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Collective Action in Decentralized Autonomous Organizations (DAOs): Free Riding and Algorithmic Design

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“Encumbered forever by desire and ambition

There's a hunger still unsatisfied

Our weary eyes still stray to the horizon

Though down this road we've been so many times”

-High Hopes, Pink Floyd

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Introduction

The fact that human is probably the only animal that tries to understand its own behavior in a structured and analytical manner, reveals how intimate the topic of collective organization and cooperation is. Collectivization manifests itself in a broad spectrum of applications, from economic enterprise to self-organization in hobby clubs, and political action groups. Yet again, regardless of the numerous disciplines and resources devoted on the subject, a novel real-world experiment of algorithmic governance[1] has gone largely unnoticed. A blockchain[2] Decentralized Autonomous Organization (hereinafter DAO) is defined as *"an organization that's self-governing and not influenced by outside forces: its software operates on its own, with its by-laws immutably written on the blockchain, not controlled by its creators. DAOs are formed by groups of like-minded individuals with specific projects and goals in mind. Its identity is formed through consensus. Its authority is defined through voluntary endorsement and, ultimately, network effects. A DAO is purely software: in itself it does not have the capabilities to manufacture a product, write code, develop hardware or sweep the streets. It requires actors in the physical world for this purpose, called Contractors."* (Tual 2016).

In simple terms, one can think of DAOs as online communities, companies, hobby clubs, or special interest groups[3]. Organizations serving specific objectives, enabled by treasuries that are

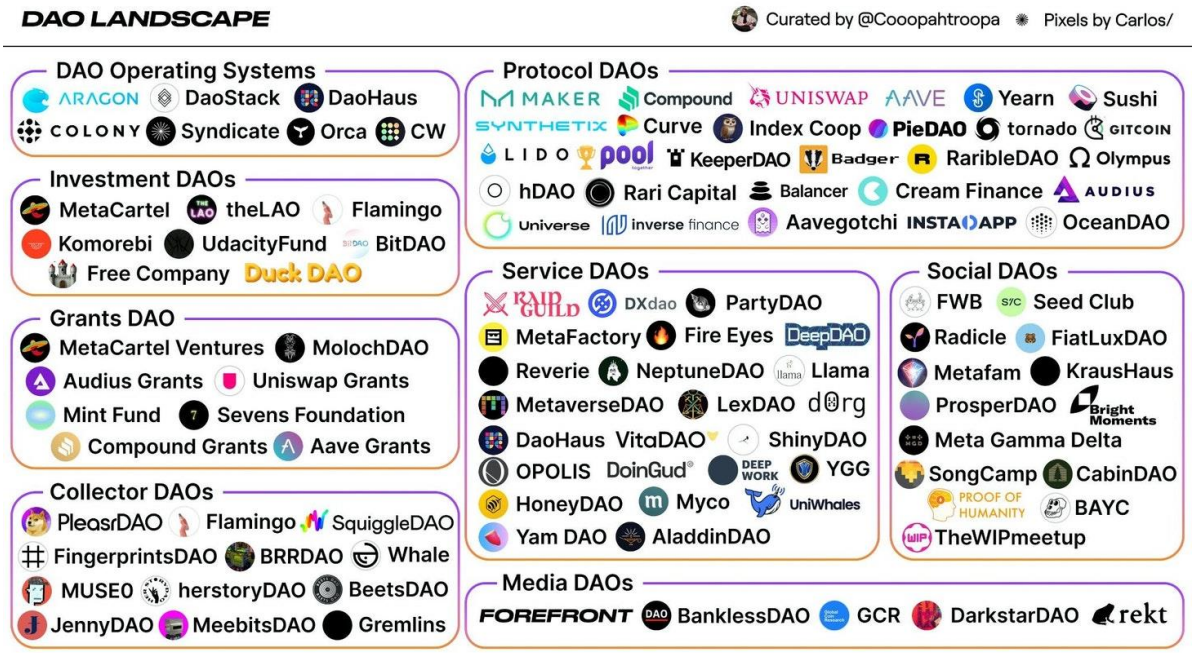
[1] The discussion around the meaning of algorithmic governance in social sciences is still ongoing and lacks consensus (Issar and Aneesh 2021). In this paper, the term is used to describe all those different software designs that encompass and coordinate human cooperation in the context of organizations.

[2] Blockchain is indispensable to DAOs. For those who are not familiar with it, it can be (very) simplistically thought as a public list (chain) consisting of timestamped blocks of information. This list is fully public and maintained in multiple copies by many members of the network. New information is added in new blocks and validated with consensus mechanisms between those holding copies of the list. Blockchain is a larger technological concept, with Bitcoin and Ethereum being some of its applications.

[3] A notable example is ConstitutionDAO, under which people collectively tried to buy an original copy of the US constitution from a Sotheby's auction. https://www.constitutiondao.com/.

collectively managed by their members, and some form of contribution in becoming member in their vast majority, if not all in all of them. Contributions are accumulated in their treasuries, and then through novel and experimental methods of decision-making, group members decide how and for what to mobilize their collective wealth. At the time of writing, one can find more than 4000[4] DAOs focused on, among other, software development, investment, gaming, digital art, real asset acquisition, and hobbies.

Figure 1 non-exhaustive overview of the DAO ecosystem (purrplecat.eth, et al. 2021).



Specifically, they use computer software to codify and enforce their social and management contracts – named smart contracts (MINN 2019). Smart contracts not only redefine the concept of social consensus found in companies' statutes (Morrison, Mazey and Wingreen 2020) and constitutions (Wessel, O'Brolcháin and Haynes 2016), but also revolutionize administrative processes by seamlessly executing decisions and enforcing rules. Moreover, smart contracts enable

[4] As reported by DeepDAO - one of the most prominent and used platforms for DAO analytics. https://deepdao.io/organizations

all interested members to participate in direct decision-making, while also providing with alternatives to traditional one person one vote decision-making systems that are indispensable to western democracies.

Besides the heaps of online rhetoric and complex technocratic designs, DAOs do not offer a panacea, as algorithmic governance remains dependent upon human actors for its design and evolution. The indispensability of the human factor became evident from the very first DAO, named "The DAO" (Jentzsch 2018). This first ever DAO only survived for merely two months after its initial launch in 2016. Specifically, a hack led to the loss of approximately one third of its collectively managed treasury (around $50 million) (Dino, Vlad and Emin 2016). The early enthusiasm of its supporters quickly spiraled into a heated debate of whether Ethereum's founder Vitalik Buterin should intervene and revert[5] the loss – something that would constitute a violation of blockchain's core concepts of immutability and decentralization. Eventually, intervention was favored. This development showcased a very familiar pattern in human behavior: *"when governance of The DAO deviated from the expected course of events (those modelled in game theory by the designers), the social actors fell back to traditional strong network ties. In doing so, governance of The DAO discredited its ideological underpinnings, and even exposed a worrisome lack of managerial prowess that would typically use forms of rationalizing behavior drawn from risk management or crisis mediation."* (DuPonte 2017, 172).

The story of *The DAO* showcases how even such a groundbreaking institution with strict rule enforcement and common identity could not escape traditional problems of human cooperation (Issar and Aneesh, What is algorithmic governance? 2021). Motivated by that realization, I set to

[5] In practice discarding the old chain of blocks, and transition to a new copy of it. The old chain is still functioning under the name Ethereum Classic (ETC), and the new chain - which is the most widely recognized today along Bitcoin (BTC), is Ethereum (ETH).

explore how one of the most notable problems of individual behavior in groups, free riding, interplays with structural variables of DAOs like size, objective, level of decentralization, governance processes etc. Ultimately, I hope to answer whether DAOs can help overcome the problem of free riding, while also determining the specific institutional arrangements that enhance participation.

The puzzle of this paper comprises of behavioral and structural components. For each one, I borrow from the work of two scholars of high academic esteem, namely Mancur Olson and Elinor Ostrom, respectively. Initially, I extract the free riding patterns described in Olson's book *"The Logic of Collective Action: Public Goods and the Theory of Groups"* as hypotheses to be examined[6]. In that book, Olson challenged traditional conceptions around collective action by arguing that *"unless the number of individuals in a group is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, rational, self-interested individuals will not act to achieve their common or group interests"*[7] (Olson 1965, 3). His theory bridges between individual behavior and the group, while his findings are still grounds of extensive concern for DAO experts today.

For the structural factors, I turn to Elinor Ostrom - Nobel Prize in Economics *"for her analysis of economic governance, especially the commons"* (Nobel 2009). Her pioneering work, especially the Institutional Analysis and Development Framework (IAD) (E. Ostrom 2011) can help dissect the *"organizational template(s)"* (McGinnis 2011, 16) of DAOs in a way that preserves complexity while making them accessible to non-blockchain native readers, and find and operationalize structural variables such as rules and algorithmic design to be used in the

[6] I refrain from using the verb "test" with regards to hypotheses as I am opposed to the treatment of complex social phenomena as physical science tests.

[7] Ostrom named this the "zero contribution thesis".

interpretation of results. Lastly, I use empirical quantitative data drawn from six case studies to see whether traditional expectations of free riding as explained by Olson hold in decentralized institutions with characteristics similar to these studied by Ostrom. For that, I capitalize upon the extensive capture of decision-making data of DAO members, the democratization of computation in non-technical fields of academic inquiry, and the rise of new data-centered research paradigms (Hey, Tansley and Tolle 2009).

In sum, I select six representative DAOs as case studies, then identify key variables using Ostrom's IAD framework, and lastly, test Olson's key assumptions made in the book *"The Logic of Collective Action A Theory of Groups and Organizations"* regarding individual participation and size by analyzing the voting data of the members of the selected DAOs.

Findings suggest that decentralized (polycentric) institutional designs can help overcome the problem of free riding. Moreover, group purpose does not emerge as an important variable in shaping collective behavior, even though the initial group members of non-economic organizations are more dedicated to their group's governance compared to their counterparts. These findings provide with evidence suggesting that individualistic forces are very complex and diverse and can, given the right institutional configurations, provide with beneficial group outcomes. Individual risk minimization though multistep governance processes and voting power delegation are two such configurations found to be beneficial for collective governance.

The value proposition of DAOs for academic research stems from the fact that they possess both traditional and groundbreaking attributes. That makes them both accessible with existing interdisciplinary knowledge, and the same time appealing and promising in their technical and social novelty that relates to numerous fields of science. From political philosophy, to cybernetics, public policy, law, and economics among many other (Garrod 2016). Overall, the success and

recognition of DAOs is of vital importance because of their potential to address some of the most critical questions faced by these disciplines and sub-disciplines. Examples include economic scalability, curbing plutocracy[8] without disincentivizing growth and funding, trust and resilience (Jun 2018), direct participation democracy, transparency in accounting, and public goods provision (Rozas, Tenorio-Fornés and Díaz-Molina1, et al. 2021) just to name a few. It must be thus understood that the value proposition of DAOs, described above, calls for a bidirectional relation between academia and the DAO community/ecosystem. Only then can the latter capitalize upon heaps of existing knowledge and avoid another *"tragedy of the commons"* (Hardin 1968), to keep providing with evidence and tools concerning numerous disciplines for academic researchers to scrutinize, and in turn, export as long-term applications and norms in the real world.

Literature Review

At its core, this paper makes a case in favor of decentralized governance as means to overcome persistent shortcoming in human collective action – predominantly free riding. Thus, it draws mostly from the respective family of literature covering polycentricity[9], collective action, and common goods. I also draw case-specific knowledge from other non-academic DAO-related sources like forums, discord channels, and documentation. The theoretical study of DAOs as polycentric common goods systems is enabled by the historical convergence of two different

[8] The potential for different algorithmic designs is massive, with a notable example being quadratic voting[8] (Lalley and Weyl 2018), which was put to the test in the Colorado House of Representatives in 2019 (Bloomberg 2019). Under such a system, the more votes a member submits on a proposal, the higher the cost of each additional vote gets for that voter (squared). Ex. voting option 1 once will cost 1$, voting a second time the same option will cost 4$, a third vote will cost 9$.

[9] Scholars have adopted the term "polycentricity" which can be considered a broader concept including decentralization as an extreme form of polycentricity (Carlisle and Gruby 2019). Throughout this paper, these terms are used interchangeably.

discourses that were largely integrated in the mid of the past century. The one studied the management of collective goods – common/public goods and emerged before the 19th century. The other is more contemporary, having emerged in the 1950s, and focused on polycentric governance. Below, I present the trajectory of each, leading up to their convergence in the work of Elinor Ostrom, upon which this paper is largely built. The literature on commons identified inherent problems in organizing the use of collectively owned and managed resources, while scholars of polycentricity supported that polycentric arrangements in collective organization can help overcome the problems of the commons.

The discussion around cooperation over collective goods is so old that it includes Aristotle. Considering time and capacity constraints, my theoretical exploration begins from the lecture, and subsequent publication, that was delivered in 1833 by British economist William Forster Lloyd (Lloyd 1833, 1980). There, he described the issue arising in managing the commons through the example of overgrazing of a public pasture. It would take until the 1950s for the topic of collective action and public goods to be brought into the academic spotlight by four prominent authors and their respective work. Namely, Michael Polanyi, Mancur Olson, Garett Hardin, and Elinor Ostrom. Their overarching opinions about cooperation falls in one of two categories. Optimists who believe that under the right institutional circumstances people can overcome cooperation problems when managing common resources, comprising of Ostrom and Polanyi, and pessimists who support that most – if not every time, behavioral forces will lead to failure in cooperation, comprising of Olson and Hardin. This dichotomy of opinions is accompanied by a difference in how the authors of each bloc consider individual behavioral forces vis-à-vis structural/institutional forces. Specifically, Olson and Hardin emphasize the decision-making processes of individuals in the context of groups and organizations, while Ostrom and Polanyi consider the systemic forces that transform

individual behavior and ultimately outcomes. Simplistically put, the analysis of the first authors moves from within the individual towards the environment, while Olson and Polanyi look from the higher systemic level below towards the individual. In the following paragraphs, I provide with more details about the work of every author.

Michael Polanyi in his book *"The Logic of Liberty"* (1951) was the first to introduce the concept of polycentricity. He departed from how scientific discovery is structured as an analogy and proceeded to suggest that such a polycentric arrangement of authority can address issues faced in other domains like the socialist calculation problem (ALIGICA and TARKO 2012). The then-abstract concept of polycentricity spread into multiple other fields, occupying a place in the public debate today.

Mancur Olson contributed with his book *"The Logic of Collective Action Public Goods and the Theory of Groups"* (1965). He differed substantially from Polanyi not only in terms of scope but also with regards to his optimism about the potential of organizations to overcome the problem of free riding by their members. He also starts from a high-level example, the competitive market consisting of companies, but contrary to Polanyi he transposes it down to individual inside the same organization. His subsequent analysis is then driven by causal inferences based on individual payoff functions and choices, with little consideration for the diversity in institutional contexts and the power of individuals to shape them.

Garrett Hardin formalized the use of the term *"tragedy of the commons"* in his homonymous article (1968). His analysis starts from the simple example of a public pasture, and then builds a causal chain of actions from the perspective of an individual herder. He then deploys this model to address overpopulation (E. Ostrom 1990, 2-3). Ultimately, in one of his most cited excerpts, he claims that *"Ruin is the destination toward which all men rush, each pursuing his own best interest*

in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all." (1968, 1244).

Elinor Ostrom, troubled by Hardin's tragedy of the commons, and motivated by Polanyi's work on polycentricity, took the subject to governance studies. There, she tried to observe how people self-organize under diverse institutions, showing that under the right structural conditions (E. Ostrom 1990, 90) people can overcome cooperation problems like free riding. Ostrom took her study on the field and observed the structural arrangements of multiple cooperatives in the real world. Most of which, like grazing pastures, water basins, and fisheries, involved common goods utilized collective by multiple actors. She effectively bridged the commons literature with governance studies and polycentricity, all while providing with both empirical observations and metatheoretical tools. Ultimately, Ostrom found that there are multiple cases were humans achieve collective organization even when managing common goods. These observations contradict the claims and findings of Hardin and Olson who foreshadow constant tragedies and underperformance of polycentric management systems. In this paper, DAOs are assumed to be complex analogies of the organizations Ostrom studied, managed in a polycentric manner, and functioning as resource systems with a common treasury and governance process (Rozas, Tenorio-Fornés and Díaz-Molina1, et al. 2021) . The analysis conducted aims to uncover whether these new observations also give merit to Ostrom's optimism about collectivization vis a vis Olson's pessimism – founded on the tendency of group members to free ride.

Theory and Hypotheses

In this chapter, I present why DAOs are compliant with the assumptions made by Olson and Ostrom and can thus be subjected and contribute to their theories. In the end of the chapter, I present the specific hypotheses that are evaluated in the Findings section.

The most important and distinct common denominator between DAOs, Olson, and Ostrom is the type of goods involved. For the classification of goods, I draw from the subtractability and exclusion criteria developed by the Ostroms (Ostrom and Ostrom 1977).

Table 1 Typology of Goods based Exclusion / Subtractability criteria. From (E. Ostrom 2005, 24)

		Subtractability of Use	
		Low	High
Difficulty of Excluding potential beneficiaries	Low	Toll Goods	Private Goods
	High	Public Goods	Common Pool Resources

At the individual level, DAO members consume different amounts of time participating in decision making (voting, proposing), educating themselves, contributing with their existing expertise, and communicating with other members. Moreover, the members of all six DAOs studied need to stake an amount of wealth to acquire the governance token or NFT of the respective organization. Both activities, devoting time and money, represent opportunity costs for every member. Thus, investment of time and money are necessary for the governance of DAOs and the accomplishment of their objectives.

Even at this initial point, it is evident that DAOs involve individual opportunity costs, corresponding to the preferred - but not mandatory, *"significant economic aspect"* (Olson 1965, 6). Even in the cases of Gitcoin and Assange DAO, both of which are not profit oriented to the extent of the other four cases, one can still outline more economic elements compared to *"communal groups"* as adopted by Olson from (Coyle 1930) using as examples of non-communal groups *"Philanthropic and religious organizations"*. For example, Gitcoin awards grants to decentralized apps software developers, to new DAOs, and on protocol research. None of these payments can be considered philanthropy, but rather compensation for the production of public goods in the blockchain ecosystem. At the same time, Assange DAO tries to maximize its treasury by investing[10] in NFTs, aiming to provide with the maximum possible amount in funds to support the legal costs faced by Julian Assange.

The mobilization of capital in the six DAOs covered by this study produces a multitude of different goods. I survey these goods by starting from the outflows – these goods that the DAOs contribute to the greater ecosystem and can be enjoyed by non-members. Assange DAO provides with advocacy in support of whistleblowers and freedom of speech in press – purely public goods. Gitcoin DAO governs the funding for a plethora of different initiatives like research on diversity, climate protection, art, and Ethereum infrastructure, all of which fall under the category of common goods. On the other hand, the other four DAOs are not geared towards public goods, even though the fact that most of the software developed in each one of them is publicly available and could thus be considered one (Rozas, Tenorio-Fornés and Hassan 2021). Uniswap's primary service – exchange between fiat and crypto, is a toll good since the company can block specific addresses from using it. Olympus DAO, as a byproduct of its economic functions, provides with a

[10]https://snapshot.org/#/assangedao.eth/proposal/0x01bb8d0d78f9330d0b3d977e1b156e27ae5457e4ff694b2918e03b6a56147f5f

price floor for its coin - OHM, which could be considered a public good in terms of less market volatility. City DAO does not provide with any observable good that can be enjoyed by non-members, with the only non-strict exception being its legal status as one of the very few legally recognized DAOs in the physical world, something that could work as a blueprint for other DAOs or even as a proven case in support of favorable legislation which would benefit other DAOs. (MINN 2019, 178). Similarly, Decentraland DAO also does not provide with any good that can be enjoyed by non-members - with the global exception of software as a public good still applying.

At an internal level, Olympus DAO and Uniswap provide with return on investment, collective intelligence, and investment scale for their members. City DAO provides with claims on physical land – once again a form of scaled return on investment. Decentraland with leisure through its digital game world. Lastly, Assange DAO and Gitcoin DAO provide their members with the same common good as those who are not members.

The different types of goods produced internally and externally reflect the diversity of objectives between the selected DAOs. Despite these differences in types of goods produced, when it comes to their governance, all six DAOs clearly operate as a public good system. One that consumes person hours to provide with governance which is necessary in providing with all the flows described above. Person hours are finite for every DAO, calculated as 24 hours per member that holds governance rights. Moreover, the effects of social governance are non-excludable for DAO members since they are enforced by the algorithm for everyone, and joint in use along all DAO members. Ostrom recognized that public goods and common pool resources are very identical when it comes to the tendency of *"free riding"* (E. Ostrom 1990, 32), a centerpiece in Olson's theory on collective action.

Building upon the concept of governance participation, on the first pages of his book, Olson notes that his study presupposes the total absence of *"coercive"* and *"other special devices"* that *"make individuals act in their common interest"* (Olson 1965, 2). DAOs are very helpful case studies because all mechanisms are codified in software and with full transparency. After reviewing the forums, websites, and documentation of all six, no special device was found that incentivizes or punishes members with regards to their participation in governance processes. Uniswap employs an inflationary model for its token which applies to all holders and doesn't create any form of preferential treatment. Gitcoin included a heavier weight in governance token allocations to early participants (those who opened or submitted a bounty or grant), but no effect in governance is assumed since initial participants were totally oblivious to this development which happened before the governance token had even been conceived.

Summarizing, DAOs are organizations with defined objectives, without mechanisms that would conflict with Olson's theory, that produce a plethora of goods by using a public good – social governance, as a major factor of production. What are his claims for individual and aggregate behavior in that context?

Mancur Olson summarizes his theory as: *"unless the number of individuals in a group is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, rational, self-interested individuals will not act to achieve their common or group interests"* (Olson 1965, 3). Based on that, the first hypothesis about DAOs emerges: <u>The individual contributions of members for the production of the organization's governance, as a public good, will decline as the group grows larger (H1)</u> Also, the aggregation of individual behaviors extends the above hypothesis on an institutional level, by asking whether larger groups provide with a more optimal amount of the collective good (Olson 1965, 35). The causal

mechanism that Olson describes in support of this proposition also uncovers claim – adopted as the second hypothesis for the present paper. *"Where small groups with common interests are concerned, then, there is a systematic tendency for overexploitation of the great by the small!"* (Olson 1965, 29). Thus, members that are less invested into the organization's objective will contribute less to its governance (H2).

Both hypotheses are studied with regards to the different patterns that emerge under various structural factors beyond size. For that, I employ Ostrom's IAD framework.

Research Design

The research design consists of both qualitative and quantitative components. I draw my hypotheses on individual free riding behavior from the theoretical work of Mancur Olson, then outline institutional variables and how they relate with the work of Mancur Olson by using the metatheoretical IAD framework of Elinor Ostrom, and lastly bring them all together using quantitative data drawn from six case studies. Overall, the methods can be characterized as mixed, involving case study analysis with qualitative and quantitative tools. I supplement both with domain specific knowledge, acquired by studying the documentation, forums, and discord channels of more than 10 DAOs, and by engaging in the founding of two DAOs over the past three years.

For the quantitative component, data were retrieved from two sources: DeepDAO[11] and Snapshot[12]. Both platforms were selected for their wide acceptance and recognition in the DAO ecosystem, and for their easily accessible APIs.

[11] https://deepdao.io/

[12] https://snapshot.org/#/ API: https://hub.snapshot.org/graphql

DeepDAO is an analytics platform that aggregates data for thousands of DAOs, providing with the largest known open collection of such data. On top of automated collection methods, the DeepDAO team also *"enriches"* specific DAOs, meaning that extra data are collected manually by their team. After being granted with a personal API key, a file containing information about 1075 DAOs was downloaded. For each one, the following were listed: name, organization id, description, logo, members, active members, votes, proposals, tokens, governance. After that, I selected those 6 that serve as case studies for the present paper. The main selection criterion was capturing the largest possible - yet manageable in terms of readers' understanding, breadth of objectives and algorithmic designs. Moreover, all DAOs selected enjoy wide acceptance and recognition in the blockchain community.

Snapshot is also one of the most popular (DAO and Gitcoin 2021), if not the most popular, platform for off-chain[13] DAO governance. DAOs own profiles on the platform and then their members can propose and vote on proposals there in accordance with each organization's rules. Custom voting systems can be written in code and deployed on the platform. An open GraphQL API allows the export of relevant data. Python programming language (Van Rossum and Fred L. 2009) was used along requests[14] library to automate collection. Two datasets were downloaded for each one of the 6 target-DAOs; the individual voting choices of members across all proposals, and the timestamp

[13] Decision making processes can either take place on-chain or off-chain. On-chain processes are registered on the blockchain and are automatically executed by smart contracts. They incur a transaction cost (gas fee) to all those participating. Off-chain processes are not registered directly on the chain and participating does not involve a cost most of the times. The latter are preferred by DAOs for being more cost efficient, and thus lifting barriers of participation to members with more limited means. Some DAOs use both methods, off-chain for signaling, and on-chain as a terminal step.

[14] https://requests.readthedocs.io/en/latest/

of every proposal. Target DAOs are: Gitcoin, Assange DAO, Olympus DAO, Decentraland, Uniswap, and City DAO, with details for each one presented right below.

Table 2 Selected case studies general information. Data from organizational websites and DeepDAO.

	Gitcoin	Assange DAO	Olympus DAO	Decentraland DAO	Uniswap	City DAO
Formal Objective [15]	"Build and fund digital public goods "	"To inspire a powerful solidarity network and fight for the freedom of Julian Assange. "	"Build a policy-controlled financial reserve currency"	"Decentraland DAO owns the most important smart contracts and assets that make up Decentraland (first-ever virtual world owned by its users)"	Governing the "Uniswap protocol (peer-to-peer system designed for exchanging cryptocurrencies on the Ethereum blockchain)"	"Build a city of the future where everything is on-chain, making the physical world decentralized, transparent, immutable and permissionless"

[15] The one stated on the organizational website/FAQs/Documents.

No. Members [16]	20083	7801	8552	3150	322252	5639
No. Active Members [17]	3416	1061	8428	962	8194	2981
No. Votes	39311	3553	44787	28893	34722	1405
No. Proposals	80	11	200	1112	81	73
Website	https://gitcoin.co/	https://assangedao.org/	https://www.olympusdao.finance/	https://decentraland.org/	https://uniswap.org/	https://www.citydao.io/

This paper is based on a descriptive methodological approach (Gerring 2001) that aims to provide with observations that reflect real world data rather than strict causal patterns. Unfortunately, DAOs have gone largely unnoticed in academic literature. The lack of qualitative background work on the subject makes efforts like this one especially challenging (DuPonte 2017, 166), and often faced with criticism by both blockchain maximalists[18] and academics. In an effort to open up this study to the maximum possible diversity of readers, I selected a mixed methods approach.

[16] Number of addresses holding the governance token.

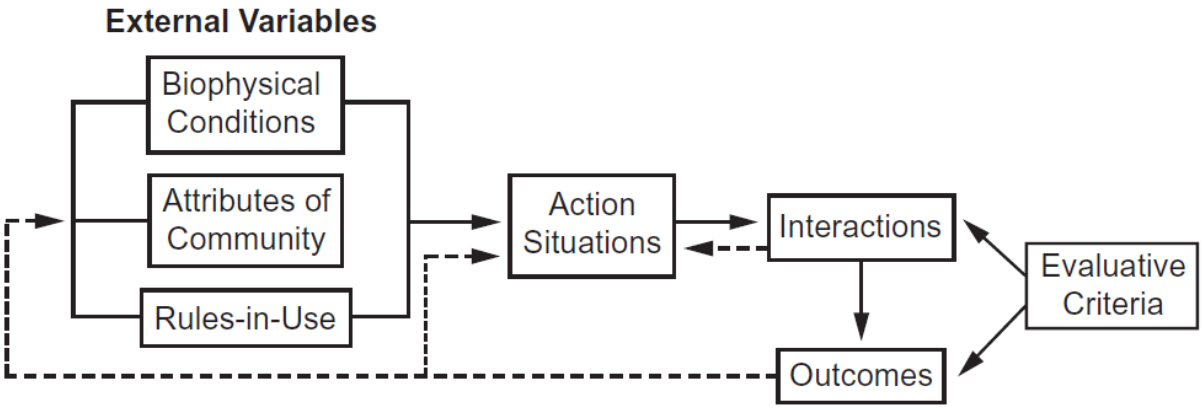
[17] Number of addresses that have voted or proposed at least once.

[18] Users of blockchain who support the omnipotence of the technology and reject the opinions of outsiders to their community (Jones 2018). Usually combined with strong libertarian views about the state and the

I use Ostrom's Institutional Analysis Development Framework (IAD) (Kiser and Ostrom 1982) to dissect DAOs and place them in a context of study that is relevant to the one of Olson. The IAD is powerful in allowing for the transfer of concepts from high level frameworks to theories and models (E. Ostrom 2011). In the process, it uncovers the full thought process, and allows for higher exportability to the reader and to related future studies of the topic. Then, I draw from the field of data analysis to make descriptive observations in support of my arguments. The methodological approach chosen has the potential to capture both structural and behavioral elements in groups and organizations, along with their development over time, addressing some of the challenges faced by the IAD framework (E. Ostrom 2011, 23-24). Overall, the combination of methods and tools – which I describe in detail below, hopefully provides with a well-rounded and concrete study that considers both structural and behavioral outcomes and variables.

The IAD framework consists of the following building blocks:

Table 3 The IAD framework. Figure taken from (E. Ostrom, Background on the Institutional Analysis and Development Framework 2011,



economy, echoing the ideas of John Perry Barlow in his "A Declaration of the Independence of Cyberspace" (Barlow 1996).

The process carried out below serves to answer: *What are the measurable evaluative criteria that adequately and intuitively describe the outcomes emerging out of the given Action Situation?* This is achieved by visiting and explaining how each one of the IAD components pertains to DAOs, ultimately pointing out my assumptions, and how variables emerge out of theory and empirical observations.

Biophysical Conditions: The broad environment is digital and catallactic[19], especially intense with regards to volume and velocity of information and communication.

Attributes of community: Trust and reciprocity are enhanced by the common faith in decentralization but hindered by the complete anonymity between members. Communication between members is easy through multiple channels like Discord and online forums. Online reputation - mostly displayed in terms of number of twitter followers, is greatly valued but not a strict prerequisite. With regards to the demographics of DAO members, one of the very few studies conducted on the topic revealed a majority of males, aged 20-40 years old (DAO and Gitcoin 2021). Participation in a DAO de facto assumes adequate technical literacy.

Rules: Rules are enforced by computer algorithms, called smart contracts, and are part of the larger *"organizational template"* (McGinnis 2011, 16) which is strict. These rules are very difficult to amend and require high levels of consensus and the authorization of some custodian subgroup of members. Such groups of members that are entrusted with critical processes are called *governance layer.*

[19] An alternative term used to describe the economy, and which extends to include multiple levels of analysis and forces at play. According to Friedrich Hayek *"the order brought about by the mutual adjustment of many individual economies in a market*" (Hayek 1978). This termed is preferred here since it better encapsulates the systemic driven factors of this study which aims to preserve and make sense out of complexity.

In the following paragraphs, I decompose DAOs according to the IAD, starting from the *"action situation/arena"*:

Actors: DAO governance members. For anyone to become a DAO member, a crypto wallet that holds the native token or NFT of that organization needs to be connected to the DAO's platform. This serves as a proof that the owner of that wallet is a member of the organization. City DAO is a case of NFT based membership, while the other five DAOs operate using a governance token. I assume that each wallet address represents a member. Even though a person can practically own more than one wallet registered in the same DAO, there is no discernible benefit in doing that. *Positions:* Governance participating members (submitting proposals, voting), governance delegating members (members that hand over their voting power but not financial claims to other members), delegates/representatives (members that hold voting powers given to them by others), governance inactive members (members that own voting power but do not participate in decision making). In our examples, half the DAOs (Gitcoin, Decentraland, Uniswap) allow for the delegation of voting power, while the other three organizations (Assange, Olympus, City) do not. *Allowable actions:* Propose on a variety of issues like investment, administration (ex. hiring a full-time worker) and activities (ex. hold a virtual meetup); vote on active proposals; do nothing. These actions are easily quantifiable, and offer a connection between individual choices, external variables, and outcomes, as shown in Table 2. *Potential outcomes:* The allowable actions produce, in aggregate, the following measurable outcomes: Change in the organization's governance structure through participation and decision making and secondary effects in individual voting behaviors of their members (behavior). Empirical data and measurements with regards to these outcomes serve as test for Olson's theoretical claims.

Level of control over choice: Ownership of governance tokens or of a membership NFT is mandatory for a person to be considered member of a DAO. Beyond that, voting, delegating, or doing nothing are a matter of individual choice across all six case studies. Proposing is regulated – subject to specific rules, discussed in the appropriate section in detail. *The information available:* Transparency and public access to information are very high compared to traditional organizations. At the institutional level, members (and even nonmembers) can know among other: The value of assets under management of the treasury at real time, the backbone algorithm of the organization, and other general statistics like number of members. At a lower level, the individual cost benefit functions are not very straightforward but not impossible to assume since members can see how much others participate in decision making (voting or proposing), their past choices, and the amount of wealth their wallet controls (it is probable though that someone with a substantial portfolio of coins will distribute them across many wallets). *Interactions:* Actors interact in two different settings in respectively different ways. Communicating on channels like Discord and voting on proposals on platforms like Snapshot. The use of pseudonyms, that most of the times cannot be matched with their wallets, while communicating, renders this type of interaction difficult to study with regards to governance participation. On the other hand, votes on Snapshot are publicly available. Voting not only can be considered an interaction with the voting process (structural), but also is a commitment of personal time, and if in agreement with the votes of other actors, a form of consensus. The similar assumption can be safely made when a member proposes, and then votes on that proposal. *Outcomes:* The agreement or disagreement between the votes of members leads to changes in consensus (or decision-making coherence), and in aggregate participation.

Considering all the points made above, I chose the following variables for the qualitative component of this paper: Individual votes representing the opportunity cost of time devoted by the member in studying and understanding the relative proposal, and opportunity cost of money for the amount staked in the DAOs treasury for the governance rights used. The number of common votes between two members, manifesting agreement for some proposal(s). I combined these two variables into one, creating the pairwise weighted adjacency matrix (Newman 2004) of common votes between members for each DAO. In simple terms, a two-dimensional table showing how many times every pair of members has voted the same. Then I converted every such matrix into a social network object (one per DAO) where nodes represent members, and vertices represent common votes (weights reflect the exact number). Various derivations from these data were computed along with the timestamps of every proposal to study the time evolution of both behavioral and structural claims made by Olson.

Findings

In this section, I present the results of the computational analysis of DAO data with regards to the outlined hypotheses – drawn from Olson's collective action theory. In the following chapter – Discussion, I provide with a qualitative interpretation based on the following institutional factors (explanations for each variable provided below table):

	GitcoinDAO	AssangeDAO	OlympusDAO	DecentralandDAO	UniswapDAO	CityDAO
Objective	Social, Economic	Political	Economic	Hobby, Economic	Economic	Economic, Social

Membership	Open	Open	Open	Open	Open	Limited
Delegation	Yes	No	No	Yes	Yes	No
Vote Cost	Yes	No	No	No	Yes	No
Governance Structure	-	Semi-Centralized	-	-	Inflationary, Nonflexible	-
Quorum	No*	Yes	No	No	No*	Yes
Governance Layer	Stewards	Family of Assange	Policy Team	Security team	-	-
Off Chain	Snapshot	Snapshot	Snapshot	Snapshot	Snapshot	Snapshot
On Chain	Tally	-	-	-	Native portal	-
Power	1 token – 1 vote, indirect Quadratic Voting	1 token – 1 vote	Weighted Tokens	Weighted Tokens	1 token – 1 vote	NFT, switching to Quadratic Voting
Proposals	Fully Open	Fully Open	Fully Open	Fully Open	Fully Open	Fully Open

Vote Means	Token	Token	Tokens	Tokens	Token	NFT

Many of these variables are subject to change as the governance of DAOs is a very fluid and dynamic process.

Membership: The governance tokens of all token-based governance DAOs can be bought with a crypto wallet. City DAO's NFT memberships are limited and can be only bought from secondary markets. These NFTs are also considerably more expensive compared to governance tokens that can be bought at denominations.

Delegation: Whether members can entrust others with their voting power to represent them. Such systems are gaining more popularity in the DAO ecosystem but create the danger of convergence with traditional representative democratic systems – thus losing the unique opportunities algorithmic governance provides.

Vote Cost: DAOs that also employ on-chain voting incur financial costs for their members when voting on-chain. Even though the data analyzed only come from Snapshot – where voting is free, it is interesting to see whether costs later in the governance process deter initial participation.

Governance Structure: At Assange DAO, the core team which consists of the brother, and lawyer of Julian Assange can block proposals if deemed necessary. Uniswap DAO employs an automatic inflation of 2% per year for its governance token, making passive holding of it less profitable. Moreover, its algorithm cannot be amended by design.

Quorum: Whether a minimum number of members or token value needs to vote for a proposal to be accepted. Those marked "No*" do not require quorum for the off-chain snapshot votes but do for the on-chain ones – not included in this paper's computational analysis.

Governance Layer: Subgroups of members with special duties and/or powers. Gitcoin DAO stewards are necessary for informal proposals to be put into vote, with a minimum number of them required to interact with a proposal. At Assange DAO, the core team has full veto powers. The Policy and Security teams at Olympus DAO and Decentraland have specialized powers when it comes to proposals in their domain. City DAO has specialized groups named guilds that do not exercise special duties with regards to decision making but are only responsible for operational execution.

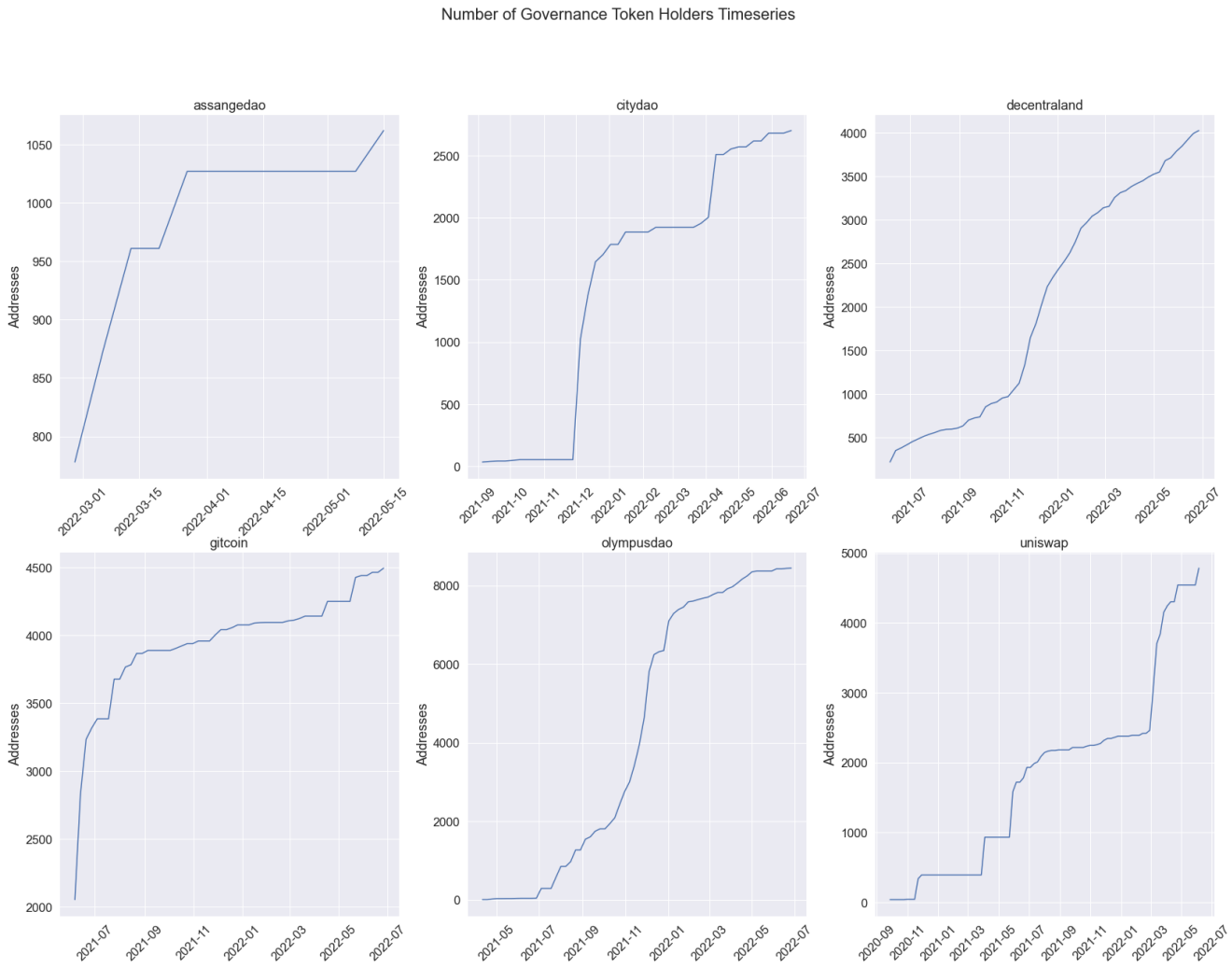
Off-chain/On-chain: On-chain governance refers to proposing and voting on some blockchain. All actions are registered as transactions, and contracts are executed automatically. As is the case with regular crypto transactions, a fee is charged (gas fee) as service to the network. Off-chain platforms do not incur fees but also require some other arrangement for the execution of coting outcomes. Some DAOs combine the two, using off-chain for sentiment signaling and on-chain for terminal voting. Different systems may apply providing with even higher flexibility in arranging human collective action through algorithmic design. Power: Voting in DAOs very rarely happens with the one-person one-vote system found in democracies. One of the main reasons is that participation is largely anonymous, and it would be easy for malevolent actors to register multiple addresses – assumed to be multiple members. Thus, one-token one-vote systems apply. Moreover, Gitcoin DAO initially allocated governance tokens based on the amount contributed to common goods funding utilizing quadratic funding (see footnotes on page 3). Weighted tokens systems consider multiple different tokens similarly to one-token one-vote system but less linearly. The NFT system found at City DAO works similarly to one-token one-vote systems but instead of tokens translating into power NFTs do. Even though NFTs set the barrier of entry higher than tokens, the standard deviation of voting power distribution between members is smaller.

Proposals: Every address that holds governance power can propose on Snapshot. At later parts of the decision-making process various governance power thresholds are enforced, meaning that members proposing need to possess a specific amount of wealth. The quantitative analysis of this paper does not cover them.

In one of her last works, Elinor Ostrom identified the importance of timeseries analysis of institutional change as a future challenge (E. Ostrom 2011). What's more, all six DAOs in focus grow larger in members over time, allowing for the study of participation with size being treated as the independent variable. Below, I examine individual participation in terms of group size and time progress. I treat each hypothesis separately, starting with H1: Does the individual contribution by group members for social governance processes decline as groups become larger?

Initially, I plotted the cumulative number of addresses over time, calculated on a weekly basis.

Figure 2 Cumulative members over time.



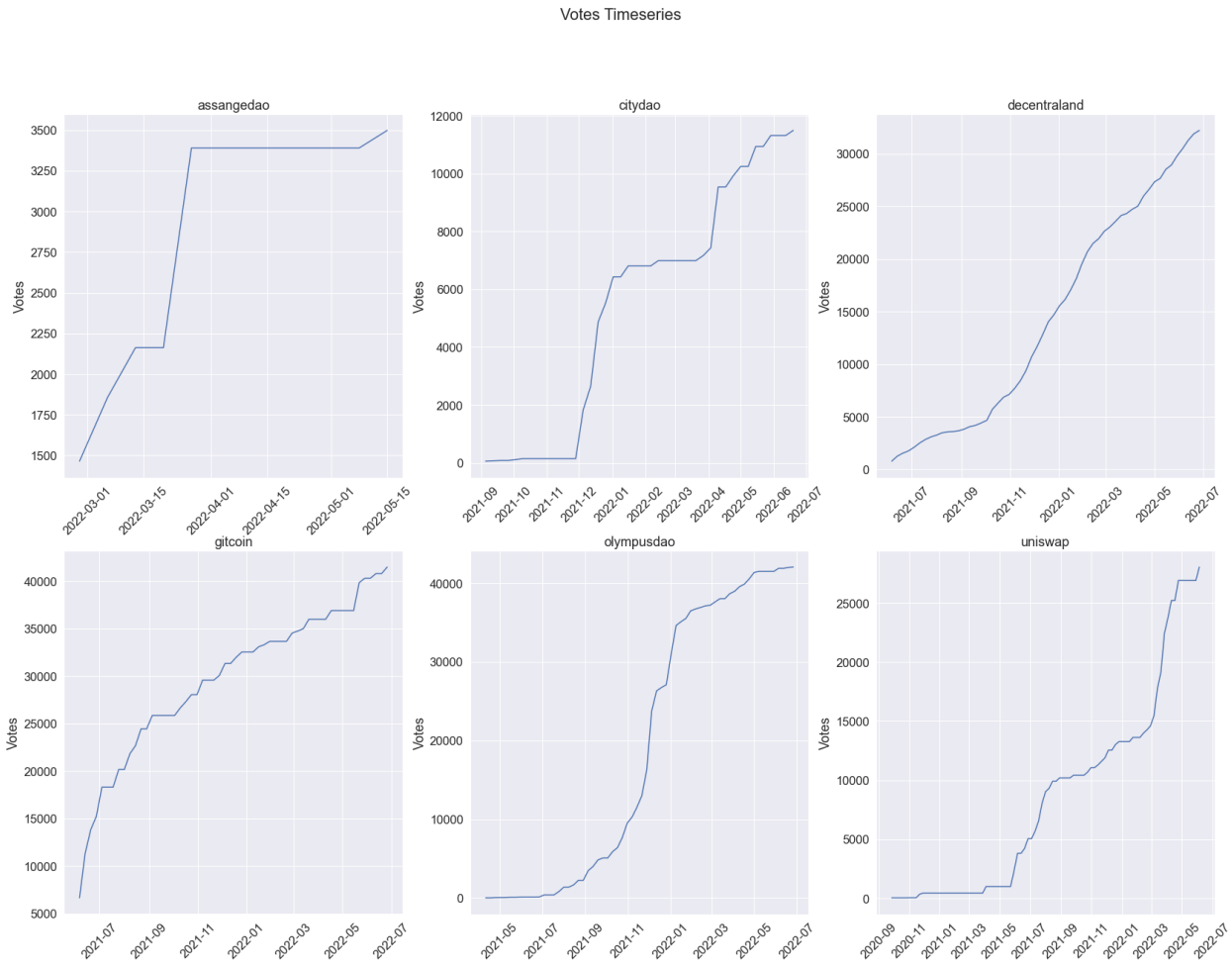
All six DAOs increase non-linearly and monotonically in governance token holders over time, a pattern that

emerges very often in most visualizations of this chapter. Assange DAO is the smallest and newest with data available only for the past four months. Another interesting observation is the fact that some organizations like Uniswap DAO, City DAO, and Olympus DAO started using Snapshot from the very first days of the DAO before a substantial number of members joined. Contrary to that, Assange DAO, Decentraland DAO, and Gitcoin DAO started utilizing Snapshot for

governance with after a substantial initial decision-making group of members was gathered. This reflects different strategies and choices. It is also important to note that the earliest dates included in the graphs above do not necessarily reflect the founding date of the DAO, as most such organizations gradually build their governance processes and do not necessarily use on-chain or off-chain platforms in their initial launch period.

The growth in members is accompanied, expectedly, by a growth in votes.

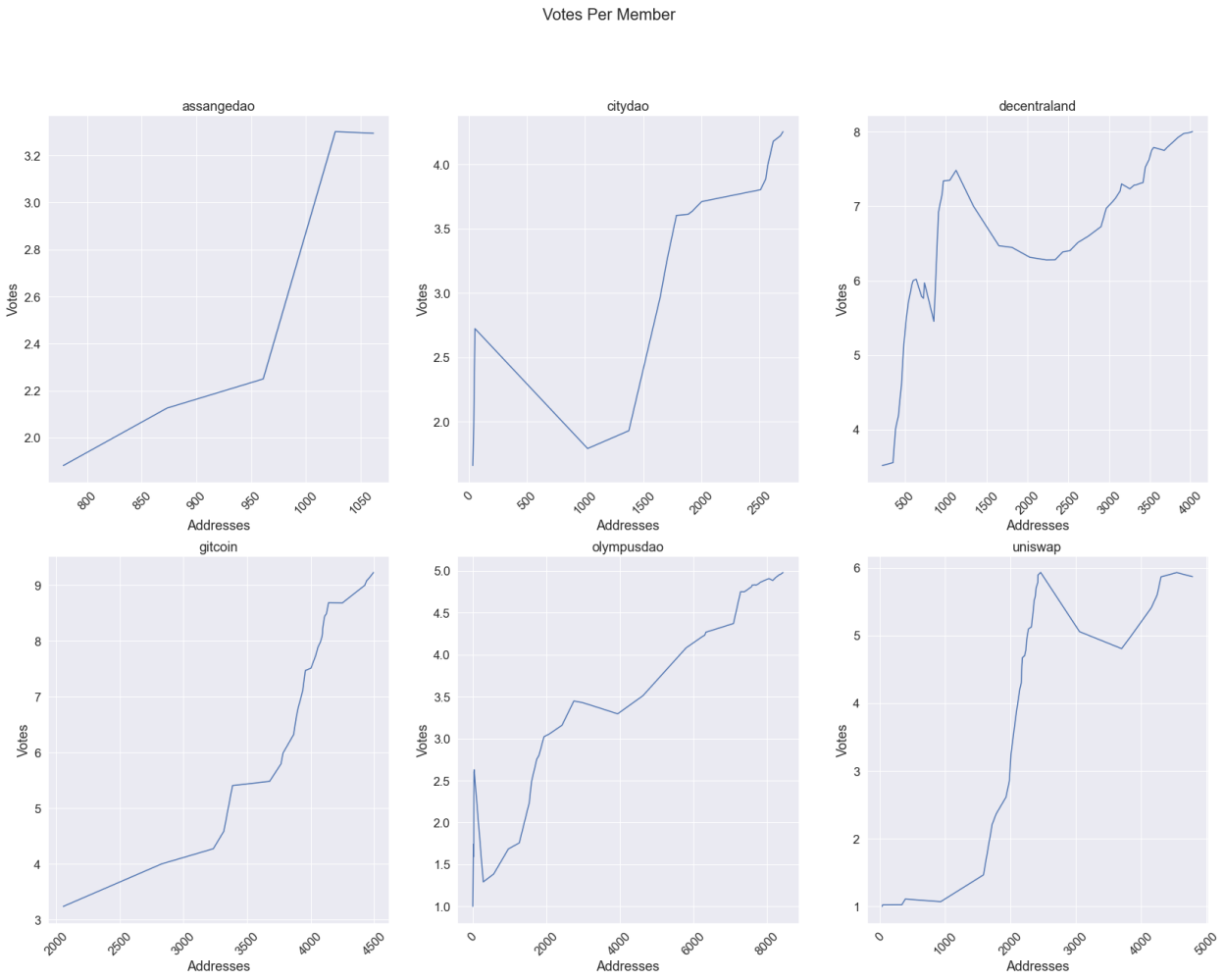
Figure 3 Cumulative votes over time.



The initial survey of members and votes offers an initial perspective into the size dynamics of the six case studies. It does not describe individual time commitment, which I calculated as the ratio

of votes and number of addresses. Below, the average votes per member is plotted against the number of governance-participating addresses.

Figure 4 Cumulative votes per number of members over time.



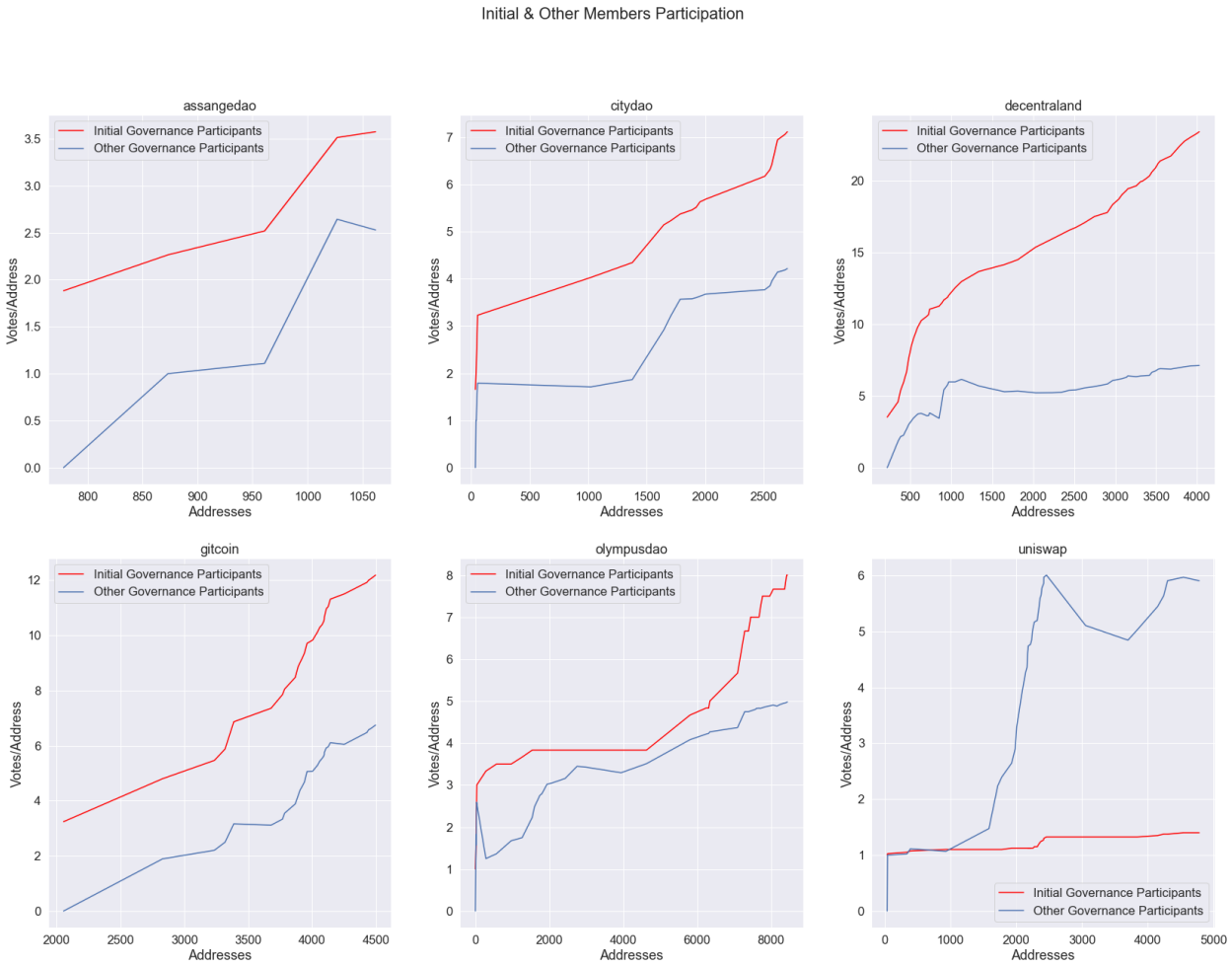
Three initial observations are worth noting. First, as organizations grow larger, average votes per member increase. This observation greatly contrasts the free riding assumption of Olson. Members spend on average increasingly more time participating in the governance process. Thus, the personal opportunity cost of time increases. Secondly, increases are non-monotonic and nonlinear, suggesting that non-linear forces are at play. Lastly, the average number of votes per member is not consistent across DAOs for the same number of members. For example, at 3000 addresses,

Gitcoin DAO members average approximately 4 votes while Uniswap DAO members average 5 votes.

The quantitative exploration of the second hypothesis – whether members that are less financially and/or ideologically invested in the group's objective contribute less to the governance of the organization, is substantially more challenging compared to the first one. The straightforward solution of calculating participation based on the amount of voting power addresses hold is very difficult for numerous reasons. To begin with, wealth in decentralized finance fluctuates wildly. Moreover, it is common practice for wealthy members to spread their wealth across multiple addresses to avoid drawing too much attention on them since the wealth of every address is fully public. In addition, wealthy individuals delegate voting power since they invest their wealth in multiple DAO. Lastly, many addresses that appear as major holders of governance tokens may be commonly managed DAO treasuries and not individual members.

To address these challenges, I focused more on the non-economic investment component of the hypothesis. Specifically, I split the members of every DAO into two groups, denoted as "Initial Governance Participants" and "Other Governance Participants". The initial participants are all those who onboarded the DAO on the very first period (month), while other participants are all those after them. I elected such an approach after considering the fact that the first people who join a DAO are its founding members, their close social circle, and the strong believers in the DAO's objective and future success. Consequentially, I assume that the initial joiners are more invested in the DAO. In some cases, initial members also happen to include large investors brought by the founding team, similarly with startup seed investors. Then the average number of votes for every group was plotted over time and as organizations grew larger.

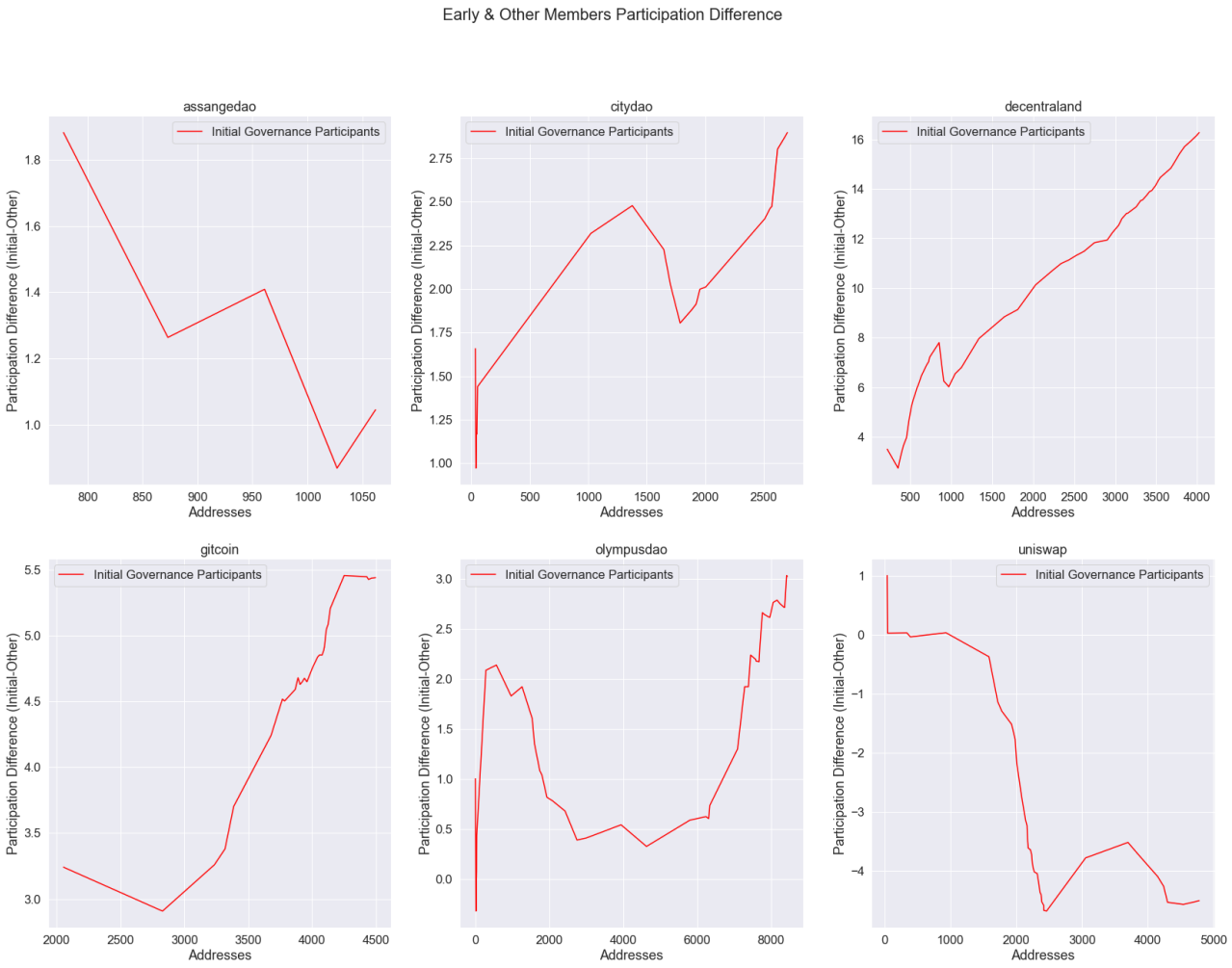
Figure 5 Cumulative votes of initial and other members.



Emerging patterns are very different. The higher level of average votes in the initial participants can be largely attributed to the fact that the size of their group is constant, thus the fraction of votes per members increases more compared to the fraction of the votes per member of the other group of participants. What is of high importance is the time development of participation – be reminded in that regard that the x-axis also corresponds to increasing time periods. Overall, very different patterns emerge across the six cases visualized, with Uniswap being the only one where the group of secondary participants surpassed the one of initial ones.

In order to better compare the participation between heavily invested and other members, the differences between the average number of votes per member in the initial minus the other group were calculated.

Figure 6 Initial members' votes minus other members'.



Evidence partially support Olson's claim that the majority will free ride on the heavily invested minority. Although no linear pattern emerges, hinting that multiple other forces are at play. The case of Uniswap, as a striking exception, calls for additional analysis.

Discussion

The findings presented in the previous section strongly support the main proposition of Elinor Ostrom that structural institutional arrangements can address problems of collectivization and resource management by overcoming free riding – leading up to tragedies of the commons. In this chapter, I take a deeper look into the specific institutional configurations and how they relate to the findings presented in the previous chapter.

Starting from the most striking observation, similar participatory patterns emerged between groups of different objectives, suggesting that ideological, social, and economic motivations have similar impact on individual members, contrary to what traditional theory has suggested. Thus, identity is not sufficient on its own to motivate participation (Olson 1965, 13). Moreover, the accomplishment of political goals like freedom of the press (Assange DAO), social goals like collective land ownership (City DAO), entertainment (Decentraland DAO), and income (Olympus DAO) have similar impact on group participants – as manifested by participatory outcomes. Of course, it should be recognized that for the time being, DAOs have only served mostly as a proof of socio-economic systems integration and not purely as proof of social organization (Racsko 2019) . Whether the ecosystem will manage to detach itself from decentralized economics and evolve into a new social action paradigm remains an open question.

While the existence of a minimum votes requirement (quorum) as protective barrier against majority attacks does not have a clear impact on participation, multistep governance processes that include both off chain and on chain methods are associated with higher levels of participation for the same levels of size across the six cases. Not only do such systems provide similar protection as quorum ones do, but they also seem to enable more participation. Redundancy and complexity

in such systems has been known to reduce errors and costs (Blomquist 2009, 116), thus enabling more participation. Members recognize that governance comes at a cost, not only in financial terms (gas fees for voting on-chain) but also in terms of risk and reputation. These fears are lifted by introducing a risk-free initial step (off-chain vote) which is recognized by all community members as non-binding and exploratory. Group members are then more eager to voice their opinions knowing that it bears little to no risk, financially or reputationally. In doing that, conflicts are diffused early on and without any serious impact on the governance of the organization (E. Ostrom 1990, 99-101), while preserving diversity of opinions and harnessing collective intelligence. In that regard, a future project could explore the concept of collective intelligence in DAOS by analyzing the exchange of ideas on their forums and/or discord serves. The democratization of high-quality Natural language Processing tools offers a unique opportunity in pursuit of such a goal.

Unintuitively, DAOs with governance designs that allow for the delegation of voting power have comparably higher participation. This is specifically evident in Decentraland DAO, Gitcoin DAO, and Uniswap DAO, all three of which achieve higher participation for the same levels of size, compared to the other three organizations. Considering how participation was measured, there two possible forces at play. Initially, some free riders become more motivated to delegate their power for a minimal cost (the time needed to delegate) than do nothing for no cost, providing the potential for other members that would be otherwise disincentivized to participate due to their limited voting power to gain critical mass and increase participation by becoming delegates of others. The ease with which communication is facilitated between members in DAOs also acts as a catalyst – leading to more optimal outcomes (Hamman and Weber 2011). This topic remains very contentious in DAO-specific non-academic literature, providing with new opportunities for

researchers to dig deeper into the social dynamics of delegation as more governance data get captured and publicized. The present paper could also be extended to include community-related network analysis methods to observe and study internal subgroup dynamics.

The findings pertaining to the second hypothesis provide with more granular insights into the interplay of behavior and institutional design by also considering asymmetries between members. Revisiting the observation that group objective does not seem to be an important differentiating factor in terms of individual contribution, the same argument does not extend to the first members of the DAO. When it comes to initial joiners, those of non-purely economic organizations, in our case all but Olympus DAO and Uniswap DAO, are comparatively more invested in their objective, participating more than their counterparts of purely economic organizations. As organizations scale in size, the participation of new members does not follow the same steady growth of the founding ones, leading to a convergence of aggregate individual behavior across all types of different organizations. The almost linear participation growth of initial joiners in five out of six case studies points towards the existence of a strong group-level behavioral pattern, with modeling potential.

The calculation of the difference between the participation of the two groups over time shows a growing tendency in three out of six DAOs (Gitcoin DAO, City DAO, Decentraland DAO) for the majority to free ride on the few initial members. This does not hold true for the rest of the organizations, with Uniswap being the most obvious case with outlier-like characteristics. Why are initial members at Uniswap not increasing their participation as their counterparts in other DAOs? Uniswap has received sharp criticism[20] in the ecosystem for not being truly decentralized

[20] https://cryptonews.com/news/what-is-this-uniswap-governance-drama-about-11058.htm and https://otherinter.net/research/uniswap-governance-findings/#how-to-study-a-social-organism

due to the very high concentration of voting power to few members – accused of collusion, and for the non-amendable governance process (Fritsch, Muller and Wattenhofer 2022). Consequentially, major members do not participate in the process unless a proposal is of immediate importance to them, knowing that the current internal status quo favoring them cannot be overturned. This case provides strong evidence in support of Ostrom's institutional design principles (E. Ostrom 1990, 90) by showing that when all conditions found in successful common pool resource organizations are not met, problems of cooperation are going to emerge.

The results of the analyses conducted within this paper should be interpreted with caution. Not only because DAOs lack the historical continuity needed to make them fully credible paradigms, but also because complex social forces like online trends have also been at play. In overcoming these limitations, future research could expand to include more case studies and other environmental variables.

Conclusion

This study not only tested the validity of existing theories, but also deployed them to generate insights into the interplay of institutional variables (objective, size, level of centralization, etc.), and individual behavior.

Initially, I assumed that Ostrom's work on common pool resources is very relevant to blockchain-based Decentralized Autonomous Organizations. Not only because DAOs operate as public good resource systems like the majority of Ostrom's case studies, but also because DAOs are decentralized in their governance processes – echoing Ostrom's concept of polycentricity. For these reasons, the IAD framework was used to dissect and operationalize the complex structural arrangements found in DAOs. Then, the Collective Action Theory of Mancur Olson was utilized

to connect the theoretical framework of Ostrom covering high level institutional variables with low level individual behaviors such as free riding.

I then analyzed empirical quantitative data with regards to the theoretical claims of these two authors, providing with new insights regarding individual behavioral and institution building. Specifically, I observed that DAOs are very similar to Ostrom's common pool resource systems in that they can help overcome the tragedy of the commons by complying with the design principles identified by her. Consequentially, free riding is not as omnipresent as suggested by Olson, and it can be avoided through proper designs and decentralization in decision making. Identity and group purpose are also less important for individual participation, except when it comes to the first members of the group. Not only do such members participate more than others, but their participation follows a distinct linear growth trend as groups increase in size. In addition, the initial and founding members of non-economic organizations are motivated to participate more than their counterparts in purely economic organizations. This implies that modes of analysis that consider all members of a group similar with regards to their payoff functions and behavior are weak in capturing real world diversity, and not productive in generating suggesting for building better institutions or modeling human behavior.

In this paper, the mixed methods approach helped preserve complexities and ultimately come up with suggestions for building better institutions. Specifically, it was found that multistep governance systems can enhance participation by lowering reputational and risk costs for participants. Similarly, the ability to delegate one's voting power to another member of the groups mobilizes members that would otherwise not participate at all.

Overall, the findings suggested that diverse individualistic motivations make group members participate in the production of collective goods. When these non-purely economic motivations are placed in a healthy self-regulating system of decentralized governance, individuals can achieve high levels of cooperation overcoming the tendency to free ride. With these observations, I hope to invite further research on the topic of DAOs, which – as shown, can have both practical and theoretical implications for numerous sectors within and outside academia.

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