Exploring Decentralized Governance: A Framework Applied to Compound Finance

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Abstract. This research proposes a methodology which can be used for measuring governance decentralization in a Decentralized Autonomous Organization (DAO). DAOs, commonly, have the ambition to become more decentralized as time progresses. Such ambitions led to the creation of decentralized governance models that use governance tokens to represent voting power. Relevant research suggests that the distribution of the governance tokens follows centralized accumulations in a few wallets. By studying the accumulations of voting power from a DeFi protocol, this research presents a framework for identifying and measuring decentralization via analyzing all the various governance sub-systems instead of focusing on one or a small group. Governance within a DAO is a multi-layered process. By examining the decentralization of each layer or subsystem within the overarching governance structure, we can compose a comprehensive understanding of the entire protocol. To demonstrate this method, this paper uses the Compound Finance protocol as a case study. The first sub-system that this research discusses is the delegated and self-delegated wallets which are the only entities that can participate in the voting process in the Compound platform. The second sub-system is the actual proposals and votes that have taken place in the protocol's governance. Data is derived directly from the protocol's web data and for two time periods.

Keywords: DAOs · DeFi · DAO Governance · Decentralization · Compound Finance

1 Introduction

Decentralized finance (DeFi) is now an established term in the crypto ecosystem. Financial services that can be offered to both businesses and individuals in a decentralized manner are at the core of the DeFi ecosystem. Some of the provided services may include: exchanges, lending and borrowing, taxes, credit, insurance, etc. [23,3]. Decentralized Autonomous Organizations (DAOs) are at the core of most of the DeFi protocols [23]. As the name suggests, a DAO shall use decentralized ways to be operated and governed. Although the services and governance operations of the DeFi protocols rely purely on the decentralized ledger [22,7], the decentralization of the governance and decision-making process in the DeFi DAOs has to be questioned [1,20,14].

Decentralization is an aspect long discussed in the blockchain ecosystem. In Bitcoin and proof-of-work systems in general, decentralization of the nodes and hashing power is necessary to build trust and transparency in the ecosystem [24]. With the introduction of proof-of-stake and governance tokens in DAOs decentralization moved from "computer decentralization" to "economic decentralization". As it will be discussed in Section 3.1 most of the current research focuses on studying only one decentralization sub-system. Blockchain applications are formed from a "stack" of different sub-systems [21] forming a decentralized service to the end user. This "stack" starts from underlined ledger to the user interface and each sub-system connects with the next one unidirectional. If one sub-system is compromised then all the dependent ones above can be also compromised. Therefore, monitoring decentralization has to be done in the various sub-systems in order to provide answers to the whole platform.

1.1 Motivation

Decentralized autonomous organizations have adopted smart-contract-based governance structures. Instead of operating on a traditional founder, manager, and employee hierarchy base, in the majority of the operational DAOs, decisions on management and development of the organization are made by governance token holders and their delegates. As will be discussed in Section 3, current studies use decentralization monitoring methodologies similar to the ones used on mining nodes. The operations and consensus of DeFi protocols and in general DAOs, form more complete multidimensional decision-making systems in comparison with blockchain consensus protocols. This system requires a better understanding of the decentralization structure and the methodologies on which decentralization can be measured.

1.2 Contribution Summary

Research questions:

1. How can we analyze more decentralization dimensions in a DAO?
2. How do we monitor decentralization of a DAO via studying the different sub-systems?
3. How can we introduce the time dimension in the decentralization analysis?

This research will use one of the first governance token-based organizations named Compound as a case study on the proposed framework. Since all the well-established DAOs use such governance models to operate [17], the analysis of this organization will be used as a case study to formulate answers to the research questions. Compound was chosen as it provides accessible available data in their font-end without the need to look at the on-chain data. Compound is a marketplace that allows individuals to borrow and lend digital assets. This platform is a decentralized protocol that is built on top of the Ethereum blockchain.

All users can interact with the protocol's governance by voting and proposing via the COMP token delegations [4]. Decentralization of governance data, including voter delegations, proposal votes, and vote totals, will be analyzed quantitatively in this article.

Specifically, this paper will include in Section 2 the description of the Compound protocol and its governance methods. Section 3 shall contain the relevant work on the subject and the discussion of the given literature. It is the Methodology and Data overview that is being discussed in Section 4. And lastly, Section 4.2 may contain a description of the findings and Section 6 that will consist an applied use of the proposed framework will consist of a general discussion and future work.

2 Compound

The Compound protocol allows its users to stake (the process of "locking") up their crypto assets in order to earn interest or rewards and lend or borrow some of the supported assets such as: Ethereum, DAI, SAI, USD Coin, Tether, Augur, etc. [2]. This decentralized application allows anyone that owns such crypto assets to engage in the lending and borrowing process without the need to involve traditional financial services [8].

The main vehicle on which this protocol operates is the cTokens which are digital assets that represent the staked amount in the platform [8]. cTokens are "Ethereum Request for Comment"- 20 (ERC-20) [5] Ethereum tokens that take the form of every underlined asset, such as cETH, cDAI, cREP, etc. These tokens are transferable and tradable due to their on-chain nature, therefore, other decentralized Applications (dApps) can support them. Interest is calculated and offered through the Compound protocol based on the available liquidity for each of the offered crypto assets on the platform. The rates are connected to the supply and demand of the market and they are constantly adjusted. For every 15 seconds each user's cTokens are increased by 1/2102400 which is equal to the fraction of 15-second blocks per year [8,4,2].

2.1 Governance

The Compound protocol can only be configured or upgraded by the COMP governance token holders or their delegations. Changes that go through the voting mechanism include collateral variables, interest rates, new markets, system characteristics, and so on. The COMP governance token has one-to-one voting power. COMP owners can delegate votes to themselves or any other Ethereum wallet [4]. Holders of COMP are unable to vote or create a proposal unless they have delegated their tokens to themselves or to another address [8]. The proposals are executable code that can modify the protocol and/or its operations. In order for an individual to create a proposal they need to have at least 60,000 COMP delegated to their address [8]. If the total majority of votes surpass the minimum of 4% of total delegated COMP (i.e. 400,000 COMP) then the proposal is quoted

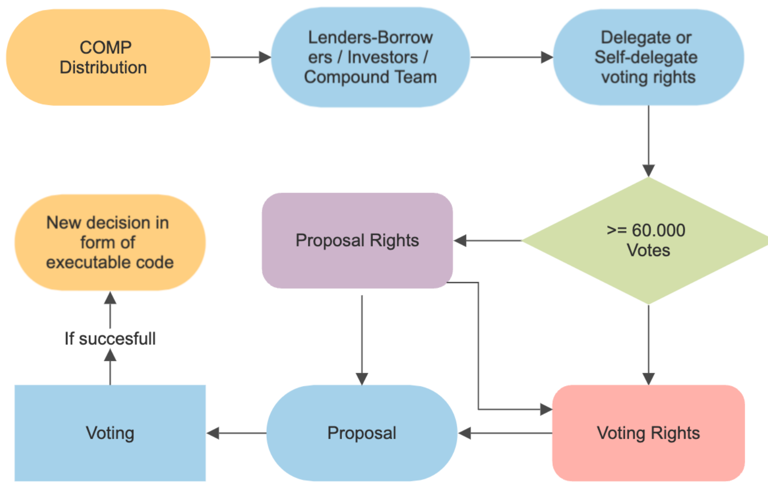

Fig. 1: Compound Governance Process

in the Timelock smart contract that will stay at a minimum of 48 hours before being implemented into the protocol [8,9,4]. This process is generally described in Figure 1.

3 Relevant Work

The relevant literature in the area of Defi governance decentralization mainly focuses on the governance token distribution from major DeFi protocols. The [20] focus on the distribution of governance token from IDEX, MakerDAO, Compound, Curve, and Uniswap. The approach of the authors focuses on how the governance token distribution of all the holders is compared to the top 20 holders. The results suggest high levels of centralization of voting power across the protocols but the authors do not provide mathematical metrics to back their results. [14] aims to also study the level of decentralization between DeFi protocols by using decentralization metrics. The study explains the governance models of Balancer, Compound, Uniswap, and Yearn Finance and derives data from Defipulse. The authors observe high amounts of centralization across the applications with the Gini Coefficient [6] taking values from 0.82 to 0.98 and Nakamoto Coefficients [15] from 82 to 9; with Compound being the most centralized platform. Their research provides good foundations on how to apply decentralization metrics in DeFi and what types of wallets sampling methods may exclude, but the limitation of the study is the absence of the time dimension and the delegation of votes. Moreover, [1] extends previous research by introducing new decentralization metrics that can be applied in DAOs and measures the governance decentralization of Uniswap, Maker, ShushiSwap, UMA, and Yearn Finance. This research also introduces the time dimension by sampling their data with 6-month intervals and again the indexes indicate the high centralization of governance in the DeFi ecosystem. The most relevant study that follows similar approach to this paper is from [12]. The authors of the paper conducted an empirical study on the state of three prominent Decentralized Autonomous Organizations (DAO) governance systems on the Ethereum blockchain: Compound, Uniswap, and ENS. They used a comprehensive dataset of all governance token holders, delegates, proposals, and votes to analyze the distribution and use of voting power in these systems. The authors also evaluated the level of decentralization in these systems and studied the voting behavior of different types of delegates.

3.1 Literature Discussion

The majority of the previous studies have introduced methods for calculating decentralization on the governance token distributions from mainly Ethereum on-chain data on wallets that hold governance tokens. This method is excluding delegations and only covers the centralization dangers of the token holder subsystem. In the case of Compound, COMP token holders are not a solid part of governance; instead, their delegates are. Therefore, this is the main subsystem on which decentralization analysis can be conducted, alongside other important sub-systems below the delegates which are the proposals and actual votes that are submitted. Additionally, the importance of including the fundamental governance aspects of each individual DAO before conducting a decentralization analysis was not discussed in the given literature and can be a great subject of future research.

4 Methodology and Data

The methodology consists of data gathering from the official Compound Governance Website and then the presentation of existing decentralization metrics in order to find estimations on how decentralized is the governance of this Defi protocol. All the used code and data sets are uploaded and available on a GitHub [1] repository.

4.1 Data

This research relies on information manually scraped from the official Compound website [9]. The samples consist of two main sets, the first set is the top 100 leader-board based on their voting power and the individual proposals that were issued into their voting system. Due to the difficult sampling process and the distinct characteristic of this research is the leader-board sampling from two time periods (August 2021 and January 2022) and the decentralization monitoring of the actual governance process on the proposals. Yet an other reason for the two

[1] https://github.com/manospgl/COMPDecentralization

sampling periods falls on the nature of blockchain it self. Because the token and delegate ownership exist on-chain then a clear time-window cannot exist, we can only extract a "snapshot" of the ledger as we do now. In order to get an extensive data sampling for such protocols a sampling framework must be used in order to get automated snapshots of the ledger. The data were manually extracted from the HTML website code found in Compound Governance page. The ambition for the DeFi protocols is to become more decentralized as time passes, thus, the sample of data derives from two time periods. Additionally, the proposals by nature are a recurrent process so they include the time dimension. The Compound leader-board consists of the address IDs, address names, votes (translates to delegations owned), vote weigh and proposals voted. Additionally, due to the already identified names of many of the addresses, extensive research on the internet on the identity of every address has been conducted and it's included on the leader-board data sets. The proposals include a total of 82 proposals from the initial proposal on May 2020 to January 2022. The samples contain the "for" and "against" address names together with their votes, the total "for" and "against" addresses that were involved in the proposal, the total "for" and "against" votes, the address that posted the proposal and the poll result as seen in Figure 2.

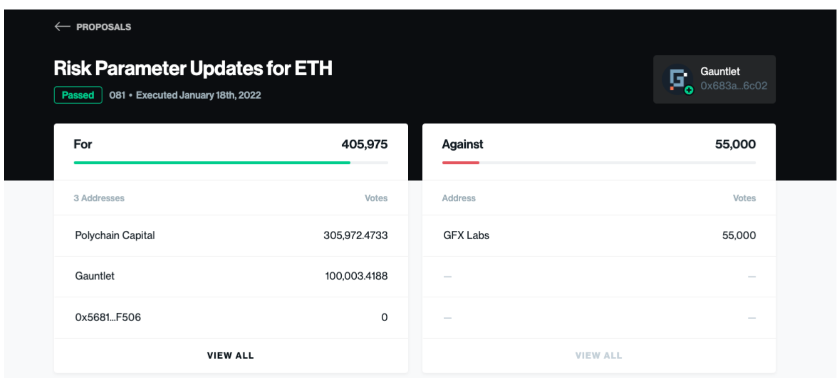

Fig. 2: Compound Proposal 081 screenshot

4.2 Methodology

The initial part of the proposed framework consist of the fundamental analysis of the various governance layers for given protocol, as demonstrated in Section 2 After identifying the distinct sub-systems, the goal is to measure the level of decentralization in all the systems via the use of existing decentralization metric coefficients, the Gini and Nakamoto. Gini Coefficient is used in economics as a measurement of statistical dispersion in order to represent the income or wealth inequality in a society [16]. The main purpose of this index is the measurement of inequality among frequency distributions as delegations of governance tokens. This coefficient takes values from 0 to 1, with 0 representing the perfect equality and 1 the maximum inequality of the values [10]. Mathematically the Gini coefficient is based on the Lorenz curve which, in the case of token distributions, plots the proportion of the total tokens on the number of the population. This index is also mathematically defined by the half of the relative mean absolute difference which is equivalent to the Lorenz Curve definition [13]. In more detail, the Gini Coefficient is given by Equation 1 [10].

$$Gini(u) = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|u_i - u_j|}{2\sum_{i=1}^{n}\sum_{j=1}^{n}u_j} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|u_i - u_j|}{2n\sum_{j=1}^{n}u_j} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|u_i - u_j|}{2n^2\bar{u}} \quad (1)$$

where u_i is the total voting power (Governance token voting delegations) for each wallet i with a total of n wallets and $\bar{u}$ is the average in normalized scale [10].

On the other hand, Nakamoto Coefficient is defined as the minimum number of entities in a system or sub-system that obtain equal or more than 50% of the total capacity, this is calculated by aggregating the minimum of the subsystems [19]. Mathematically, the Nakamoto coefficient for a subsystem u with N entities with $j_1 > ... > j_N$ the proportions that each of the participants N controls in the subsystem such as $n : \sum_{i=1}^{n} j_i > \frac{1}{2}\sum_{i=1}^{N} j_i$, can be defined as seen in Equation 2 [19].

$$N = \min\left(n : \sum_{i=1}^{n} j_i > \frac{1}{2}\sum_{i=1}^{N} j_i\right) \quad (2)$$

In the case of this study, the Nakamoto coefficient is the minimum number of entities (wallets) that can control more than 50% of the voting power.

The proposed decentralization analysis framework for Compound finance governance model consists of the following parts:

1. Distribution of usable governance power (e.g. delegated tokens), static and overtime.
   - Majority power distribution over the addresses that hold the majority of votes
   - Distribution tendencies over a time period
2. Qualitative characteristics of the dominant addresses
   - Identification of the dominant addresses
   - Identifying possible incentives according to the nature of the organisation or the individual behind the address
3. Proposal dominance distribution
   - Dominance on wallets that create proposals
   - Dominance on voting results
4. Used voting power analysis

- Probabilities of desirable result from the power dominant addresses
- Decentralization of the used power over past votes

For analyzing the proposal dominance distribution and and used voting power analysis the paper uses the voting data from the proposals. The proposing and result dominance is observed by the wallets that submitted the proposal and each voting result. In order to get the probabilities of desirable result from the dominant addresses this research used each of the dominant addresses voting history. The probability of a desirable result ($P_{desired}$) from a specific address i is determined by dividing the number of desirable results (votes for a proposal that succeeded or votes against a proposal that failed) by the total number of times that address i participated in voting as seen in 3.

$$P^{i}_{desired} = \frac{\text{Number of desired results from address } i}{\text{Total vote participation of address } i} \tag{3}$$

Moreover, the last part of this analysis contains the study of the decentralization levels of the voters. The sampling of the proposal follows an assenting chronological order. In order go plot the possible decentralization trend, the research used the Gini and Nagamoto coefficients in the total votes that were submitted in each individual proposal.

Compound decentralization analysis using the proposed framework Considering that the fundamental sub-system structure of Compound has been discussed in Section 2, In this section, shall take the aforementioned data and do our own statistical research to get a better sense of how decentralized the Compound protocol's governance really is.

Fig. 3: Top ten voting dominance

4.3 Top 100 Leaderboard

The first step of the analysis for the voting leader-board data is to observe the power of the top vote delegated COMP holders. In detail, the voting power dominance of the top 10 wallets from the two time periods shall be presented.

Figure 3 Shows the dominance of the top 10 addresses compared to the sum of the voting power of the entire leaderboard. What the graph shows, is the undeniable dominance of the top 10 voters on the token distribution, with 56,8% dominance on August 2021 and 55,5% on January 2022. It is obvious that in both cases the Nakamoto Coefficient is 8. The distribution of power suggests that if the top 8 wallets will like to form a consortium they can potentially influence any poll to their liking. What the data from the proposals should provide is how this voting power is actually been used.

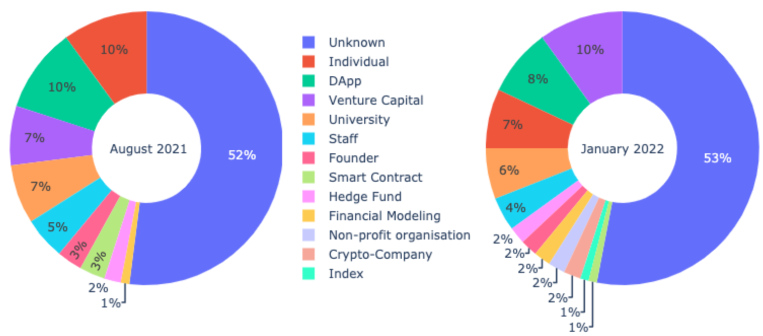

Fig. 4: Delegated Voters Category Distribution

Category	Count (August 2021)	Count (January 2022)
Venture Capital	7	10
Hedge Fund	2	2
Founder	4	2
Financial Modeling	1	2
Unknown	52	53
Non-profit organisation	-	2
Individual	10	7
Crypto-Company	-	2
DApp	10	8
University	7	6
Index	-	1
Smart Contract	3	1
Staff	5	4

Table 1: Distinct Address categories and their count of occurrence

The next step of this research is to observe the demographics of the address owners. Applications built on the blockchain, including the blockchain technology itself, advocate for privacy and independence [18]. One could argue that in a decentralized distribution system, only unknown persons will operate and influence a protocol, in keeping with the principle of anonymity and individuality. However, it is inefficient to begin building a platform and its laws solely via the efforts of individuals, especially in the absence of a centralized developing team to make the early judgments and funding. Therefore, most of the DeFi platforms start with centralized development and funding with the ambition to become decentralized overtime. While centralized entities like Venture Capitalists (VCs), founders, etc. may be entitled to a disproportionate share of the tokens at the outset, it is only fair to spread the initial governance token allocations to the early public users, the early investors, and the founding team.

Fig. 5: Weighted Delegated Voters Category Distribution

Hence, this study is aiming at observing this transition. As was mentioned in section 4.1 Compound provides some of the known names from the leaderboard. From individual research of every address, the data suggest the following distinct categories of the addressees. Table 1 shows all the individual categories for the addresses on the top 100 leader-board, their number of occurrences, and Figure 4 presents visually their distribution. As mentioned before, it is important, in terms of decentralization, who owns the majority of the voting power. As Figure 4 and Table 1 suggest that the majority of the voters, in terms of wallet population, are held by unknown individuals.

Also, the Compound governance model does not advocate for a scheme in which one wallet equals one vote in elections; rather, it proposes a mechanism in which one token equals one vote. Therefore, it is more valuable to study the distribution of wallet types weighed on their voting power. Although previously it is observed that the majority of the wallets have unknown origins if each category is weighed to their voting dominance then the distribution is significantly affected. Figure 5 shows that the majority of the voting power is held by Venture Capitals, and their total power has grown between August 2021 and February 2022 with the power of unknown wallets also shrinking in that period.

Lastly, the decentralization metrics for the top 100 voter leaderboard shall be analyzed. The numbers suggest that the Gini Coefficient for August 2021 is 0.764 and for January 2022 is 0.753. Additionally, Figures 6 and 7 visualize the

Lorenz curve and outline the Nakamoto coefficient in both time periods is equal to 8. The Lorenz curve (solid line) represents the cumulative distribution of voting power among delegates, sorted in ascending order. The x-axis represents the cumulative proportion of delegates, while the y-axis represents the cumulative proportion of voting power. The line of equality (dashed line) represents a perfectly equal distribution of voting power. The deviation of the Lorenz curve from this line illustrates the degree of inequality in the distribution of voting power. The Nakamoto coefficient is represented by the vertical dashed line, indicating the minimum proportion of delegates that together hold more than 50% of the total voting power.

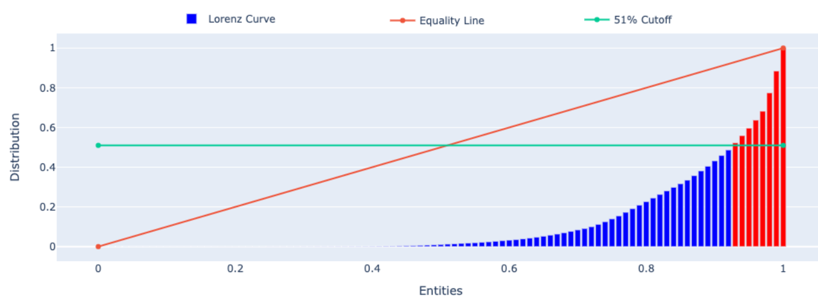

Fig. 6: August 2021 leaderboard

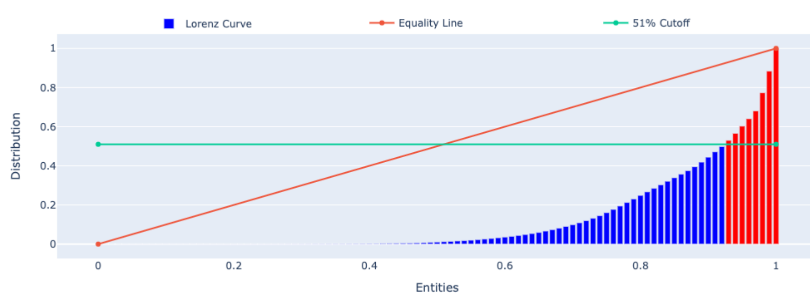

Fig. 7: January 2022 leaderboard

4.4 Proposals

At this stage, all the decentralization analysis is done in order to formulate what a selected few can potentially do due to their concentrated power. A similar analysis of the proposals shall provide how decentralized the power that has actually been used in the governance of this protocol is.

Figure 8 visualizes the distribution of the proposal results. The individual possible proposal results are passed, failed, and canceled. Figure 8 presents that the majority of the results are passed compared to the other two possible outcomes. Additionally, Figure 8 shows the distribution of the wallets that have posted a proposal. It is observed that the majority of the proposals are posted by only three wallets. The lack of diversity of wallets posting proposals was expected due to the fundamental protocol requirement that a wallet must have more than 65.000 votes to post a proposal.

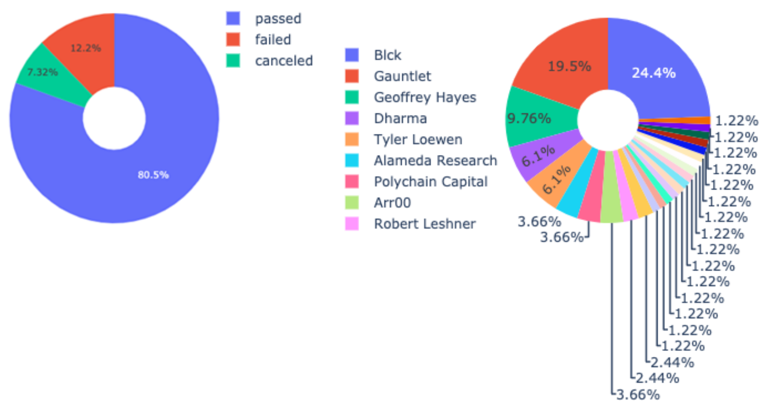

Fig. 8: Proposal Results and Domination of Wallets that Proposed

It is of high interest to observe the influence the majority holders obtain. In order to accomplish that, the study has taken the average probability of success (success is stated when the vote is equal to the poll result) on the two different vote options (for and against) and on their average. Figure 9 shows the probability of success for the top 10 wallets (From August 2021). This graph shows the major influence that the top 10 wallets have on the result of the proposal. For the positive votes, the top ten wallets have an average success probability of over 90%. It is observed that only seven out of ten wallets have voted negatively and their probability of success is much lower than the positive ones. Despite that, all the top 10 (with the exception of "Ox6dd7...c7b5" which haven't voted in any election) have probabilities of success over 80%.

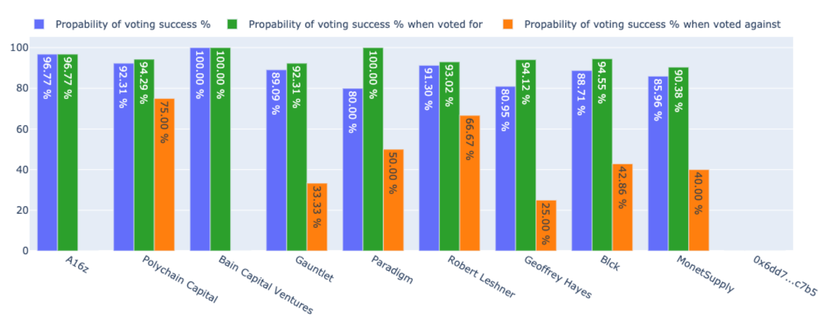

Fig. 9: Probabilities of Proposal Success form top 10 wallets

This study will conclude by examining what the decentralization metrics suggest for the ideas. Because the proposals are a recurrent process it is suggested that all the individual proposal metrics shall be studied. For the Gini coefficient, the average is 0.768 with a Standard Deviation of 0.128. The Nakamoto coefficient average is 2.9 with a Standard Deviation of 1.031. It can be observed that the average Gini coefficient is similar levels as the top wallet leader-board, but a significant deviation on the Nakamoto coefficient at 2.9 compared to 8. The decline of the Nakamoto coefficient suggests that on average 2.9 wallets hold the voting majority. But as it has been discussed previously it is important to study whether the level of decentralization is either rising or declining. Figure 8 plots all the decentralization metrics from all the proposals. The proposals are sampled with assenting chronological order, thus providing a linear time dimension on the graph. From Figure 10 it can be observed that indeed there is a small negative trend in the Gini coefficient, due to major vote holders involved over the last proposals, resulting in a similar observation with the leader-board with both sets having decentralization growth. We also observe some outliers in the

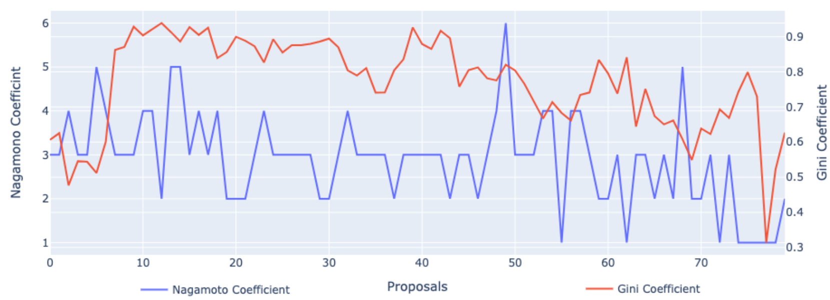

Fig. 10: Nagamoto and Gini coefficients timeline

proposals in both the coefficients. This is caused due to the nature of Gini and Nakamoto coefficient. Firty, both coefficient do not perform great as a decentralization metric when the sample population is small. This can be described with a short applied example: if in a single proposal they were only two address with exactly equal balance of votes this, then the Gini takes value of 1, stating full decentralization, and Nakamoto takes the value of 2 suggesting high levels of centralization (proof in Appendix A). Similar case to this example is observed on proposal 080 were only two wallets voted with 305969,8246 and 70014,3833 votes each, hence outliers values are observed in Fig. 2. Secondly, Nagmoto is by nature volatile because it only takes integer values compered to the Gini.

5 Discussion

The web data of delegates was more important than on-chain governance token allocations, as in prior publications. Decentralizing COMP holders may provide various consequences. The top delegated voters possess little or no COMP tokens, which is why the outcome would have been different. At the time of writing this article, Etherscan[2] and Compound's[3] website [9,11], state that the top delegated voter A16z's COMP token balance is zero. A16z has the most voting power, yet they have zero COMP tokens, and the other top 8 delegated voters (who have more than 50±% of the voting power) own only 50.9 of the 1,5 Million distributed COMP tokens. Thus, this DeFi protocol's decentralization study based on governance token distributions would be incorrect compared to the delegated wallets.

Furthermore, following the limitations of this work, the following questions are still open and can be included in future research. How each individual protocol can defer on the governance decentralization layering? What are the driven forces behind voting and voter interactions? What are the limits of the decentralization indexes?

Additionally, future research should also focus on delegation mapping and processes. A rigorous study of all governance-related protocol transactions will be used to map delegates, proposals, and votes. Future research may apply similar methods to a bigger sample of DeFi ecosystem DAOs and beyond.

6 Conclusions

This study proposes a new framework for evaluating decentralization levels in a Decentralized Autonomous Organizations. The Compound DeFi lending/borrowing protocol was used as a case-study in order for the authors to apply their methodology. Web-scraping in the governance web interface of the Compound platform over two time periods provided the data. Venture Capital businesses and other private organizations have a significant voting power concentration. In both time periods, the delegated voter leaderboard was analyzed using Gini and Nakamoto decentralization coefficients. The above criteria were applied to all votes submitted in proposals through January 2022. Results indicate significant voting success in the top ten delegated voters with Gini indexes of 0.764 and 0.753 for August 2021 and February 2022, respectively, and Nakamoto coefficients of 8. Finally, the decentralization levels of votes filed into proposals with an average Gini coefficient of 0.768 and average Nakamoto coefficient of 2.9, both indexes decreasing. The aforementioned statistics indicate that the delegated votes and proposal subsystems have low decentralization but are trending toward higher decentralization.

References

1. DeFi, Not So Decentralized: The Measured Distribution of Voting Rights, HICSS, vol. 55. ScholarSpace is the institutional repository for the University of Hawai at Mānoa and is maintained by Hamilton Library (2022)
2. Academy, B.: What is compound finance in defi? (9 2020), `https://academy.binance.com/en/articles/what-is-compound-finance-in-defi`

[2] https://etherscan.io/address/0x9aa835bc7b8ce13b9b0c9764a52fbf71ac62ccf1

[3] https://compound.finance/governance/address/0x9aa835bc7b8ce13b9b0c9764a52fbf71ac62ccf1

3. Andrei-Dragos, P.: Decentralized finance (defi) -the lego of finance. Social Sciences and Education Research Review **349**, 314–341 (2020), https://www.researchgate.net/publication/343054092_DECENTRALIZED_FINANCE_DEFI_-THE_LEGO_OF_FINANCE
4. Bavosa, A.: Building a governance interface (4 2020), https://medium.com/compound-finance/building-a-governance-interface-474fc271588c
5. BitcoinWiki: ERC20 Token Standard – Ethereum Smart Contracts – BitcoinWiki — en.bitcoinwiki.org. https://en.bitcoinwiki.org/wiki/ERC20 (2021), [Accessed 29-Jan-2023]
6. Ceriani, L., Verme, P.: The origins of the gini index: extracts from variabilita e mutabilita (1912) by corrado gini. The Journal of Economic Inequality **10**, 421–443 (2012)
7. Christodoulou, P., Christodoulou, K.: A decentralized voting mechanism: Engaging erc-20 token holders in decision-making. In: 2020 Seventh International Conference on Software Defined Systems (SDS). pp. 160–164. IEEE (2020)
8. Compound: Compound docs (2022), https://compound.finance/docs
9. Compound: Compound governace (2022), https://compound.finance/governance
10. Dorfman, R.: A formula for the gini coefficient. The review of economics and statistics pp. 146–149 (1979)
11. Foundation, E.: Etherscan (2021), https://etherscan.io/
12. Fritsch, R., Müller, M., Wattenhofer, R.: Analyzing voting power in decentralized governance: Who controls daos? arXiv preprint arXiv:2204.01176 (2022)
13. Gastwirth, J.L.: A general definition of the lorenz curve. Econometrica: Journal of the Econometric Society pp. 1037–1039 (1971)
14. Jensen, J.R., von Wachter, V., Ross, O.: How decentralized is the governance of blockchain-based finance: Empirical evidence from four governance token distributions. arXiv preprint arXiv:2102.10096 (2021)
15. Kusmierz, B., Overko, R.: How centralized is decentralized? comparison of wealth distribution in coins and tokens. In: 2022 IEEE International Conference on Omni-layer Intelligent Systems (COINS). pp. 1–6. IEEE (2022)
16. Milanovic, B.: A simple way to calculate the gini coefficient, and some implications. Economics Letters **56**(1), 45–49 (1997)
17. Morrison, R., Mazey, N.C., Wingreen, S.C.: The dao controversy: the case for a new species of corporate governance? Frontiers in Blockchain **3**, 25 (2020)
18. Sims, A.: Blockchain and decentralised autonomous organisations (daos): the evolution of companies? alexandra sims* (the final version of this article is forthcoming in the new zealand universities law review). 28 New Zealand Universities Law Review **96**, 1–29 (2019). https://doi.org/http://dx.doi.org/10.2139/ssrn.3524674
19. Srinivasan, B.S., Lee, L.: Quantifying decentralization (7 2017), https://news.earn.com/quantifying-decentralization-e39db233c28e
20. Stroponiati, K., Abugov, I., Varelas, Y., Stroponiatis, K., Jurgelevicience, M., Savanth, Y.: Decentralized Governance in DeFi: Examples and Pitfalls (2020), https://static1.squarespace.com/static/5966eb2ff7e0ab3d29b6b55d/t/5f989987fc086a1d8482ae70/1603837124500/defi_governance_paper.pdf
21. Touloupou, M., Christodoulou, K., Inglezakis, A., Iosif, E., Themistocleous, M.: Benchmarking blockchains: The case of xrp ledger and beyond. In: Proceedings of the Fifty-third Annual Hawaii International Conference on System Sciences, (HICSS 55). HICSS, vol. 55, p. 8. ScholarSpace is the institutional repository for the University of Hawai at Mānoa and is maintained by Hamilton Library (2022)

22. Vlachos, A., Christodoulou, K., Iosif, E.: An algorithmic blockchain readiness index. In: Multidisciplinary Digital Publishing Institute Proceedings. vol. 28, p. 4 (2019)
23. Werner, S.M., Perez, D., Gudgeon, L., Klages-Mundt, A., Harz, D., Knottenbelt, W.J., Calcaterra, C., Kaal, W.A.: Decentralized finance (defi). SSRN Electronic Journal pp. 1–19 (2021). https://doi.org/10.2139/ssrn.3782216
24. Zhang, R., Xue, R., Liu, L.: Security and privacy on blockchain. ACM Computing Surveys (CSUR) **52**(3), 1–34 (2019)

Appendix A Proof for Gini and Nakamoto coefficients when $n = 2$ and $u_1 = u_2$

Gini coefficient using Equation 1:

$$Gini = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} |u_i - u_j|}{2n^2 \bar{u}} \tag{4}$$

With $n = 2$ (the number of addresses) and $\bar{u} = v$ (the mean of votes for each address), we get:

$$Gini = \frac{|v - v| + |v - v|}{2 \times 2^2 v} \tag{5}$$

The term in the numerator becomes 0 (because $|v - v| = 0$), hence:

$$Gini = 0 \tag{6}$$

This confirms our previous intuition that the Gini coefficient would be 0 in this case, indicating perfect equality.

Nakamoto Coefficient using Equation 2:

$$N = \min \left(n : \sum_{i=1}^{n} j_i > \frac{1}{2} \sum_{i=1}^{N} j_i \right) \tag{7}$$

Here, j_i represents the sorted list of addresses by votes in decreasing order. But since we only have two addresses and each has an equal amount of votes, the list is either $[v, v]$ or $[v, v]$ depending on how you sort it.

If we take $n = 1$, then $\sum_{i=1}^{n} j_i = v$, and $\frac{1}{2} \sum_{i=1}^{N} j_i = v$. Since the two quantities are equal, $n = 1$ does not satisfy the condition of n being the minimum such that $\sum_{i=1}^{n} j_i > \frac{1}{2} \sum_{i=1}^{N} j_i$. Thus, we have to take $n = 2$, which satisfies the condition, because $\sum_{i=1}^{2} j_i = 2v$, and $\frac{1}{2} \sum_{i=1}^{N} j_i = v$.

So we get:

$$N = 2 \tag{8}$$

This indicates that it would take both addresses to reach a majority of the voting power. This is consistent with our previous explanation that the Nakamoto coefficient would be 2 in this case.