A Longitudinal Analysis of DAO Decentralization

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Author Note

The data in this study was collected by researchers Andrea Peña-Calvin, Javier Arroyo, Andrew Schwartz, and Samer Hassan from the Complutense University of Madrid, made available in their paper, 'The Concentration of Power and Participation in Online Governance: The Ecosystem of Decentralized Autonomous Organizations'.

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Abstract

Decentralized Autonomous Organizations (DAOs) offer a new method of governance that relies on a blockchain's transparent, decentralized, and programmable qualities (Tan et al. 2024). Previous research on DAOs found low participation rates in voting and a high level of inequality and centralization (Tan et al. 2024). A longitudinal analysis of DAO proposals was performed to determine if DAOs become progressively decentralized over time. The Gini and Nakamoto coefficients were calculated for 33 DAOs, and it was found that DAOs typically remained highly centralized and unequal and grew more centralized regardless of the type of decentralized application (dApp) the DAO governed.

Keywords: DAO, decentralized autonomous organizations, dApp governance, on-chain governance.

A Longitudinal Analysis of DAO Decentralization

Decentralized Autonomous Organizations (DAOs) have emerged as a new form of organizational governance, leveraging blockchain technology to create decentralized, transparent, and autonomous operations (Hsieh et al. 2018). DAOs differ from traditional hierarchical organizational structures, aiming to distribute decision-making power among a broad base of people (Hsieh 2024). DAOs began as a theory among computer scientists in the 1990s. Since then, the idea has been instantiated, with billions of dollars in funds being managed by DAOs (MetisDAO 2022). By 2022, DAOs had managed 20 billion USD, illustrating the importance of better understanding this organizational concept (MetisDAO 2022). This includes analyzing factors such as security, efficacy in governing decentralized applications (dApps), and the degree to which DAOs are decentralized and autonomous.

DAOs differ from typical organizations in that changes made by DAOs are enforced by smart contracts on a blockchain (Antonopoulos and Wood 2018). Smart contracts are programmable, self-executing programs that run on a blockchain (Hassan and De Filippi 2021). The use of smart contracts is intended to prevent a centralized entity from being able to manipulate the execution of DAO decisions (Hassan and De Filippi 2021). This tamper-proof execution ensures that the governance of the organization remains decentralized. DAOs exist on a blockchain, making it accessible for anyone to participate in governance, as public blockchains are borderless and permissionless (Antonopoulos and Wood 2018). DAOs are also transparent in their processes, as all agreements and changes occur on an immutable public ledger (Antonopoulos and Wood 2018). This provides a historical source of truth of all changes made by a DAO that can be revisited at any point in the future. DAOs commonly govern dApps, including those that interact with billions of dollars. The degree to which dApp governance is decentralized varies based on factors such as voting participation and a DAO's unique structure, like its governance rules and requirements to pass a proposal (Tan et al. 2024). The degree to which DAOs are decentralized and accurately represent the intentions of dApp users is a key concept explored in this paper.

Existing research on DAOs has been produced across different disciplines, most notably in economics, computer science, and organizational theory. Economics researchers have argued that DAOs can improve an organization by reducing the need for trust within the organization, as the blockchain provides a decentralized network where transactions are processed and recorded (Müller-Bloch et al. 2024). DAOs have also changed over time, initially using smart contracts to automate governing operations and now including multi-signature wallets and token-weighted voting systems (Schneider 2021). Multi-signature wallets allow multiple individuals to collectively authorize a transaction, reducing the chances of centralization in the execution of proposals (Schneider 2021).

A standard design of DAO voting uses a token-weighting system (Ding et al. 2023). In this framework, a voter's influence is based on the quantity of tokens they allocate to a specific proposal (Ding et al., 2023). The token used for voting is typically referred to as a governance token, which often has a dollar value associated with it and is available for purchase on cryptocurrency exchanges. Researchers have heavily criticized the token-weighting system as it favors those with access to more capital (Ding et al. 2023). It also favors investors who receive a large proportion of governance tokens in exchange for providing funding. Additionally, founding team members typically receive a significant portion of the total token allocation, which may allow core team members to have substantial voting power. Despite these criticisms, DAOs have proven to effectively leverage blockchain technology to enable permissionless and borderless participation.

Previous research has considered alternative voting designs, notably quadratic voting (Fan et al. 2023). This design decision is intended to better reflect voters' intentions by decreasing voting power quadratically as more votes are cast by the same voter (Fan et al. 2023). In addition to differing voting designs, there are also subDAOs, which are semi-autonomous units within the larger DAO framework intended to solve problems of scalability and governance constraints that exist with an entire community of users voting on changes to an organization (MakerDAO 2023). MakerDAO and Kwenta DAO are two examples of dApps that implement subDAOs.

Previous literature on DAO decentralization has suggested that a high concentration of voting power is a problem. For example, Feichtinger et al. (2023) found that the Gini coefficient, a measure of the concentration of power, was high for many DAOs, indicating a high concentration of power. This analysis included notable DAOs like Euler Finance and Compound DAO. They also found low participation rates, as low as ten voters, in some proposals. Additionally, the researchers suggest that a heavy reliance on smart contracts poses security risks and a risk to the sustainability of DAOs. Similarly, Peña-Calvin et al. (2024) analyzed DAO decentralization across different DAO platforms like Snapshot and Tally and found highly concentrated voting power. They also found that DAOs with increasingly high participation rates were still associated with a high amount of inequality, resulting in a dynamic comparable to an oligarchy. In this instance, the large concentration of voting power among a few individuals negated the positive democratic effects of increased voter participation. Participation in DAOs was also associated with a short lifespan of a DAO (Peña-Calvin et al. 2024).

As illustrated, previous DAO literature suggests insufficient equality and decentralization. However, there is a lack of analysis on decentralization trends, as DAOs are intended to grow increasingly decentralized over time. This question is fundamental to answer, as many decisions about how a dApp is built assume the progressive decentralization of a dApp after launching a DAO. Further research on this question can improve the standard mental model of builders by providing a clear overview of decentralization trends in previously launched dApps. This paper furthers the previous literature on DAOs by evaluating the trends in inequality and decentralization of DAOs over a recent timeframe. Our analysis also considered the degree to which a dApp belonging to a specific category—Decentralized Exchange (DEX), Derivatives Protocol, Layer Two Scaling Solution (L2), Stablecoin Issuers, Liquid Staking Protocol (LSP), Decentralized Finance Protocol (DeFi), Bridging Protocol—relates to the level of equality and decentralization. Finally, our analysis addresses the question, "What is the current landscape of decentralization?" (Tan et al. 2024).

Hypothesis: DAOs grow increasingly decentralized with less inequality over time.

Data Source

The data analyzed was collected by researchers Peña-Calvin, A., Schwartz, A., Arroyo, J., and Hassan, S. for their paper, "Concentration of Power and Participation in Online Governance: The Ecosystem of Decentralized Autonomous Organizations." The findings were presented at The ACM Web Conference 2024, held in Singapore. The data was sourced from DAO governance platforms listed on DeepDAO, including Aragon, DAOHaus, DAOstack, Realms, Snapshot, and Tally. DeepDAO is an analytics website for DAOs. The experimenters collected the data in 2023 using DeepDAO's API. For our analysis, only DAOs on Snapshot were analyzed.

The data was restructured into a hierarchical format to make it more comprehensible. The hierarchy starts with information about each DAO, followed by details on their proposals, and then information about the voters of those proposals, including each voter's power for each proposal. Finally, data on the outcomes of the proposals was included. The researchers cleaned the data by removing votes with negative or null weights. Null weights were defined as instances where a voter's weight was less than 0.015% of the total voting weight for a proposal. DAOs with no proposals or only one member were excluded from the dataset. After this filtering, the dataset contained 10,541 DAO deployments, 186,228 proposals, and 21,606,463 votes.

Methods

Data Inclusion Criteria

Our analysis only included DAOs that use the platform Snapshot. Snapshot offers gasless transactions when voting on proposals. Gas is the fee paid to individuals securing the network when transacting on a blockchain (Meister and Price 2024). Due to recent advancements in layer two scaling technology, interacting with the blockchains using scaling solutions has negligible costs. However, this was not the case consistently from 2021 to 2023, the years the data represents. Layer two scaling solutions are protocols built on top of a blockchain that process transactions off-chain and later settle them on the main blockchain, helping to lower user costs (Song, Qu, and Wei, 2024).

DAO Inclusion Criteria

To determine which DAOs were included in our analysis, we selected the top 20 DAOs from each category based on specific criteria. The categories and their respective criteria are as follows: layer two scaling solutions (fees collected), bridging protocols (volume of assets transferred), stablecoin protocols (outstanding supply), lending and borrowing protocols (volume of active loans), liquid staking protocols (total assets staked), derivatives protocols (trading volume), and decentralized exchanges (trading volume). DAOs that did not use the Snapshot platform were excluded from the analysis. The data used to determine the inclusion criteria was sourced from Token Terminal filtering from January 1, 2024, to August 15, 2024, to most closely represent the current state of the blockchain industry. After selecting the DAOs, we cross-referenced them with those in our existing dataset to identify which were present in both sets, resulting in a final total of 33 DAOs that were analyzed.

Justification of Inclusion Criteria

Fees were used as inclusion criteria for layer two scaling solutions as the amount of fees paid is a good indicator of the overall network usage. This is meaningful because layer two scaling solutions were created to increase the usability of layer one blockchains. The success of bridges was measured using the volume transferred, as the purpose of bridges is to transfer assets between blockchains and blockchain networks. For derivative protocols and decentralized exchanges, trading volume was analyzed as this indicates platform usage. The inclusion criteria for lending and borrowing protocols were based on the volume of active loans, as this represents the success of these protocols in attracting borrowers, which is fundamental to the lending and borrowing model. Stablecoin issuers were evaluated based on outstanding supply, which indicates the level of trust and demand for stablecoins as a store of value. Liquid staking protocols were selected based on the total assets staked, as these platforms are designed to stake users' assets to secure the Ethereum network.

Voting Weight and DAO Categories

When voting on a proposal, voters allocate governance tokens to the proposal option they prefer. The number of tokens a participant allocates relative to the total number of tokens allocated to a proposal is their voter weight. DAOs manage various types of dApps, and similar dApps typically share a common goal with similarly structured smart contracts. As such, the types of changes that can be made to the smart contracts of dApps vary based on the category of the dApp. Our analysis explores whether the design of these smart contracts by category is related to the level of decentralization of a DAO.

Nakamoto Coefficient

The Nakamoto coefficient measures the minimum number of entities needed to collaborate in order to control 51% of the total mining power in a blockchain network (Lin et al. 2021). A higher Nakamoto coefficient indicates that more people are required to reach a 51% threshold. The formula can be calculated as follows:

$$N = \min\left\{k \in [1, \dots, K]: \sum_{i=1}^{k} p_i \geq 0.51\right\}$$

This coefficient is a simple way to depict the security of a blockchain and its decentralization. In our research, the Nakamoto coefficient was one metric analyzed to measure the degree to which DAOs are decentralized. Previous studies, such as Peña-Calvin et al. (2024), also calculated the Nakamoto coefficient to evaluate DAO decentralization.

Gini Coefficient

The Gini coefficient was created to measure economic inequality by considering the distribution of wealth (Kwon et al. 2019). Like the Nakamoto coefficient, it is commonly used to measure inequality in mining power distribution (Kwon et al. 2019). The formula can be calculated as follows:

$$\mathrm{G} = \frac{\sum_{\mathrm{A_i},\mathrm{A_j} \in \mathrm{A}} \left|\mathrm{N}_{\mathrm{B}_{\mathrm{A_i}}} - \mathrm{N}_{\mathrm{B}_{\mathrm{A_j}}}\right|}{2|\mathrm{A}| \sum_{\mathrm{N}_{\mathrm{B}_{\mathrm{A_j}}} \in \mathrm{N_B}} \mathrm{N}_{\mathrm{B}_{\mathrm{A_j}}}}$$

$N_{B_{A_i}}$ refer to the number of blocks generated by each block producer A_i. The set $(\{N_{BA_i} \mid A_i \in A\})$ represents the number of blocks produced by each entity in the set of all block producers A. If the deviation of N_B is minimal, the Gini coefficient will be near 0. Conversely, a higher deviation will result in a Gini value approaching 1. Previous researchers like Feichtinger et al. (2023) have studied DAO decentralization using the Gini coefficient, finding the high concentration of voting power. Our use of the Gini coefficient to measure inequality builds upon previous researchers' use of the coefficient.

Mann-Kendall Test

To evaluate if a DAO decentralizes over time, the Mann-Kendall Test was implemented. Mann-Kendall is a non-parametric test to assess trends over time and has minimal assumption requirements (Kendall 1975). The test statistic S is calculated as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i)$$

Where n is the number of data points, x_j and x_i the data values at times j and i, respectively, and $\operatorname{sgn}(x_j - x_i)$ is the sign function. The Nakamoto and Gini coefficients were calculated for each DAO and DAO category to identify significant trends in equality and decentralization. In our analysis, we considered both the presence of significant trends and the direction of these trends (centralized or decentralized) using the Mann-Kendall Test. The test does not measure size or rate of change.

Results

Frequency and Trends of DAO Proposals

To better understand DAO voting trends, we calculated the average number of proposals per month for every DAO and created a series of line plots based on their categories. Based on our plots, it is apparent that the number of monthly proposals is similar between different DAO categories, and the average number rarely falls above ten proposals. The mean number of proposals per month for each category are as follows: Layer two protocols ($M = 1.60$), Bridges ($M = 2.42$), Derivatives ($M = 1.28$), DEXs ($M = 3.84$), DeFi ($M = 5.11$), Stablecoin Issuers ($M = 6.19$), and LSP ($M = 3.68$).

Measuring Inequality

A preliminary analysis of inequity was performed by calculating the Gini coefficients for every DAO, which can be found in Table 2 under the 'Gini coefficient' column. Most DAOs have a high level of inequality, with about 88% having a Gini coefficient above 0.80 and nearly 50% exceeding 0.90. These findings support the previous analyses of Fritsch et al. (2022) and Peña-Calvin et al. (2024), which also found high Gini coefficients of DAOs to be problematic (Fritsch et al. 2022; Peña-Calvin et al. 2024). Table 2 depicts a line plot of the average monthly Gini coefficients aggregated by DAO category to determine inequality trends. Based on this plot, it is apparent that the Gini coefficients of DAOs tend to remain stable or increase over time, suggesting a consistently high and potentially growing amount of inequality.

The Mann-Kendall test was performed on the calculated monthly Gini coefficients based on DAO category to determine if there were statistically significant increasing or decreasing inequality trends. Our findings show that the DEX ($\tau = 0.164$, $p = 0.002$) and the Stablecoin Issuer ($\tau = 0.558$, $p < 0.001$) categories exhibited significant positive trends in their Gini coefficients, while other categories did not exhibit statistically significant trends (L2s: $\tau = 1.000$, $p = 0.089$; Bridges: $\tau = 0.064$, $p = 0.528$; Derivatives: $\tau = 0.139$, $p = 0.088$; Lending and Borrowing: $\tau = 0.051$, $p = 0.472$; Liquid Staking: $\tau = 0.200$, $p = 0.060$). This indicates that, in contrast to our proposed hypothesis, most DAO categories do not exhibit increasing equality;

instead, equality remained constant or worsened. The increased inequality of DEXs and Stablecoin Issuers is exemplified by the positive Tau values of these categories. A comparison of every category's Tau value and p-value can be found in Table 3.

Table 4 presents the Gini coefficients for each dApp category, providing values at the 25th, 50th, 75th, and 100th percentiles to illustrate nuanced changes in inequality. After performing the Mann-Kendall test on every DAO's monthly Gini coefficient, 18 out of the 33 DAOs exhibited some statistically significant trend. Of the 18 DAOs with significant trends, only Stader DAO's and Stargate DAO's Gini coefficients decreased significantly, suggesting an overall increase in their equality. A line plot of Stader DAO's Gini coefficient can be found in Figure 4. QuickSwap was a notable DAO, showing an almost significant decrease in its Gini coefficient ($\tau = -0.333$, $p = 0.08$). Additionally, Table 6 lists the DAOs with significant changes in their Gini coefficient over time, categorizing them based on whether they became more or less equal. A summary of all p-values and Tau statistics from the Mann-Kendall test of each DAO can be found in Table 2. Overall, these findings do not support our proposed hypothesis of progressive decentralization, although they highlight noteworthy instances of increased decentralization.

Decentralization and The Nakamoto Coefficient

In addition to the Gini coefficient, the Nakamoto coefficient was analyzed for every DAO and dApp category. The Nakamoto coefficient differs from the Gini coefficient, as the Nakamoto coefficient measures the number of people needed to achieve 51% of voting power. Therefore, it is possible to see an increasing Gini coefficient and Nakamoto coefficient simultaneously. This is because the overall distribution of power can become slightly more unequal, reflected by a higher Gini coefficient, while more entities still gain power, increasing the Nakamoto coefficient.

Similar to the results of high inequality found using the Gini coefficient, we found high levels of centralization. Approximately one-third of DAOs have an average Nakamoto coefficient below two, meaning only two people are required to collude to achieve the majority of voting power. Table 3 illustrates the results of the Mann-Kendall test for the average monthly Nakamoto coefficients for every DAO category. Stablecoin Issuers ($\tau = -0.507$, $p < 0.001$) had significant negative trends in their Nakamoto coefficients, suggesting increased centralization in this category. The other categories did not show statistically significant trends (L2s: $\tau = -0.667$, $p = 0.308$; Bridges: $\tau = 0.014$, $p = 0.893$; Derivatives: $\tau = 0.028$, $p = 0.734$; DEXs: $\tau = -0.037$, $p = 0.487$; Lending: $\tau = 0.025$, $p = 0.719$; Liquid Staking: $\tau = 0.143$, $p = 0.177$). The Nakamoto coefficient p-values and tau values for each DAO can be found in Table 2. For a more detailed perspective, Table 5 displays the changes in the Nakamoto coefficient at the 25th, 50th, 75th, and 100th percentiles across different DAO categories.

Rocket Pool DAO is an interesting instance of an increasing Nakamoto coefficient and Gini coefficient, indicating a greater number of people required to achieve a 51% attack and a small increase in the concentration of voting power. Figures 4 and 5 display the line plots for Rocket Pool's Nakamoto and Gini coefficients, respectively. DAOs that show statistically significant increases in decentralization were 0x Protocol ($\tau = 0.496$, $p = 0.039$), Aave ($\tau = 0.434$, $p = 0.002$), Stargate DAO ($\tau = 0.727$, $p < 0.001$), and Uniswap ($\tau = 0.524$, $p < 0.001$). While our findings show that most DAOs tend to be and remain centralized, some are becoming increasingly decentralized, indicating the potential effectiveness of DAOs as a robust new governance model.

Discussion

One strength of this study is that it explicitly considers DAOs that play a significant role in the blockchain industry, involving trading, lending, staking, and bridging of tens of billions of dollars. While DAOs were previously more theoretical and managed fewer funds, this paper provides insights into dApps that are highly relevant in 2024. The findings of this paper are consistent with the previous analyses of DAO researchers, supporting the claim that DAOs are insufficiently decentralized. While there lacks evidence to support the general progressive decentralization hypothesis, a few instances of DAOs that grew more decentralized were found. This study expands on previous academic literature by examining trends in decentralization over time using DAOs' Nakamoto and Gini coefficients and considering the category of dApp each DAO governs. Our results showed similar levels of centralization and inequality irrespective of the DAO category. This could suggest that smart contract design and purpose are unrelated to decentralization and equality, although further research on this relationship is required to know definitively.

A broader question worth considering is the standard at which DAOs operate relative to traditional companies. DAOs are significantly more transparent, with greater user insight than traditional organizations, as all changes exist publicly on an open and decentralized ledger. Although our results suggest that 'decentralized autonomous organization' is an incorrect description of how dApps are governed, DAOs offer a new standard of operating that can be improved over time. Furthermore, DAOs unlock permissionless access to participate in governance in a way that is entirely borderless. DAOs also pose an opportunity to mitigate the power of monopolists through democratizing decision-making and distributing created value more fairly. Future research may seek to further understand the designs of the DAOs that exhibited increased equality and decentralization in this study. Another potential research direction could involve assessing the risks of a heavily centralized governance structure and its impact on a user's or institution's willingness to use a dApp.

Limitations

One limitation of this study is that the data analyzed is up until 2023 and, therefore, does not reflect the most recent developments in the industry. Furthermore, the strict inclusion criteria for DAOs, while emphasizing relevant DAOs, excluded additional DAOs that could have been included in our analysis. DAOs like Uniswap and Arbitrum were included, which use Snapshot for 'temperature checks,' a technique to gauge community sentiment about a proposal, and for executing proposals. The entire lifespan of a DAO was also not included in our analysis, as many DAOs have governance processes before transitioning onto Snapshot. There were also some instances of DAOs leaving Snapshot. DAO designs vary significantly in aspects such as proposal requirements, voting power delegation, and the presence of subDAOs. These aspects were not included in our analysis. Additionally, only DAOs using Snapshot were included, and Arbitrum was the only Layer 2 solution represented, which may have skewed the results for that category. Stargate DAO, which exhibited increased decentralization, had abnormally large participation, which may be indicative of botting behaviors. Other blockchains with innovative governance designs, like Solana, were also not considered in this analysis. The criteria for measuring a dApp's success could also be debated, as these metrics could be artificially manipulated. For example, trading volume could be inflated through automated trading. The Nakamoto coefficient can also be artificially inflated by having a single individual control many wallet addresses, making it appear as if the number of people required to achieve a 51% majority is more than it is, as we suspect of Stargate DAO. One proposed solution in previous literature is to link a person's identity to their vote, which could also be an interesting research topic for further exploration. Although this study has limitations, our findings accurately represent the current state of DAO decentralization, especially for major DAOs with significant funds in their treasuries, and highlight key trends while critically evaluating the notion of 'progressive decentralization.'

Conclusion

To determine if DAOs become progressively more decentralized over time, a longitudinal analysis of 33 DAOs was performed, evaluating their Gini coefficient and Nakamoto coefficient. This question provides insights into the potential efficacy of DAOs in governing organizations and the current state of DAO operations. Our findings did not support the initial hypothesis that DAOs become increasingly decentralized. Instead, most DAOs were found to maintain consistently high levels of inequality and centralization or experience increased inequality and centralization over time. Our findings also highlight that regardless of the type of dApp a DAO governs, there are still consistent trends in centralization and inequality. Therefore, our findings are consistent with the previous research of Tan et al. (2024) and Peña-Calvin et al. (2024). DAO governance structures are evolving, enabling transparency and borderless, permissionless participation. This new approach to governance is still in its early stages, with potential for more robust models as new iterations are tried and tested.

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Tables

Table 1

Overview of DAO categories, inclusion criteria, and the names of DAOs selected

Category	Inclusion Criteria	DAO
Layer 2 Solutions	Fees Generated	Arbitrum
Cross-Chain Bridges	Transfer Volume	Stargate, Across, Hop, Synapse
Derivatives Exchanges	Trading Volume	dYdX, Level Finance, MUX, GMX, ApolloX, Perpetual Protocol
Decentralized Exchanges	Trading Volume	CoW Protocol, Uniswap, Balancer, ParaSwap, Curve, 0x, 1inch, QuickSwap, DODO
Lending Platforms	Active Loans	Aave, Radiant Capital, Euler, Morpho, Gearbox, BendDAO, Venus
Stablecoin Issuers	Outstanding Supply	Frax, Angle Protocol, Magic Internet Money
Liquid Staking Platforms	Assets Staked	Lido Finance, Rocket Pool, Stader

Note. This table provides a summary of DAO categories, the inclusion criteria of each DAO category, and the names of the 33 DAOs that were analyzed in this paper.

Table 2

Gini and Nakamoto coefficients for each DAO, and the Mann-Kendall test results

DAO	Gini Coefficient	Nakamoto Coefficient	Mann Kendal Gini Tau	Mann Kendal Gini P-Value	Mann Kendal Nakamoto Tau	Mann Kendal Nakamoto P-Value
0x Protocol	0.929	1.934	0.127	0.648	0.496	0.039
1inch Network	0.945	2.375	0.516	0.010	0.296	0.166
Aave	0.994	1.910	0.631	0.000	0.434	0.002
Across DAO	0.920	2.731	0.467	0.272	0.067	1.000
Angle Protocol	0.879	1.194	0.537	0.001	-0.474	0.009
ApolloX	0.746	3.522	0.111	0.727	-0.378	0.156
Arbitrum DAO	0.979	5.132	1.000	0.083	-0.667	0.333
Balancer	0.929	3.438	0.429	0.000	-0.516	0.000
BendDAO	0.804	2.226	0.055	0.830	-0.034	0.868
CoW DAO	0.983	3.768	-0.121	0.638	-0.462	0.053
Curve Finance	0.864	1.518	-0.309	0.218	-0.278	0.240
DODO	0.828	5.050	0.091	0.737	-0.492	0.027
Euler	0.882	6.623	0.273	0.283	-0.624	0.008
Frax	0.878	1.676	0.698	0.000	-0.627	0.000
GMX	0.949	7.617	0.615	0.003	0.078	0.713
Gearbox	0.795	85.528	0.790	0.000	-0.790	0.000
Hop	0.976	2.112	0.462	0.030	-0.605	0.005
Level Finance	0.984	1.519	0.600	0.136	0.733	0.056
Lido	0.912	2.271	0.700	0.000	0.063	0.636
MUX	0.821	1.667	0.600	0.136	0.183	0.643
Magic Internet Money	0.897	2.536	0.390	0.046	-0.678	0.001
Morpho	0.964	1.265	0.214	0.548	0.242	0.425
ParaSwap DAO	0.790	14.030	0.766	0.000	-0.692	0.000
Perpetual Protocol	0.917	2.378	0.399	0.021	-0.041	0.818
QuickSwap	0.890	3.955	-0.333	0.079	-0.180	0.340
Radiant Capital	0.959	6.593	-0.143	0.720	0.571	0.061
Rocket Pool	0.503	23.370	1.000	0.000	0.310	0.249
Stader	0.896	1.885	-1.000	0.017	0.837	0.052
Stargate DAO	0.855	4106.440	-0.505	0.008	0.727	0.000
Synapse Protocol	0.874	1.944	0.407	0.047	-0.517	0.016
Uniswap	0.986	2.251	0.517	0.000	0.524	0.000
Venus Protocol	0.892	1.200	0.242	0.311	-0.160	0.510
dYdX	0.985	2.235	0.451	0.009	0.293	0.103

Note. This table displays the Nakamoto and Gini coefficients calculated for every DAO and the Tau and p-values of the Mann-Kendall test performed on every DAO's average monthly Gini and Nakamoto coefficients.

Table 3

Inequality and decentralization trends filtered by DAO category.

Category	Gini Tau	Gini P-Value	Nakamoto Tau	Nakamoto P-Value
L2s	1.000	0.089	-0.667	0.308
Bridges	0.064	0.528	0.014	0.893
Derivatives	0.139	0.088	0.028	0.734
DEXs	0.164	0.002	-0.037	0.487
Lending	0.051	0.472	0.025	0.719
Stablecoin Issuers	0.558	0.000	-0.507	0.000
Liquid Staking	0.200	0.060	0.143	0.177

Note. This table displays the results of the Mann-Kendall test performed on the aggregated average monthly Nakamoto and Gini coefficients for every DAO category.

Table 4

Changes in Gini coefficients across time for DAOs

Category	Start Value	25% Value (Change)	50% Value (Change)	75% Value (Change)	100% Value (Change)
L2s	0.959	0.973 (1.540%)	0.990 (1.730%)	0.994 (0.360%)	0.994 (0.000%)
Bridges	0.842	0.306 (-63.640%)	0.933 (204.850%)	0.943 (1.050%)	0.888 (-5.840%)
Derivatives	0.807	0.821 (1.760%)	0.980 (19.300%)	0.907 (-7.410%)	0.936 (3.190%)
DEXs	0.825	0.905 (9.790%)	0.857 (-5.290%)	0.923 (7.670%)	0.937 (1.550%)
Lending	0.937	0.573 (-38.840%)	0.798 (39.210%)	0.918 (15.130%)	0.945 (2.880%)
Stablecoin Issuers	0.808	0.852 (5.440%)	0.810 (-4.920%)	0.967 (19.300%)	0.976 (1.000%)

Note. This table displays the relative changes of inequality by DAO category measured by the Gini coefficient.

Table 5

Nakamoto coefficient over time per DAO category

Category	Start Value	25% Value (Change)	50% Value (Change)	75% Value (Change)	100% Value (Change)
L2s	7.000	6.000 (-14%)	3.529 (-41%)	4.000 (13%)	4.000 (0%)
Bridges	2.000	118.000 (5800%)	2.129 (-98%)	15.199 (614%)	10235.643 (67242%)
Derivatives	5.333	4.986 (-7%)	2.000 (-60%)	3.676 (84%)	6.000 (63%)
DEXs	5.223	10.610 (103%)	4.231 (-60%)	3.618 (-14%)	3.000 (-17%)
Lending	1.000	552.435 (55143%)	17.234 (-97%)	2.549 (-85%)	3.257 (28%)
Stablecoin Issuers	4.000	1.912 (-52%)	1.173 (-39%)	1.059 (-10%)	1.000 (-6%)
Liquid Staking	2.177	2.199 (1%)	1.871 (-15%)	2.000 (7%)	16.063 (703%)

Note. This table displays the relative changes of decentralization by DAO category measured by the Nakamoto coefficient.

Table 6

DAOs separated by decentralization status

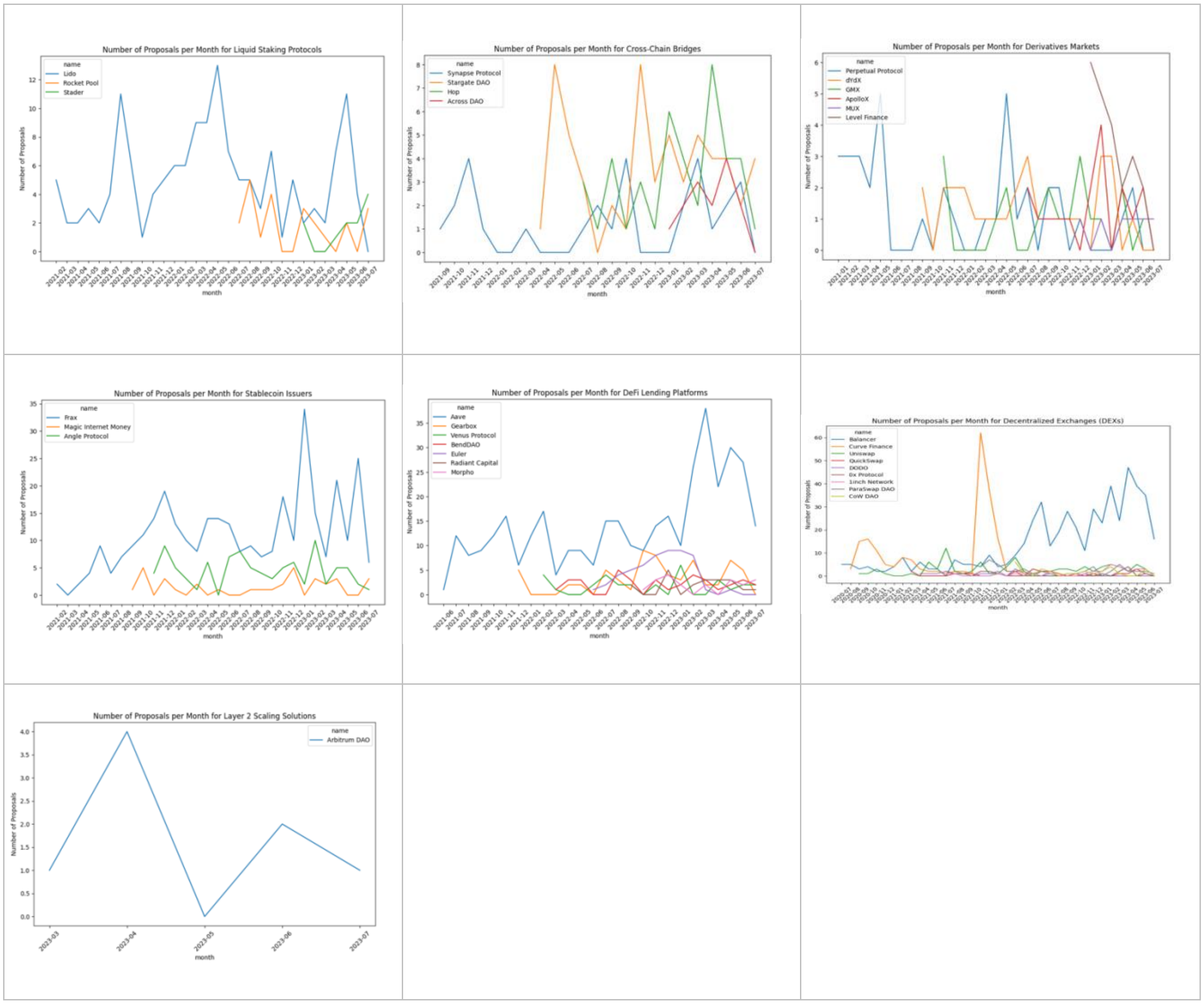
Greater Decentralization	Lesser Decentralization
QuickSwap, Stader, Stargate	1inch Network, Aave, Angle Protocol, Balancer, Frax, GMX, Gearbox, Hop, Magic Internet Money, ParaSwap DAO, Perpetual Protocol, Rocket Pool, Uniswap, dYdX, Lido, Synapse Protocol

Note: This table displays DAOs with significant Mann-Kendall test results for Gini coefficient τ (Tau) p-values, indicating trends towards greater or lesser decentralization.

Figures

Figure 1

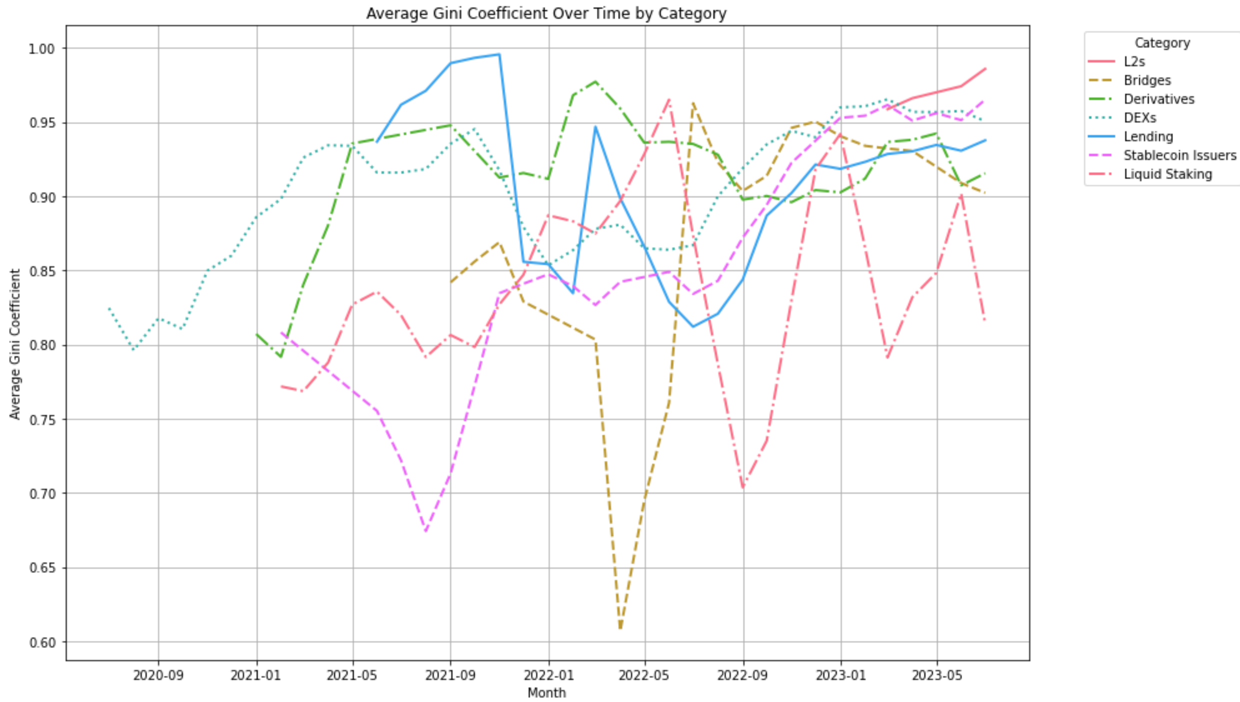
Line plots displaying the number of monthly DAO proposals.



Note: These plots display the number of proposals over time aggregated by month based on the DAO category.

Figure 2

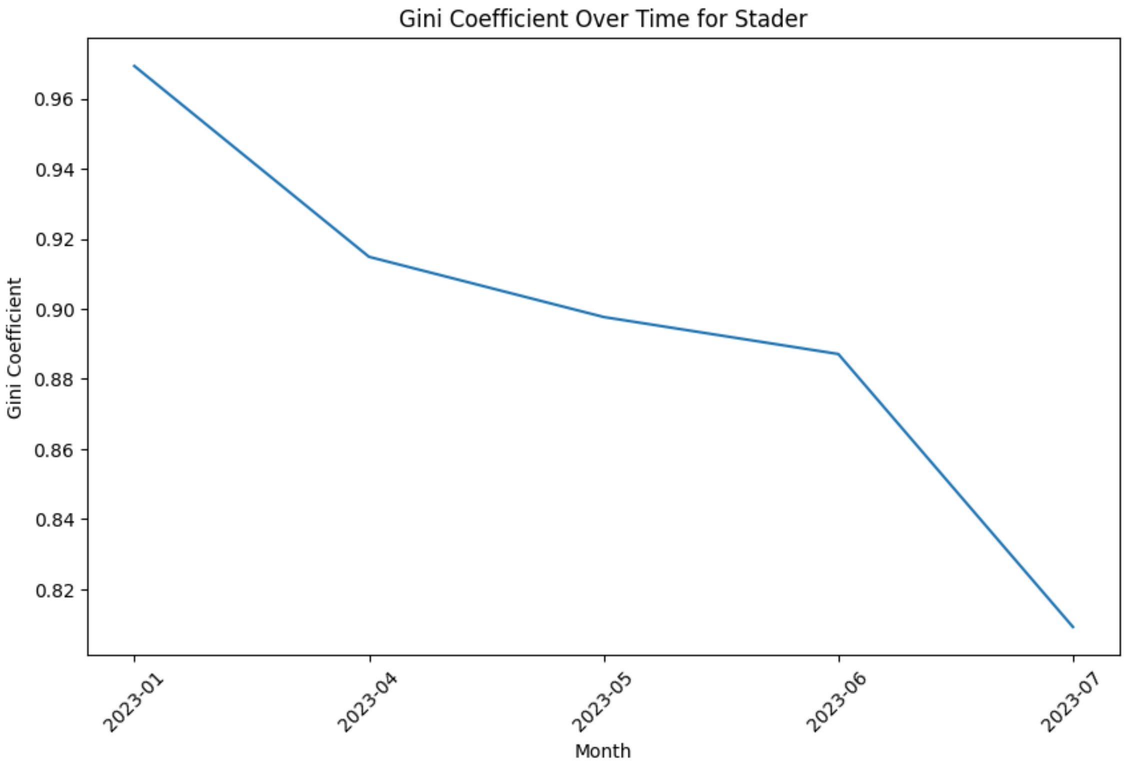
Line plot displaying the rolling average of Gini coefficients, with separate lines representing each DAO category.



Note: This plot displays the rolling average of monthly average Gini coefficients, with separate lines representing each DAO category.

Figure 3

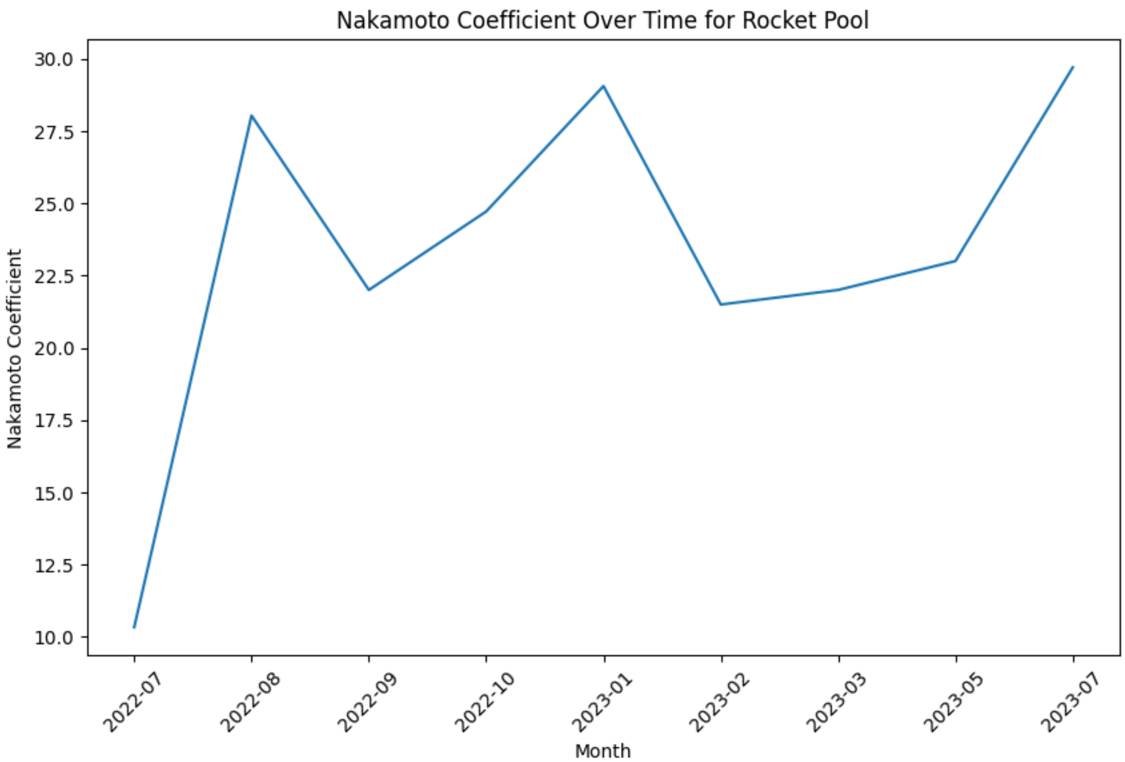
Line plot of Stader DAO Gini Coefficient



Note: This line plot shows the monthly average Gini coefficient for Stader DAO, calculated from all available data.

Figure 4

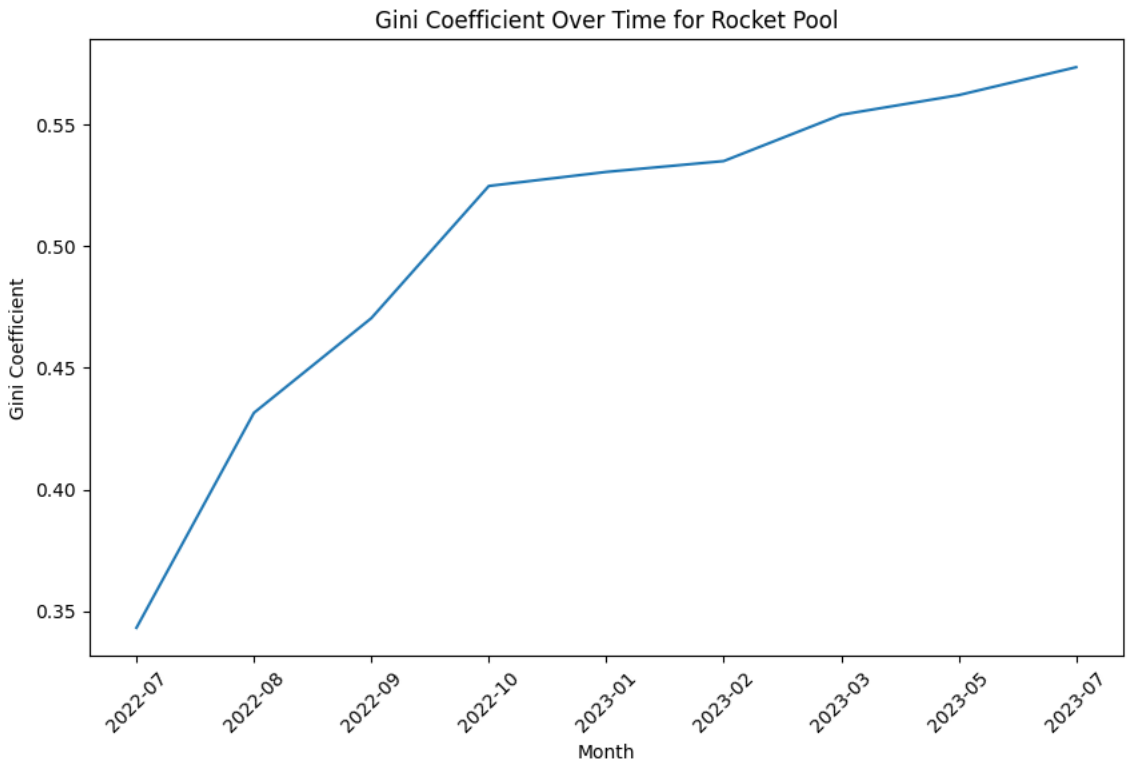
Nakamoto coefficient of Rocket Pool over time



Note: This plot shows the Nakamoto coefficient of Rocket Pool over time, illustrating a trend of increasing Nakamoto and Gini coefficients

Figure 5

Gini coefficient of Rocket Pool DAO over time



Note: This plot shows the Gini coefficient of the Rocket Pool DAO over time, illustrating a trend of increasing Nakamoto and Gini coefficients.