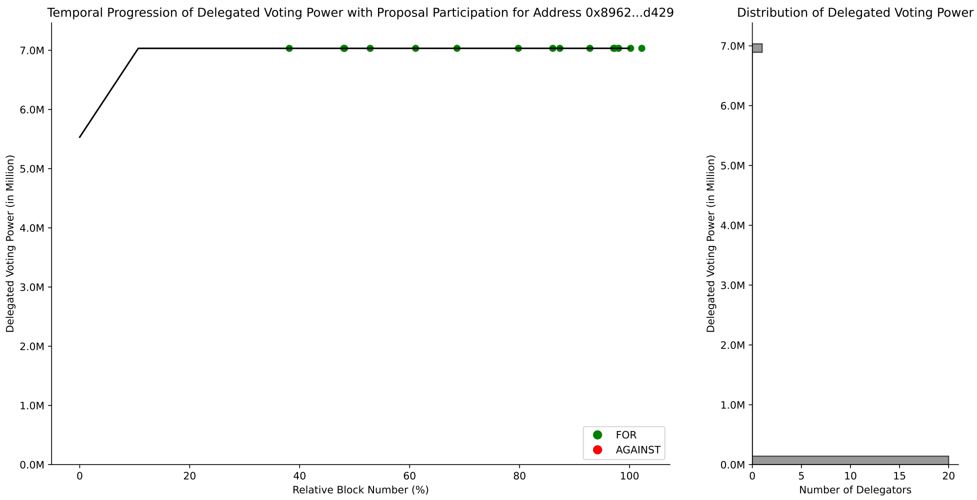


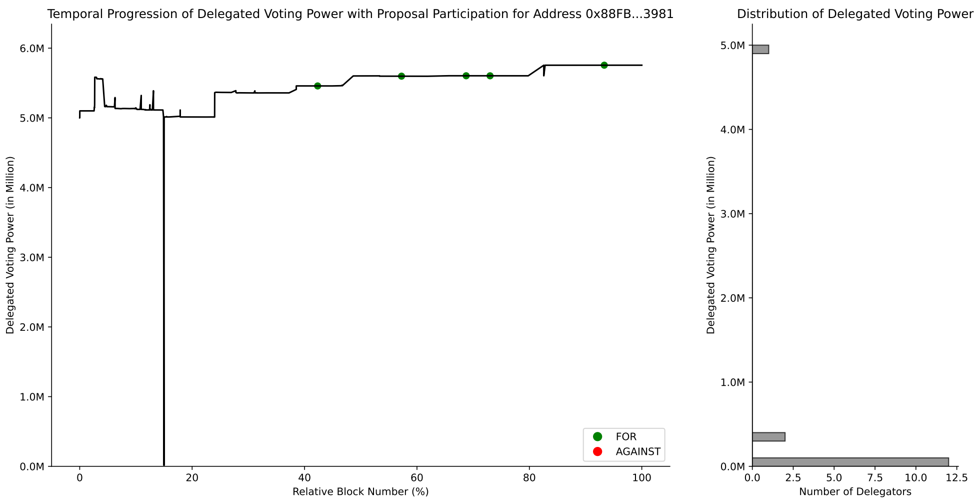
Temporal Progression of Delegated Voting Power with Proposal Participation for Address 0xe792...Cc2b
Delegated Voting Power (in Million)
0.0M
1.0M
2.0M
3.0M
4.0M
5.0M
6.0M
7.0M
8.0M
0
20
40
60
80
100
Relative Block Number (%)
FOR
AGAINST
Distribution of Delegated Voting Power
Delegated Voting Power (in Million)
0
1
2
3
4
Number of Delegators



Temporal Progression of Delegated Voting Power with Proposal Participation for Address 0xA2BF...D1d1
Delegated Voting Power (in Million)
0.0M
2.0M
4.0M
6.0M
8.0M
10.0M
0
20
40
60
80
100
Relative Block Number (%)
FOR
AGAINST
Distribution of Delegated Voting Power
Delegated Voting Power (in Million)
0.0M
1.0M
2.0M
3.0M
4.0M
5.0M
0
1
2
3
4
5
Number of Delegators


Temporal Progression of Delegated Voting Power with Proposal Participation for Address 0x683a...6C02
Delegated Voting Power (in Million)
Relative Block Number (%)
FOR
AGAINST
Distribution of Delegated Voting Power
Delegated Voting Power (in Million)
Number of Delegators


Temporal Progression of Delegated Voting Power with Proposal Participation for Address 0x8962...d429
Delegated Voting Power (in Million)
Relative Block Number (%)
FOR
AGAINST
Distribution of Delegated Voting Power
Delegated Voting Power (in Million)
Number of Delegators


Temporal Progression of Delegated Voting Power with Proposal Participation for Address 0x88FB...3981
Delegated Voting Power (in Million)
Relative Block Number (%)
FOR
AGAINST
Distribution of Delegated Voting Power
Delegated Voting Power (in Million)
Number of Delegators

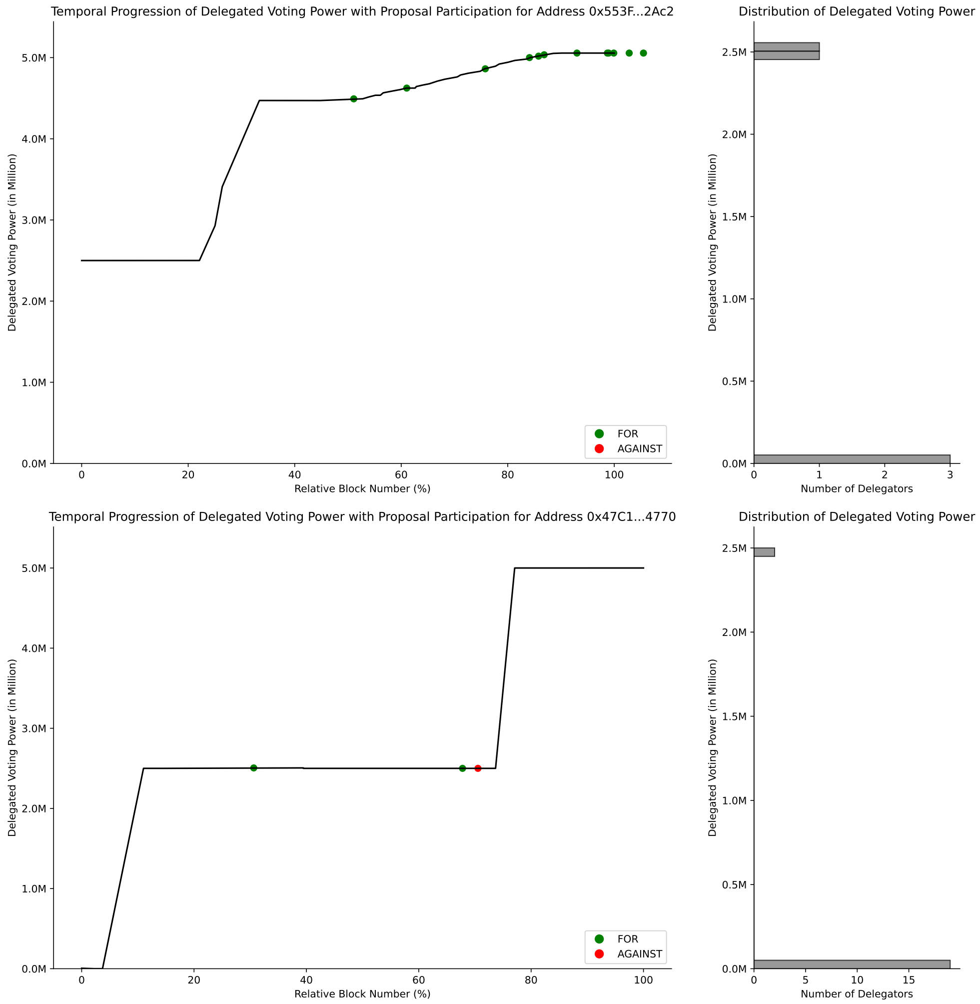


Figure 9: Progression of delegated voting power over time for the eight addressess holding the highest voting power and non-zero participation rate, with individual proposals denoted ('for' vote in green, 'against' vote in red). Right: Distribution chart showing the number of delegators and their corresponding delegated voting power.

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