POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Governance of blockchain-based decentralized applications: an exploratory study

TESI DI LAUREA MAGISTRALE IN
MANAGEMENT ENGINEERING
INGEGNERIA GESTIONALE

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Academic Year: 2021-22

Abstract

Blockchain has emerged as a technology capable of redesigning the patterns of human interaction and coordination among organizational agents, and it offers opportunities for enforcing agreements and achieving large-scale cooperation in ways that are not enabled by traditional systems. As a result, blockchain supports the institution of new types of decentralized organizations with coordination systems and incentive alignment that have traditionally been the domain of top-down hierarchical structures. One of the most compelling manifestations in this sense is decentralized applications (DApps): "trustless" applications running on peer-to-peer networks with no single entity controlling them. Despite increased interest from practitioners and academics, it remains unclear what the business implications of DApps are and how their governance differs from that of traditional organizations. To address this gap, this research analyzes how blockchain technology affects governance systems leveraged by Dapps, how power flows within these structures, and how decentralization is achieved in practice. Starting from a database of the top 150 DApps in terms of global user adoption at the beginning of 2022, six cases have been selected and interviewed to understand their governance practices, the reasons behind their adoption, the degree of decentralization achieved, and future expectations. The study investigates which factors influence the effective distribution of powers in DApps, enabling truly decentralized governance. The work sheds light on who holds decision-making power, how it is dispersed among stakeholders, and how key decisions are made and enforced in DApps.

Keywords: Blockchain; governance; Dapp; application; decentralization; power; decision-making.

Abstract in italiano

La blockchain è emersa come tecnologia in grado di ridisegnare i modelli di interazione umana e di coordinamento tra agenti organizzativi, offrendo inoltre opportunità per far rispettare accordi e raggiungere cooperazione su larga scala in modi non consentiti dai sistemi tradizionali. Di conseguenza, la tecnologia blockchain consente l'istituzione di nuovi tipi di organizzazioni decentralizzate con sistemi di coordinamento e allineamento degli incentivi che tradizionalmente sono stati appannaggio di strutture gerarchiche top-down. Una delle manifestazioni più interessanti in questo senso sono le applicazioni decentralizzate (DApps): applicazioni "senza fiducia" che operano su reti peer-to-peer senza che una singola entità le controlli. Nonostante il crescente interesse da parte di professionisti e accademici, non è ancora chiaro quali siano le implicazioni manageriali delle DApp e come la loro governance differisca da quella delle organizzazioni tradizionali. Per colmare questa lacuna, la presente ricerca analizza come la tecnologia blockchain influenzi i sistemi di governance utilizzati dalle Dapp, come il potere fluisca all'interno di tali strutture e come la decentralizzazione venga realizzata nella pratica. Partendo da un database delle prime 150 DApp in termini di adozione globale da parte degli utenti all'inizio del 2022, sono stati selezionati ed intervistati sei casi per comprendere le loro pratiche di governance, le ragioni alla base della loro adozione, il grado di decentralizzazione raggiunto e le aspettative future. Lo studio analizza quali fattori influenzano l'effettiva distribuzione dei poteri nelle DApp, consentendo una governance realmente decentralizzata. Il lavoro fa luce su chi detiene il potere decisionale, come viene disperso tra diversi stakeholders e come vengono prese ed eseguite le decisioni chiave nelle DApp.

Parole chiave: Blockchain; governance; Dapp; applicazione; decentralizzazione; potere; processo decisionale.

Contents

Introduction

Blockchain is a technology invented by Haber and Stornetta in 1991 to solve the issue of ensuring the integrity of digital records in the context of time-stamped digital documents. The work of Haber and Stornetta, published in the Journal of Cryptology, "proposes computationally practical procedures for digital time-stamping of documents so that it is infeasible for a user either to back-date or to forward-date a document even with the collusion of a time-stamping service."

It was not until 2008, that the blockchain started to gain relevance with its first use case as the underlying technology behind Bitcoin. The person or group known by the pseudonym Satoshi Nakamoto introduced the innovative idea of a virtual, decentralized, peer-to-peer currency. The aim was to create an open-source protocol for configuring a peer-to-peer network in which it is possible to exchange the virtual currency efficiently and safely without the need for an intermediary or central authority to trust, while avoiding the double-spending problem (Nakamoto, 2008). Various attempts to develop a digital currency had been made in the past, but none were able to solve the double-spending problem without the need for a centrally trusted party (Swan, 2015).

Despite the fact that the concept of blockchain seems extremely complicated and difficult to understand, it is in fact quite simple to grasp. Blockchain is fundamentally a database with some peculiar characteristics that make it different from traditional databases. Firstly, it is a distributed ledger, meaning it is shared, operated, and replicated by a network of nodes owned by different individuals with no central administrator. Consensus algorithms are needed to define which copy of the independently updated ledger is correct. A second characteristic is that data is broken down and stored in sets of records, called "blocks," that are linked together using cryptography. Each block contains a signature, called a hash or digest, of the data contained in the block and the cryptographic hash of the previous block, thus forming a linear chain. All blocks are linked in a sequential way, leading to a third important unique feature of the blockchain: immutability. Data can only be added; it cannot be edited. This is because tampering with data would result in a change to the digest of the block and would require all subsequent blocks to be regenerated accordingly and the network of nodes to recognize the changes. Lastly, a public blockchain is transparent, meaning anyone can publicly access and download a copy of the database and see what it contains.

At first, Bitcoin remained known to only a small group of miners and early adopters. Due to the high volatility and conflicting attitudes of legislators towards cryptocurrencies, Bitcoin's development was somewhat restrained. While it was considered a currency in some cases, it was more often prohibited or not recommended. However, the advantages of blockchain technology have attracted increasing interest, especially with the introduction of smart contracts on the Ethereum blockchain. A smart contract represents digital contractual clauses that can be embedded into blocks and be performed automatically upon the verification of certain predetermined conditions. Thus, blockchain technology evolves as a distributed computational tool enabling the development of decentralized applications (also referred to as DApps, Dapps, or dapps) beyond the exchange of currency. From 2014 to 2018, blockchain received increasing attention as one of the future's potentially disruptive and revolutionary technologies.

After a phase of frenzy and inflated expectations followed by a crypto crush and disillusionment, blockchain technology has matured slowly. Various platforms have been developed to try to solve the performance problems and limitations of Bitcoin and Ethereum. Rationalization and a greater understanding of the technology brought more evidence of how it could benefit many sectors that can capitalize on distributed ledgers by eliminating the need for a middleman, lowering costs of transactions, infrastructure, and personnel, and providing higher data transparency and security.

The application of blockchain technology has then developed from digital currency into finance and gradually extended into health care, supply chain management, gaming, gambling, market monitoring, smart energy, copyright protection, the Internet of Things (IoT), and other industries (Angelis & da Silva, Casino et al., 2019, Yano et al., 2020). It is now widely recognized that the potential applications and advantages introduced by blockchain are unlimited, but the diffusion and adoption of the technology take place through a laborious process in continuous evolution.

While Web 2.0 enables people to communicate and exchange information on a global scale, it does not allow for scale-based coordination, nor has it brought equal access to information and economic opportunities. Dominant centralized platforms have arisen, exerting control over and profiting from user-generated data and content. As the expression of the arising Web 3.0, Dapps can potentially redesign patterns and paradigms of human interaction and coordination by distributing power and value across peer-to-peer networks (Atzori, 2015). Decentralization at scale can incite economic and societal changes by creating more inclusive, equitable, efficient, and collaborative systems (Lumineau et al., 2021). Public-blockchain-enabled applications can enable new types of organizations with coordination systems and incentive alignment that have traditionally been the domain of top-down hierarchical structures (Anderson, 2019). Still, the transition to a decentralized social and economic paradigm is yet to take place on a large scale as decentralized applications experiment with different governance structures in search of productive pathways and stability. Indeed, the governance of blockchain projects is essential to determining protocol updates because of their ability to evolve and adapt, to build transparency and accountability, and to manage and coordinate communities toward the same goal. As a variety of different actors interact and are involved with decentralized applications, developers face the interesting challenge of implementing systems that distribute decision-making power amongst stakeholders. Understanding how decentralized applications are governed is crucial not only for users, contributors, and investors but also for policymakers to come up with recommendations.

Even though blockchain is now drawing ever-increasing attention in both corporate practice and academia, the topics of governance and decentralized applications have been only superficially analyzed. It is still unclear what the business implications of DApps are and how their governance practices differ from traditional organizations'. Most of the research on blockchain has been focused on the technical aspects of the technology, exploring topics such as network security, smart contracts, cryptography, digital storage, data privacy, and authentication. Applications (with the term application referring to practical use) in the fields of fintech, AI, IoT, commerce, supply chain, healthcare, insurance, digital identity, art, and games are being developed and analyzed by academia, whereas decentralized applications (with the term application referring to a software program) have gathered little interest thus far.

This research aims to contribute to the limited literature on the subject by offering a complete analysis of how blockchain technology affects governance systems leveraged by decentralized applications and how and at what levels decentralization is achieved in practice. The work aims to shed light on who holds decision-making power, how it is dispersed among stakeholders, and how key decisions are made and enforced in decentralized applications.

To gain a comprehensive understanding of the topic from both a theoretical and practical standpoint, the study will first focus on existing research on blockchain technology and its impact on the development of new governance paradigms. Then, as the knowledge in these domains is still limited, it becomes crucial to gather data from those people that are facing the phenomenon under investigation "within its real-life context" (Yin, 2013). Thus, due to the phenomenon-driven nature of the research purpose, a multiple, exploratory case study is performed. Starting from a database of the top 150 DApps ranked by the number of Unique Active Wallets (UAW), at the beginning of 2022, six relevant cases have been selected: 1inch Network, Curve, Furucombo, MakerDAO, SpookySwap and Yearn Finance. The study captures their key features and understand what governance practices are implemented by such applications, the reasons behind their adoption, the degree of decentralization achieved, and the future expectations.

1 Literature review

1.1. An introduction to blockchain technology, characteristics and technical aspects

1.1.1. Background

In digital networks, information is exchanged by duplicating data and sending it across the web. The information sent may be replicated as many times as the number of message recipients, with the sender retaining a copy. The process is therefore unsuitable if the item to be exchanged has monetary value. By definition, transactions entail an exchange of assets and thus the transfer of property and ownership rights. If a digital asset could be simply copied, an agent could utilize it in an unlimited number of transactions. Within digital networks, this issue is known as the "double-spending problem" (Swan, 2015). Traditionally, such problems have been solved by the introduction of a central authority trusted by all parties involved in the transaction. This third party ensures that an asset is handled only once, without duplications, by recording all transactions in a single ledger. By querying the ledger, the authority can permit legitimate transactions while preventing fraudulent ones. The introduction of a single trusted third party, however, constitutes a cost in three ways: (i) it is more exposed to an external attack; (ii) its downtime completely halts the system; and (iii) it exerts complete control over past and future transactions.

Part of the broader family of distributed ledger technologies, blockchain can solve the double-spending problem without relying on a central authority; it does so by distributing the ledger to all nodes in a peer-to-peer network where they independently control and register transactions. It is fundamental that nodes agree on the same version of the ledger. Therefore, game-theoretic mechanisms to reach consensus are introduced. The ledger has peculiar features (e.g., immutability, security) stemming from its peculiar data structure. As a matter of fact, it is made of blocks linked together in chronological order in a single chain, hence the name blockchain.

1.1.2. Blockchain definition

The concept of blockchain was first introduced by Haber and Stornetta in 1991. Since then, several definitions have been written but no consistent and uniquely accepted definition has been yet adopted. However, numerous authors (Swan, 2015; Corea, 2019; Crosby et al 2015, Buterin, 2015) agree that blockchain can be essentially considered a decentralized, distributed ledger of transactions among network participants that are openly visible and verified by a consensus mechanism which removes the need of a central authority. Each block of data contains a timestamp and is connected to the previous one trough a hashing function so that it cannot be altered retroactively without tampering all subsequent blocks. The technology is therefore able to safely establish ownership and allows for its efficient exchange.

Blockchain technologies are included in the broader family of distributed ledger technologies, that is, systems in which all nodes in a network have the same copy of a database that can be read and modified independently by individual nodes (Vella, 2019). The primary distinction between a distributed ledger and a distributed database is the process for making changes to the ledger: in distributed ledgers, changes are governed by consensus algorithms and therefore can be made by multiple or all nodes, whereas in distributed databases, changes can only be made by a central entity (or several validators).

1.1.3. Underlying mechanisms and technical elements

Blockchain technology is grounded in existing technologies, whose knowledge is necessary to understand its working mechanisms. An explanation of the technology's properties and functioning is hereby presented in order to obtain a deeper understanding of blockchain, which is essential for examining its implications on blockchain based decentralized applications and governance systems.

Peer-to-peer Networks

Blockchains are based on peer-to-peer (P2P) networks, i.e., distributed network architectures in which all participants (nodes) share some resources (storage, processing power, etc.). Such resources are available without intermediary entities, so participants are both resource providers and requestors (Schollmeier, 2001). P2P networks are opposed to client-server centralized networks in which the provider of resources (the server) and the requestor (the client) are two different entities. According to Drescher (2017), P2P networks have the potential to reshape whole industries since they can replace intermediaries with P2P interactions.

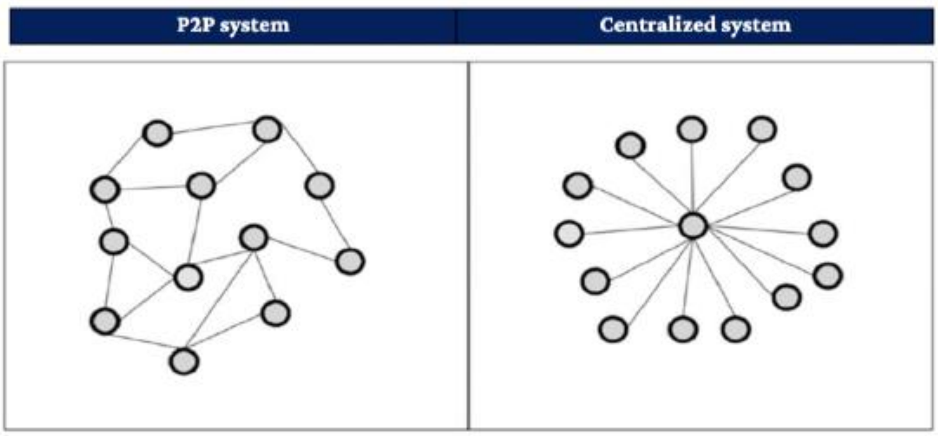

Figure 1.1: Topology of peer-to-peer networks versus centralized systems

Transaction

A transaction is the act of transferring ownership from a source of funds, called an input, to a destination, called an output (Antonopoulos, 2014). According to Drescher (2017), the information included in the transaction consists of:

- A sender: an identifier for the account that initiates the transaction and transfers ownership to another account.
- A receiver: an identifier of the account who receives ownership.
- The amount of goods to be transferred.
- The time at which the transaction is made.
- A fee to be paid to the system for executing the transaction.

It is imperative to ensure that only the account owner can transfer the property associated with the account. Every unauthorized attempt to access an account and its associated properties should be identified and denied. The mechanism used for verifying the authenticity of transactions is asymmetric encryption, also known as "public-private key encryption", which assigns each user two different keys, one of which is public and the other is private. The private key can be used to generate the public key, but not the other way around. To create a digital signature for a transaction, the sender must:

- Specify the transaction information (i.e. the transaction data);
- Generate the cryptographic hash of the transaction data;
- Encrypt the hash value of the transaction with his own private key.

Then, the sender puts the transaction data and the digital signature of the transaction together in a message; the transaction is originated and can be broadcasted to the network, in the so called gossiping phase. Usually, a single node transmits the transaction to adjacent nodes, which will recursively do the same with exponential diffusion. The generic node in the network can verify that the sender authorized the transaction by:

1. Decrypting the digital signature of the transaction with the public key of the sender, finding out the hash value of the transaction;
2. Hashing the transaction data, finding out the hash value of the transaction;
3. Checking if the hash values generated in 1 and 2 are aligned.

Block

Blockchain systems should not only guarantee data protection at an individual transaction level, as explained above, but they should also guarantee the immutability of the whole history of transactions.

A block is a container data structure that aggregates transactions for inclusion in the public ledger. The block is made of a body, which includes the list of transactions organized in a tree-like structure (Antonopoulos, 2014), and a header. The header includes the hash of the block, i.e., the result of a cryptographic function on the information contained in the block, and the hash of the previous block, thus creating a chain that links each block to the preceding one.

Blockchain systems should not only guarantee data protection at an individual transaction level, as explained above, but they should also guarantee the immutability of the whole history of transactions. The goal of the blockchain is to maintain the whole history of transaction data in an ordered fashion in a ledger.

A block is a container data structure that aggregates transactions for inclusion in the public ledger. The block is made of a body, which includes the list of transactions organized in a tree-like structure (Antonopoulos, 2014), and a header. The header includes the hash of the block (i.e., the result of a cryptographic function in which the information contained in the block is recorded) and the hash of the previous block, thus creating a chain that links each block to the preceding one.

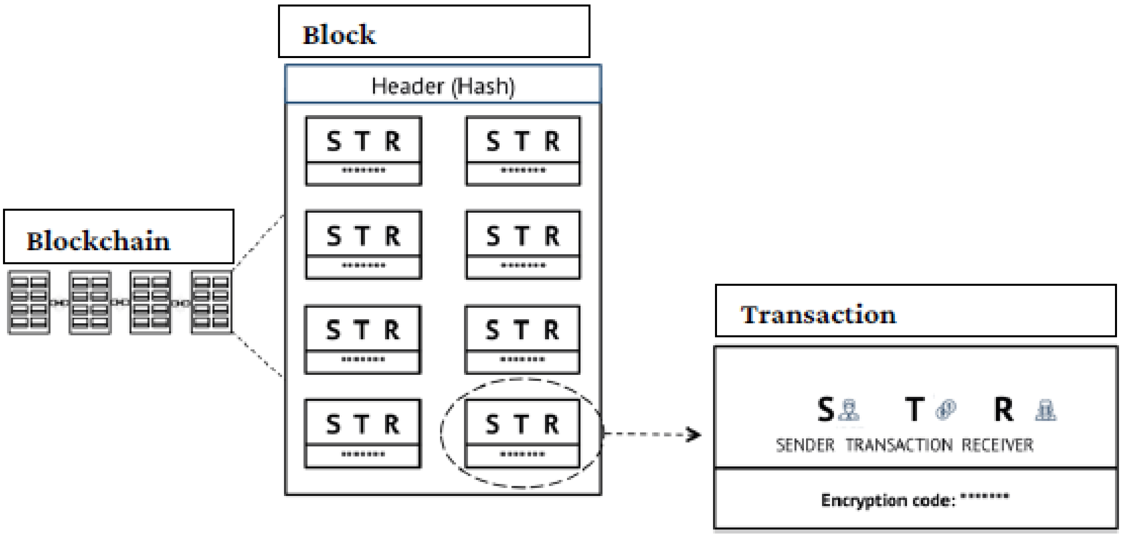

Figure 1.2: block structure

After the broadcasting phase (also called the "gossiping phase") and the independent validation by the nodes in the network, transactions need to be included in a block so they can be recorded in the ledger. The verification is carried out by validator nodes, whose role consists of constantly updating the ledger with all new transactions and agreeing on a single shared version (Antonopoulos, 2014). The nodes forming the peer-to-peer network store validated transactions in a pool, which are then aggregated into blocks and added to the chain by validators. Different nodes may work on different pools of transactions, depending on the order in which they have been received.

In the depicted situation, as it is, there is no disincentive for fraudulent nodes to create invalid blocks. Therefore, there is a need for an incentive scheme so that opportunistic behavior is discouraged by a higher payoff obtainable by playing by the rules. This is achieved through consensus mechanisms.

Hashing and hash functions

Hashing is a process that consists of applying a mathematical function on a piece of data, which can be a simple text string or entire documents and complex files, to produce an alphanumeric code of arbitrary length. The resulting code, known as hash code, or digest, is deterministic, meaning that the same input message always produces the same hash.

The little computational effort required by the operation allows a standard computer to generate the hash of a document in a few seconds. The reverse procedure, i.e., returning from the digest to the original information, is substantially impossible, therefore hash functions are characterized as irreversible. Bitcoin and many other blockchain protocols use a hash function called SHA256, which turns any input into a unique string of 256 bits represented by 64 hexadecimal digits. Any modification to the source document, no matter how slight, will result in a completely different hash value. This feature, coupled with the irreversibility of the digest, ensures that the original data is nearly impossible to be reconstructed knowing the digest only.

The table below shows a few examples of the application of the SHA256 function.

Table 1.1: SHA256 function examples on different text strings

Input	Hash
Hello world	64ec88ca00b268e5ba1a35678a1b5316d212f4f366b2477232534a8aeca37f3c
Hello world!	c0535e4be2b79ffd93291305436bf889314e4a3faec05ecffcbb7df31ad9e51a
World, hello!	477d61de387ac83b5d024a3e5582d7b33463e73fe270d555f71e4d50f0fd9a52
somefil	0004f8ca94a29af2b472033643eeb6d2231084bb0f687e512ee187dd09b5f553

1.1.4. Consensus mechanisms

Consensus mechanisms relate to the set of rules and procedures that allows to maintain and update the ledger and thus to agree on the current state of the network to guarantee the trustworthiness of the records. There are several consensus mechanisms implementable in a blockchain, and they are generally divided between two groups: proof-based and voting-based consensus algorithm (which will not be described here).

Proof based algorithms

Proof-based consensus algorithms require nodes to perform some kind of action to validate transactions and receive a reward for doing so. Since the inception of blockchain, several proof-based consensus algorithms have been developed, each with its own set of strengths and weaknesses, such as Proof of Activity, Proof of Burn, Proof of Contribution, Proof of History, and Proof of Elapsed Time. However, the two most common are Proof of Work (PoW) and Proof of Stake (PoS).

Proof-of-Work (PoW) is a validation algorithm initially designed by Adam Back (2002) in the paper entitled "Hashcash - a denial of service counter-measure" to protect a system from a denial-of-service attack. The mechanism was then implemented by Bitcoin to make it difficult to validate a block so as to prevent fraudulent use. Proof of Work uses computational resources to certify the work done by a user. The validator nodes, also called miners, compete to solve a challenging puzzle with an adjusted difficulty. Once a miner has found the solution, it will broadcast the block to the network so that other nodes can verify its correctness. If this is the case, the miner will receive the transaction fees and a reward.

Nguyen a Kim (2018) explain the process more in detail. Miners add a list of transactions that have been submitted but not yet validated into a candidate block, usually favoring the ones with higher gas fees. Then they attach the hash function of the previous block and a timestamp. After the candidate block is set up, validator nodes need to try and guess, per random attempts, a number called the nonce. When provided as an input with the block header in the hashing function, the output should match given conditions, e.g., the resulting hash must be smaller than a specific threshold. The purpose of the nonce is exactly that of making the hash of the block respect the threshold, which consists in having a leading number of zeros (see the SHA256 of the strong "somefil" in Table 1.1). The leading number of zeros required determines the mining difficulty as more attempts become necessary. Once a suitable nonce is found, the puzzle is solved, and the block is broadcast in the network so that other nodes can verify the content's validity. If all the verifications are correct, the network will add the proposed block to the current chain and restart the process with the next list of transactions. Finally, the miner is rewarded with all the gas fees from transactions included in the mined block and a fixed amount of newly issued cryptocurrency.

To attempt the solving of the puzzle, miners need to consume a high amount of computational power (also known as hash power or hash rate), which represents the work done and from which derives the name Proof of Work. Therefore, the probability of success depends on how much computational power the node holds. The system is immune to increases in computing speed since the difficulty of the problem is automatically adjusted so that each block is mined approximately after a fixed timespan elapses (e.g., in Bitcoin, a block is mined roughly every 10 minutes). The high costs of running the mining process, which requires specific hardware, and obtaining the majority of the computing power make the potential system disruption infeasible and extremely unlikely. The costs incurred for an attack are higher than the relative potential reward, providing an unprecedented level of security to the network. Moreover, the nodes' interest is in having a secure network so that the tokens they earn have value.

Proof of work has proven its worth over time, having been popularized by Bitcoin and Ethereum. However, the mechanism has drawbacks and has been recently criticized for its enormous energy consumption and low scalability, since the number of transactions validated per time period is kept constant. The level of difficulty in mining a new block ensures security but has also led to a reduction in decentralization. Given the high competitivity of the industry and the costs associated with the validation process, miners tend to join forces in large-scale mining farms, sharing computational power and increasing the probability of successfully mining a block while sharing the reward among the participants. This resulted in a few large farms possessing the most computational power in the network (De Filippi, Loveluck, 2016). The drawbacks have led to the development of different consensus mechanisms, the main one being Proof-of-Stake.

Proof-of-Stake (PoS) is a consensus algorithm designed to address the inefficiencies of Proof-of-Work in which the validators, also called "minters" or "forgers", are selected by the stake of the asset they are willing to lock in for a certain amount of time. The higher the stake the node deposits as collateral, the higher the probability of being selected as a validator. Once a node gets the chance to create a new block, it will collect and verify the transactions in the block, then broadcast it to the other minters and receive the rewarding fee (Binance Academy, 2018; Nguyen & Kim, 2018). The stake works as a financial motivator for the forger node not to act maliciously by validating or creating fraudulent transactions. If the network detects a fraudulent transaction, the forger node will lose part of its stake and its right to participate as a validator in the network. So as long as the stake is higher than the reward, the validator would lose more coins than it would gain in the event of fraud. Furthermore, using PoS would require any attackers to own at least 51% of all stakes in the network in order to perform an attack, which is very unlikely due to the resources the attacker would have to buy.

PoS algorithms solve some disadvantages found in PoW algorithms, like energy consumption, lack of speed, and low scalability, despite introducing a greater chance of a 51% attack in small chains powered by alternative coins. Main examples of proof-of-stake usage include Polygon, Polkadot, and Cardano, and Ethereum that has recently switched to such a consensus method.

Several different types of Proof-of-Stake have been then created including Delegated Proof of Stake, Leased Proof of Stake, Pure Proof of Stake, Liquid Proof of Stake, Proof of Validation and Hybrid Proof of Stake, each with some adjustments to increase democracy, mitigate the risk of majority coalitions taking over the network, enhance distribution, increase flexibility, and encourage participation.

Forks

In software engineering, "software forks" refer to modifications to free and open-source software that be copied and edited without prior permission from the original development team and without violating copyright law (Voshmgir, 2020). The term could also refer to a split in the developer community of an existing project, rather than just the code (Robles & Gonzalez-Barahona, 2017).

In the blockchain landscape, forks enable the creation of new networks by cloning the existing code or splitting an existing one into distinct development courses (Antonopoulos, 2017). As was the case with "Bitcoin Cash" and "Ethereum Classic", protocol upgrades can cause the network to split due to disagreements or deliberate secession, like what happened with "Bitcoin Gold".

Usually distinctions are made between "hard forks" and "soft forks":

- Hard fork: A protocol change that is not backward compatible, rendering older versions invalid. All validator nodes using the old protocol will treat the blocks produced following the rules of the updated version as invalid and will not include them in the ledger. This creates a permanent divergence of the chain into separate branches following different rules and containing different data. Nodes that want to adopt the new protocol will therefore have to update their software. Hard forks are implemented to improve the protocol by adding new functionality, resolving disagreements, and correcting security fallacies.

- Soft fork: A protocol change that is backward compatible with the older version. It is essentially the opposite of a hard fork. Blocks produced by miners running the updated protocol are accepted by all nodes in the network. whereas nodes that have not upgraded their systems to the new protocol version are still able to process transactions but might see them rejected if they break the new protocol rules. As more nodes upgrade their version, the chain with predominantly new blocks, accepted by all miners, becomes the longest, causing more nodes to upgrade. Soft forks result from the implementation of tighter rules than the previous version, cosmetic changes, or new functionalities that do not alter the blockchain structure.

Finally, there is also the case of accidental forks, in which the network temporarily splits into two chains due to two distinct blocks validated by different nodes and chained to the same parent block. This happens due to the propagation mechanism of information in the P2P network and the latency times of internet connections. Assume that two very distant nodes in the network's topology mine two different blocks linked to a common parent block almost simultaneously. The mined blocks are broadcast to the network and received by the nodes in different orders. Since consensus is distributed, both blocks are initially seen as valid by the receivers. As soon as a block is received, a miner halts its current operations and starts mining a new block on top of the one just received. The network now holds two different versions of the blockchain, according to whichever block is received first. When a new block is mined, one chain becomes longer than the other. The new block is broadcast, and the corresponding chain will be universally accepted to maintain consensus. Indeed, the longest chain represents the one with the highest aggregated computational power, from the first block created (i.e., the genesis block) to the most recent one, which is considered to be the correct one. The block mined on the other chain is abandoned and thus not accepted as valid, becoming an orphan block. Because of these potential forks, transactions in the blockchain are considered valid and definitive only after a few more blocks are added to the chain..

1.1.5. Properties

After having described how a typical blockchain works, the peculiar characteristics or attributes of blockchains, stemming from the innovative combination of underlying technologies, can be derived.

- Immutability: the distributed nature of the ledger, the consensus mechanism, the timestamped transactions, and the "linearity" of the data structure ensure information that has been validated and included in the blocks is impossible to be altered. If an actor tries to modify a transaction, the hash of the block in which the transaction is stored will change. Given that blocks are chained together by referencing the hash of the previous block, the other nodes in the network would immediately realize that the copy of the ledger held by the malicious node has an error and immediately reject it.
- Non-repudiation: the architecture of the blockchain, along with the use of private and public keys used to sign a transaction, also implies the non-repudiation of transactions (Xu et al., 2017). When an individual signs a transaction with his private key there is no way for him to deny having submitted that transaction to the network since the ledger is immutable.
- Decentralization and reliability: directly derived from the peer-to-peer network. The system does not need any authority to work properly; users

no longer need to trust each other in a transaction or to rely on a third party to ensure correctness. Control is not centralized but fragmented. Given that all nodes share a copy of the ledger and are able to process transactions there is no central point of failure that can be attacked or corrupted. This guarantees a high level of reliability.

- Transparency and traceability: all transactions are visible and consultable not only from the nodes composing the network but also from external observers. The ledger includes the full history of transactions, thus allowing to identify all the movements any asset has made starting from its generation or inclusion in the blockchain. These two features are fundamental to ensure user confidence in the system.
- Anonymity: the technology does not require the disclosure of identities to participate in the network or ensure trust among participants. Users are identified by randomly generated cryptographic keys.
- Scalability: the system can easily scale up in terms of welcoming new nodes thanks to the characteristics of the P2P network; as the number of nodes increases, "demand" and "supply" of resources increase at the same time since the nodes are both requestors and servers of resources. However, some blockchains suffer from scalability in terms of users and are not able to handle well a large increase in the number of transactions.
- Versatility: the technology can be beneficial to a wide variety of cases. All systems that require resource allocation or exchange may benefit from adopting the blockchain (Swan, 2015). In particular, the presence of the following conditions increases the usefulness of blockchain technology: the necessity of sharing information, mistrust among participants, heterogeneity of participants, the number of actors involved and the necessity of transparency.

1.1.6. Blockchain classification

The properties of blockchain discussed so far ensure a level of control and reliability over data that a classic database does not have. However, the level of transparency could be problematic in certain fields that require addressing the privacy of data recorded on blockchain. Having the content of transactions and addresses involved visible to outside observers is a problem in some domains. There is therefore an inevitable trade-off between the need to ensure the integrity of transactions and the willingness of the parties to keep private the sensitive information recorded in them. In a traditional centralized database system, these issues are typically addressed using access control mechanisms. Access control systems (e.g., access control lists, role-based access control) are used to define and enforce rules that limit the "read" and "write" operations that can be performed on data. To address this problem in the blockchain world, different types of blockchain have been defined and created, differentiated according to the data access control policies they allow.

The most common classification of blockchain was offered by Ethereum founder Vitalik Buterin in 2015. He identified three types of blockchain: public, private, and federated. The blockchain was first conceived by Satoshi Nakamoto as a fully public and uncontrolled network offering open access to anyone, secured by cryptoeconomics. Then, new blockchain protocols have been developed, among which are systems where access permission is more tightly controlled and rights extended to a lesser (federated) or greater extent (private).

Public blockchain

A public blockchain is an open blockchain, in which anyone in the world can read information contained, send transactions through the network, and see them included once validated. In addition, anyone can participate in the consensus process, determining what the current state is and which block blocks are added to the chain.

The network is held together by nodes in a trustless state of aligned economic incentives and cryptographic verification. The fundamental characteristic intrinsic to public blockchain is the disintermediation, potentially able to disrupt many businesses and increasing efficiency by cutting third party costs.

Private blockchain

In a private blockchain, the participation permissions are centrally administered by a private organization, restricting network access only to selected members. Participants can only join the network via an invitation that has been validated by either the network operator or a set of protocol rules (Seth, 2021). Only pre-approved parties can write to the blockchain, whilst read permissions can be extended to a wider audience if desired. The company running the blockchain could therefore reverse transactions or unilaterally change rules. As such, a private blockchain is often not considered a real blockchain but a distributed ledger that operates as a closed and secure database based on cryptographic concepts. The benefits of using blockchains within private organizations are to increase efficiency and reduce costs because of faster and more secure data verification between internal parties.

Consortium blockchain

Consortium (or federated) blockchains are a third form of blockchain networks that is governed by an organization-spanning group of members. The consensus process is managed by a pre-selected set of nodes; as could be a consortium of financial institutions (e.g. R3), each managing a node. Not all nodes need to sign each block for its validation but usually a large majority is sufficient. The right to read the information contained in the blockchain could be open or restricted to participants. Consortium blockchains provide a hybrid model between the trustless environment of public blockchains and the "single trusted entity" model of private blockchains (Buterin, 2015), thus they can be considered as partially decentralized. Banking sectors often utilize a network of consortia that protect the privacy of a user's data without concentrating authority in a single entity. R3 (for banking), EWF (for energy), B3i (for insurance), Rope, and Ripple are federated blockchains.

Permissionless vs permissioned

Subsequent literature streams (BitFury Group, & Jeff, G., 2015; Saini et al., 2019; Zheng et al., 2018) identify two dimensions of analysis: access to the network, or reading permission, and writing permissions. Resulting classifications therefore distinguish public and private blockchains according to who can access the network and read transactions, and permissioned versus permissionless blockchains according to who can write transactions and validate blocks (BitFury Group, & Jeff, G., 2015; Beck, Muller-Bloch, & King, 2018). Intersecting the two different dimensions, it is possible to derive a matrix defining four types of blockchains characterized by different permissions:

1. Public and permissionless blockchain: there are no restrictions on who may read, write and validate transactions by participating in the consensus mechanism. This layout is the one intended by Satoshi Nakamoto with the development of Bitcoin, based on core values of blockchain transparency and decentralization.
2. Public and permissioned blockchain: all users may read the ledger and submit a transaction, but their validation and inclusion into blocks is done by a limited number of trusted and verified nodes.
3. Private and permissioned blockchain: only authorized nodes can have visibility of the ledger; participation in the consensus mechanism and therefore the validation of new transactions is typically even more restricted to just a subset of users. This design resolves the privacy problems plaguing public blockchains

but introduces a central authority. Hyperledger, hosted by the Linux Foundation, is the most well-known example of this blockchain configuration.

4. Private Permissionless: this configuration does not exist in practice.

1.1.7. Smart Contracts

A contract is a set of legally binding promises that formalizes a relationship that the parties involved agree to. Smart contracts are computer codes designed to secure, enforce, and execute preprogrammed actions and the settlement of recorded agreements between people and organizations, and by doing so, they bring efficiency gains (Szabo, 1994; Szabo, 1997). The fact that contracts can be automatically implemented is not new; the novelty lies in the fact that these smart contracts are deployed on a blockchain (Greenspan, 2016; Ethereum.org, 2021). With the advent of smart blockchain can be used to do more than the ensuring the integrity of transactions in digital money transfers; they may contain logical constraints in the form of "if this, then that" that govern the specific circumstances under which value can be transferred (Morabito, 2017). When the code of a smart contract is deployed onto the blockchain, the operations and agreements between the nodes of the network can be traced, and their execution can be automatically performed by the blockchain itself without human intervention in a completely decentralized manner (Swan 2015).

The vending machine represents a classic real-life illustration of how smart contracts work. The machine acts according to the code that defines its functioning and can only perform the actions it has been programmed to do. The machine stores products and releases the selected item when two conditions are met: the user has picked the code of an available product and has inserted in the machine an amount of money equal to or greater than the price of the selected product. Once the conditions are met, the machine applies the contractual rules and renders the output associated to the input, without possibility to stop its execution. A similar logic applies to smart contracts deployed on the blockchain.

Smart contracts allow users to interact with blockchain in a completely new way that goes beyond the simple exchange of money as defined by Satoshi Nakamoto. Indeed, they find application in every field involving the execution of legal clauses among parties (e.g., transfer of ownership) or the execution of actions at the occurrence of some condition (e.g., self-driving).

As with all contractual agreements, smart contracts are incomplete by nature and cannot account for things that humans cannot foresee, but they remove the need for a third party to enforce them. Despite their code being immutable, smart contracts might be set to change behaviors according to determined conditions, after vote has been cast, the occurrence of a certain action, or after a certain time has elapsed.

1.1.8. Blockchain limits

Since its inception, blockchain technology has grown enormously but is still in the early stages of its life cycle and under continuous evolution. Blockchain has proven to bring significant advantages but is still affected by both technical and conceptual limits, slowing down its widespread adoption. One of the greatest challenges is how to address the trade-off among the components of the so-called blockchain trilemma of scalability, security, and decentralization. Several academic papers (Swan, 2015; Yli-Huumo et al., 2016; Staples, et al., 2017; Xu et al., 2017; Ismail and Materwala, 2019) and professional reports have highlighted the most important limitations that are here reported.

- Throughput and scalability. These two factors represent the most critical aspects of blockchain technology. Every transaction to be processed needs to be verified by the participants of the network, which is a time-consuming process. The number of transactions that can be processed by all the nodes in a given time is fixed and particularly limiting for blockchains adopting a proof-of-work consensus mechanism. Solving the hash puzzle is time-consuming by design to ensure security and decentralization. Bitcoin and Ethereum (prior to switching to proof-of-stake) have a maximum throughput of seven and fifteen transactions per second, respectively, whereas centralized payment systems such as credit card circuits can easily process tens of thousands of transactions per second. The expansion of the networks in terms of user base and thus the number of transactions to be validated raises a problem of scalability. Various solutions have been attempted to solve the problem, the most promising being "layer 2" solutions, which allow for the creation of secondary chains on which to register transactions independently of layer 1, to which results are sent afterwards. Other blockchain protocols attempted to overcome the limitations by employing various consensus mechanisms and architectural solutions. PoS blockchains have tackled the scaling issues of PoW, achieving better latency with less computation, bandwidth, and storage. Proof-of-stake systems are able to process thousands of transactions per second, similarly to centralized solutions. Still, improving performance and enhancing scalability often come at the expense of security and decentralization.

- Security. Distributed network architectures bring security vulnerabilities to blockchain technologies. While blockchains eliminate the single point of failure, they are susceptible to the so-called "51 percent attack", in which the majority of the network's computational power is controlled by a single or a few colluding entities. This would imply that such entity could manipulate the records in the blockchain (Yli-Huumo et al., 2016). The concentration of miners into large mining pools, which are governed by a few actors, lowers the number of parties needed to collude, hence increasing the possibility of a 51 percent attack. As already mentioned when presenting PoW, however, it is in the miners' best interest to establish a secure network so that the rewards they earn have value, given that their expenses are paid for in fiat money. PoS suffers from the same issues and may be even more vulnerable. While a 51 percent attack in PoW necessitates industrial power and the acquisition of a massive number of mining rigs, a similar attack in PoS necessitates the acquisition of financial assets. Large traditional institutions would be able to carry out such an attack on smaller blockchains with capitalization of a few billion USD or less. Also connected to security is the issue connected to the loss or theft of the private key. If a user loses its key, he immediately loses the accesses to his account and control of the related assets without any possibility to restore it. Similarly to centralized systems, one individual could also get frauded by a malicious actor and led to disclose its private key and the consequent theft of assets. Management of the keys is therefore a critical issue.

- Privacy. One of the benefits of public blockchains is that anyone can enter the network without the need for authentication; users are identified by the address connected to their own pair of keys. The difficulty of linking addresses to identities should ensure privacy (Nakamoto, 2008). Public addresses are not related to the real-world identity of their owners, but if the relationship were to be disclosed, it would be possible to know the entire history of transactions involving the actor. Indeed, as previously explained, all information regarding transactions stored on the blockchain is publicly available. There are also studies that, by analysing traffic patterns in Bitcoin, are able to map certain bitcoin addresses to IP ones. This constitutes a limiting factor, especially when concerning sensitive data and the corporate world. Reasons why some businesses might prefer using private blockchains.

Other limitations, both technical and non-technical, include: (I) the size of the ledger itself, which could limit the number of nodes able to download the entire blockchain; (II) the costs, knowledge, and implementation difficulties faced by enterprises in building and deploying a private blockchain; (III) standardization and interoperability stemming from the diffusion of several blockchains and also diverse applications, often not able to communicate among themselves and using different logic; (IV) the energy consumption required by Proof of Work consensus already described; (V) the lack of flexibility due to the append-only nature of blockchain acting as a barrier to cases requiring changes to transactions.

1.1.9. Tokens

Blockchain enables a new kind of web on which it is possible to exchange and manage value and assets. This is done through the introduction of the state of the system and the use of tokens: digital assets that can be exchanged on the blockchain in a secure and safe way without needing intermediaries. They can represent various forms of economic value or access rights. As such, tokens are used as currencies, financial securities, representations of other digital or physical goods, digital identities, a right to perform an action, the ownership of an asset, or access to a service. Tokens are defined by smart contracts containing the rights assigned to the holders, their fundamental characteristics, and a map of the accounts holding the token and their relative balances. The token contract also manages the validity and security of the tokens. Cryptographic tokens are represented as an entry in the ledger and mapped to a blockchain address. As such, they are accessible with dedicated wallet software (Voshmgir, 2020). The possibility to deploy tokens on the blockchain with few lines of code at a low cost and relatively low effort makes it economically feasible to digitally represent different types of assets in a way that might have not been previously feasible. Tokenization can improve the liquidity and transparency of existing assets market such as art and real estate, facilitating fractional ownership (Voshmgir, 2020). Tokens also have the potential to reduce transaction costs related to management of assets, reduce market frictions, provide more-transparency along marketplaces and financial systems, and finally enable new value-creation models.

Several types of different tokens have been developed and adopted, but there is not a clear taxonomy in place. While some tokens represent new asset classes like native protocol tokens, others correspond to off-chain assets of the existing economy. Regulation in the space is complex and often vague, with some jurisdictions starring to offer governmental sandboxes. Switzerland is one of the few countries providing clear regulation in the blockchain matter. As a result, the classification of tokens according to FINMA, the Swiss financial markets supervisory authority, is hereby reported. The classification approach is based on the economic function and finality of the tokens and distinguishes among three types of tokens:

- Payment tokens are cryptographic tokens intended to be used, now or in the future, as a means of payment for acquiring goods or services or as a means of money or value transfer (FINMA). They include native protocol tokens such as Bitcoin and stablecoins, i.e., tokens pegged to FIAT currency, such as USDT.
- Utility tokens are defined as tokens intended to provide holders access to an application or service by means of a blockchain-based infrastructure. They grant the holder administration or access rights.
- Asset or security tokens give the holder ownership rights and represent assets such as a debt or equity claim on the issuer. In terms of their economic function, therefore, these tokens are analogous to equities, bonds, or derivatives.

Hybrid tokens are also possible: tokens that simultaneously count for utility and payment are often used by decentralized applications, and Ethereum's own token, ETH, itself could be considered a hybrid.

Finally, Non-fungible tokens (NFTs) should be highlighted. This category results from a different classification based on the definition of "fungibility," which is the property of being able to replace or be replaced by another identical item; being mutually interchangeable. While in terms of finality, NFTs could likely fit in the asset token typology, the inclusion is not specifically stated by FINMA, and since they possess peculiar characteristics, it is better to provide a distinction. In contrast to fungible tokens, which are equal and have the same value, non-fungible tokens are digital representations of unique specific assets on the blockchain. As such, NFTs cannot be replaced with other tokens of the same type since they each possess unique attributes. NFTs include metadata that can guarantee proof of authenticity and ownership. Their implementation opens up a realm of possibilities in identification and certification systems and the representation of unique goods. Indeed, NFTs find application in the management of identities, certificates, and reputation; crypto collectibles and crypto game items; the representation of physical objects like unique artwork or real estate; and access rights replacing physical, digital keys and passwords.

1.2. Blockchain evolution, applications and governance

1.2.1. Blockchain Evolution

Angelis and da Silva (2019) have proposed framework describing three stages of blockchain maturity.

Blockchain 1.0 is focused on transactions, mainly on the deployment of cryptocurrencies in applications related to cash, such as currency transfer, remittance, and digital payment systems.

Blockchain 2.0 encompasses privacy, smart contracts, and the emergence of non-native asset blockchain tokens and capabilities.

Blockchain 3.0 expands the blockchain focus further to incorporate decentralized applications. For instance, an established distributed ledger may act as a platform for application developers to make their transactions possible.

The benefits provided by the first stage of blockchain include the removal of the need for intermediaries in financial transactions, and the consequent reduction of relative costs and facilitation of peer-to-peer exchange, and the introduction of a shared common source of truth.

The second generation, with the introduction of smart contracts, enabled the creation of platforms capable of running lines of code. This allowed to bring on the blockchain certain existing processes, improving the efficiency of operations, speed of settlements and facilitating compliance with regulations. Some examples of such applications include Trade Lens, IBM Food Trust and B3i.

The paradigm changes with blockchain 3.0 and general-purpose platforms which are not linked to a specific use case but rather offer blockchain infrastructure enabling the development of different applications through application programming interfaces (APIs). This allows other organizations, startups and developers to develop their own customized business applications and services on the blockchain of the provider.

The concept of decentralized applications and computing calls for the sharing or outsourcing of activities that would have alternatively been handled by the central organization. This modifies the traditional type of transaction structure and typically requires governance modifications, supporting a network approach that incorporates new parties. The change of organizational boundaries may have several positive effects such as increased learning and access to new capabilities or technologies, enhanced service innovativeness or speed to market of new products (Angelis & da Silva, 2019).

The three blockchain evolutions and innovations within it are not independent but linked to each other. Blockchain 3.0 keeps the same founding technical elements of previous generation, such smart contracts, tokens, cryptocurrencies, time-stamping, but including new functionalities. This does not either mean blockchain 1.0 and the internet of value are over, the different paradigms are coexisting as they have different purposes. The development of different solutions and decentralization of services can lead to the web 3.0.

1.2.2. Application fields

The potential of blockchain technology to be decentralized, immutable, secure, efficient, programmable, fast, and transparent is useful to deal with numerous operational and business issues and facilitate cooperation (Greenspan, 2016). These features led to the development of blockchain-based applications across multiple domains that previously relied on central entities or trusted third parties. Applications encompass everything from finance to supply chain management, e-voting, identity management, and IoT.

As scholars like Iansiti and Lakhani (2017) pointed out, blockchain is not to be considered a disruptive technology, but rather a foundational one. Foundational technologies are defined as those that can enable progress and applications in a variety of problem domains. As such, the two scholars drew a connection with the internet and the TCP/IP protocol. It took thirty years from the introduction of ARPANET before the protocol gained critical mass with the advent of the World Wide Web in the mid-1990s, transforming the way businesses created and captured value. "True blockchain-led transformation of business and government, we believe, is still many years away. […] (blockchain cannot) attack a traditional business model with a lower-cost solution and overtake incumbent firms quickly." (Iansiti and Lakhani, 2017).

Casino et al. (2019) propose an exhaustive classification of applications spanning multiple industries such as supply chain, business, healthcare, IoT, privacy, and data management that are enabled by the three types of blockchain (i.e. public, private and federated). The results are graphically represented in the figure below.

Figure 1.3: classification of blockchain applications by sector (Casino et al., 2019).

Of interest to this research are the applications in finance and governance. Blockchain technology finds applications in most financial fields where it is expected to benefit both consumers, the banking system, and society by transforming capital markets and improving operational efficiency and cost savings in payments, securities trading, lending, financial auditing, reporting, automated compliance and general banking services (Casino et al., 2019).

In the governance field, according to the authors, blockchain-enabled applications may alter the way governments function by decentralizing transactions and record keeping, making government services more efficient and preventing corruption thanks to transparency, automation, and security. Moreover blockchain technology supports digital voting processes that can expedite the processes, simplify and lower the cost of elections, and foster the growth of more robust democracies (Casino et al., 2019).

1.2.3. Business models implications

Business models are inherently exposed to changes that could stem from both endogenous and exogenous sources, with technology being one of the most important (Teece, 2010). Throughout history, the introduction of new technologies such as the internet, automation, and more recently, cloud computing and AI, has led to major changes in the way industries operate (Teece, 2010). All business sectors have been impacted, as have all activities along the supply chain, from procurement, production processes, and value delivery to collaboration and service provision, consequently affecting the costs associated with business models.

It is becoming evident that blockchain has the capacity to produce benefits beyond digital currencies and affect most economic sectors (Chen & Bellavitis, 2020). Blockchain technology provides numerous opportunities for the development of entirely new businesses and poses direct threats of disruption to traditional incumbents (Iansiti & Lakhani, 2017; Morkunas, Paschen, & Boon, 2019). Furthermore, it can provide solutions to industries with structural issues (Nowiński & Kozma, 2017). There are many ways in which businesses can undergo this change, ranging from a direct increase in operational efficiency and rebalancing information asymmetries to the development of open networked enterprises and novel organizational forms that challenge or supplant conventional centralized models (Aste et al., 2017; Nowiński & Kozma, 2017; Tapscott & Tapscott, 2016).

Nowinski & Kozma (2017) examine the influence of blockchain technology on existing business models and industries referring to the dimensions identified in the framework by Wirtz et al. (2016). The findings are illustrated in the picture below.

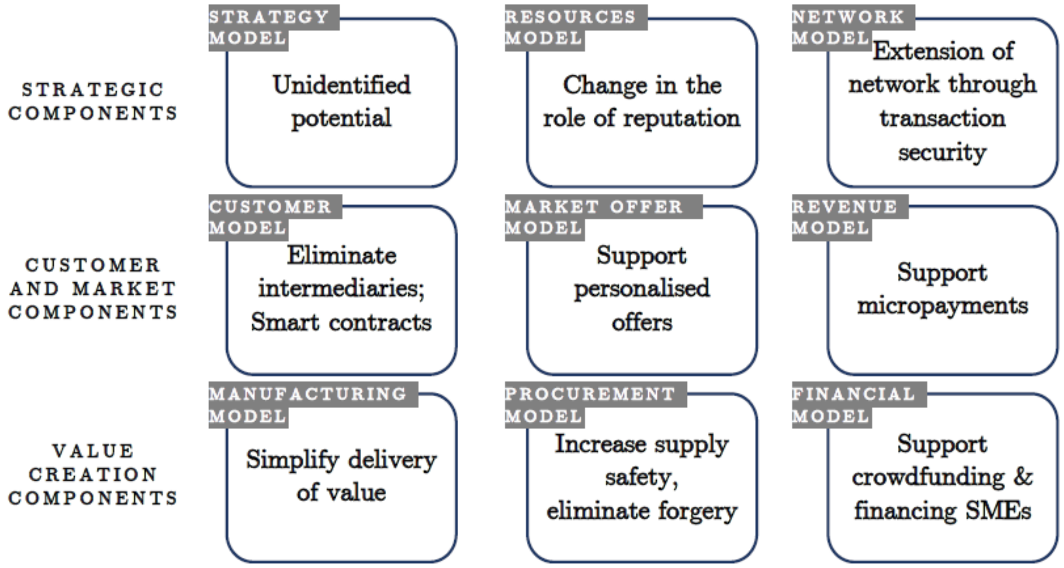

Figure 1.4: findings of Nowinski & Kozma's research on the blockchain impacts on business models

The implications that blockchain technology can have on company models extend beyond those depicted in the figure. However, this gives a valuable summary that demonstrates the blockchain's immense potential (Nowiński & Kozma, 2017).

The authors conclude by proposing three main ways in which blockchain can business models: (i) by authenticating any tangible or intangible goods or services subject to a business transaction; (ii) by facilitating disintermediation and removing associated inefficiencies, providing wide and direct access to service providers to a large number of potential users; (iii) by improving operational efficiency, shortening execution times and lowering costs.

Another more recent study conducted by Morkunas, Paschen and Boon (2019) delves further into blockchain implications on buiness models by examining the effects on the components of the Business Model Canvas developed by Osterwalder & Pigneur (2010). The authors explored the effects on all the macro-components of the framework, namely value network, value proposition and customer interface, and value monetization, or economic model, assessing the different subcomponents of each block. The figure below provides the bluprint constructed by Morkunas et al (2019) summarizing the impact of blockchain technology on a firm's business model.

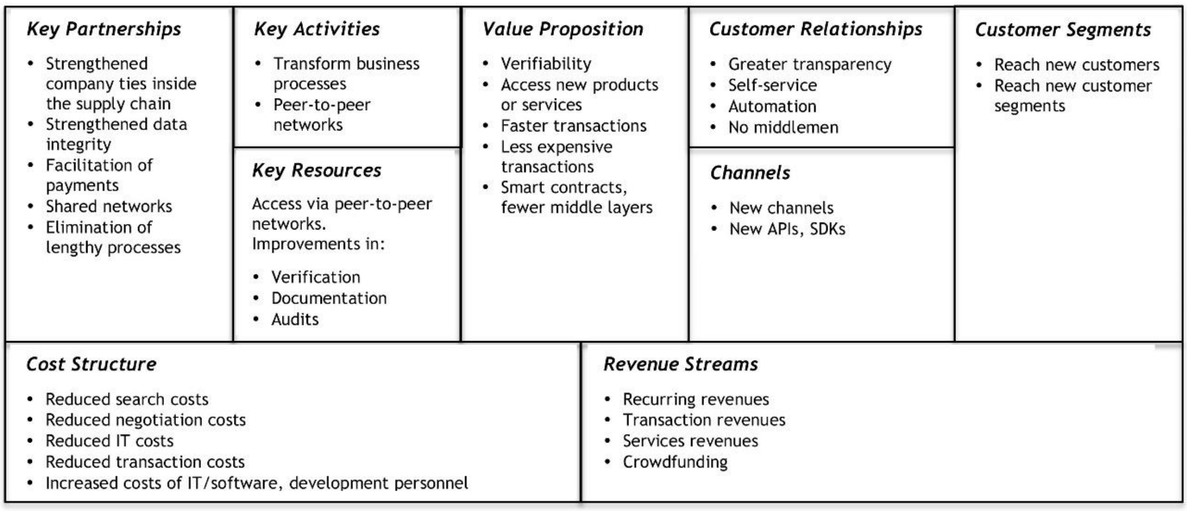

Figure 1.5: findings of Morkunas, Paschen and Boon (2019) on the impact of blockchain on a firms' business model using the Business Model Canvas.

The findings can be summarized as follows: Blockchain is a technology that promotes accessibility and, as such, facilitates access to new markets or customer segments that were previously unreachable or not economically convenient to reach. In the same way, it can provide access to new products or services that were previously not available or difficult to obtain by removing middle layers. Moreover, organizations and users alike can carry out transactions in a faster or less expensive way. Concerning value delivery, blockchain increases transparency and reduces the number of interactions needed, leaning towards a self-service or automated provision of the offer. The impact of blockchain on key activities and resources is related to the improvement of the fluidity of existing processes and assets, enabling companies to shift from traditional ownership. In the case of public blockchains, for example, companies may refrain from building an appropriate IT infrastructure because it is provided by the network itself. Moreover, many activities can be automated by leveraging smart contracts, enabling a more focused use of human resources. Partnerships along the supply chain are facilitated by disintermediation, which removes unnecessary parties, and by transparency of information and facilitation of payments. In the early stages of the development of the technology, costs are necessary to reach operational efficiency, but once reached, blockchain will create huge cost savings, especially regarding transaction costs and those stemming from principal-agent theory. Finally, blockchain enables the creation of new revenue streams and sources of funding in the form of initial coin offerings (ICOs).

1.2.4. Decentralization versus distribution

In the blockchain space, decentralization is one of the most used and misused words and is often seen and debated as the raison d'être of the technology. However, the use of the terms decentralization and distribution in the blockchain domain lacks clarity and homogeneity: often the two are used interchangeably to express the same concept, whereas some authors distinguish the two notions. Still, even definitions are often mixed up and depend on the authors' field of work, as they often derive from computer science or organization theory. Thus, it is important to define what we mean by decentralization and distribution.

Merriam-Webster defines decentralization as "the dispersion or distribution of functions and powers", whereas distribution is defined as "the act or process of distributing, dividing among several or many". From the two definitions, it follows that decentralization is simply distribution applied to a specific domain.

In 1964, engineer Paul Baran, in a study on communication networks, distinguished centralized, decentralized, and distributed networks based on network topology and the ability of nodes to operate together as a coherent entity after a physical attack. In this vision, a centralized network relies on a single central point of communication to which all nodes are linked in a star configuration, whereas a distributed network is spread across a grid-like structure with nodes interlinked one another. Decentralized networks are seen as an intermediate form, composed of a few interconnected stars, in which reliance on a single central point is not necessarily required.

The discussions that followed in the information systems domain saw the switch between the two terms. Khare and Taylor (2004) argue that while centralization requires simultaneous agreement between a leader and all of its followers, distribution requires members to apply a shared decision function, while decentralization consists of individuals applying private and independent assessments to make their own decisions.

Still in the information system domain, architectures can be defined as distributed if they verify at least one of the two following conditions: (i) The cooperating applications reside on several processing nodes (distributed processing); (ii) The unitary information assets are hosted on several processing nodes (distributed database). In general terms, therefore, a distributed system consists of: (i) one or more processing nodes, which, unlike the terminals of the centralized system, can also run applications locally; and (ii) one or more logically independent applications that collaborate for the pursuit of common objectives through a communication infrastructure.

In the field of organization theory, Vergne (2020) argues that decentralized organizations and distributed organizations are two distinct phenomena and distinguishes decentralization, as the dispersion of organizational communications, from distribution, as the dispersion of organizational decision-making. Organizations can be distributed without being decentralized, and vice versa. The author demonstrates that leveraging blockchain as the core technology to structure and process data enables digital platforms that are both distributed and decentralized.

In the book titled "*Decentralized Applications,*" Raval (2016) defines distribution adopting an information systems approach as the spread of computation across multiple nodes instead of a single one. Decentralization instead refers to the absence of one node instructing the other as to what to do. The two definitions do not exclude each other, meaning that a system can be both centralized and distributed. In this sense, the author reports Bitcoin as an example of such a system. Bitcoin is distributed because its timestamped public ledger resides on and is verified by multiple nodes. It's also decentralized because if one node fails, the network is still able to operate. According to the author, any application running on top of a blockchain or other peer-to-peer network can be both distributed and decentralized.

In a similar fashion, Yano et al (2020) describe decentralization as a measure of how independently nodes or computers agree on a set of transactions without central direction and control. Illustrating the merits of decentralized applications, the authors also introduce governance decentralization as the direct participation of users in the management of the application.

Finally, Vitalik Buterin (2017), co-founder of Ethereum, discerns three separate axes of decentralization: **Architectural (de)centralization** addresses the number of nodes constituting a system and the number of nodes needed to fail to break down communication; **Political (de)centralization** addresses control of the nodes constituting the system; and **Logical (de)centralization** addresses the independency of the interface and data structures, whether portions of a system can continue to fully operate as independent units after the system is cut in half. According to Buterin, Blockchains are politically decentralized (no one controls them) and architecturally decentralized (no infrastructural central point of failure) but they are logically centralized (there is one commonly agreed state and the system *behaves* like a single computer).

In this paper, the term "distribution" is adopted according to both Baran's definition and the term "architectural decentralization" used by Buterin. The term "decentralization" will be used to indicate political decentralization, referring to the dispersion of both control and power away from a central authority. With this classification, the distribution or architectural decentralization of dapps is determined by the underlying blockchain protocol. What depends on the application itself is the dispersion of decision-making power among parties through the governance system adopted. Indeed, the sources of decentralization are not naturally embedded in blockchain technology but are dependent on the use of the technology itself and systems created by people on top of it. Dapps have been labelled as "decentralized" mainly due to their development and functioning on top of distributed peer-to-peer networks. However, there is no clear understanding or study of the governance systems they implement or how and to what extent the decision-making process is decentralized.

1.2.5. Decentralized applications

The decentralized applications space is still emerging and far from being mature. As a result, a universally accepted definition of decentralized applications is not yet present, as developers still experiment with different models and have different opinions on what exactly a dapp is. Decentralized applications are often described as "trustless" applications running on peer-to-peer networks with the distinguishing characteristic that there is no single server or entity controlling them like in a client–server model (Angelis and Ribeiro da Silva, 2018; Tapscott and Tapscott, 2016; Yano et al., 2020; Voshmgir, 2020). Contrary to standard software applications, there is no single organization having full authority over the application's operations and development. The origin of decentralized applications dates to the advent of P2P networks: "Tor", "BitTorrent" and "BitMessage" are examples of decentralized applications running on peer-to-peer networks (Buterin, 2014; Voshmgir, 2020). With the introduction of blockchain technology, the potential of these kinds of applications has increased considerably. This paper considers decentralized applications developed on top of blockchains and their distributed networks to achieve guarantees of non-censurability.

A prototypical software application is made of a front end and a back end. The front end provides the interface through which a user interacts with the application itself, channeling inputs to the back end, which manages data and performs the operations and processes required. Similar to web applications, the front end of dapps is usually rendered through HTML, CSS, and JavaScript, but communicates with a blockchain network instead of a server (Voshmgir, 2020). Some dapps are also starting to use decentralized storage network solutions, like “IPFS”, “Filecoin”, “Swarm” or “Sia”, to host their front end and content instead of servers.

What differs between decentralized and traditional applications is the back end. In traditional applications, the back-end is stored on a server managed by the controlling organization, which directly retains and manages the flows of information. As a result, the activities performed are often unknown or, at least, not transparent. In contrast, the back end of decentralized applications consists of one or multiple universally accessible smart contracts deployed on the blockchain. Such contracts implement the logic and instructions on which the applications run, recording transactions and state transitions on the underlying blockchain network. Smart contracts are deterministic, meaning they perform the same function irrespective of the execution environment. This implies that users can see the logic of the operations they want to perform and determine the outcome even prior to the execution. Given the current limitations of blockchain systems, some dapps carry out part of their computation on a traditional back end, but its presence should not be essential for the proper functioning of the application. As a result, Wu et al. (2019) distinguish three different architectures adopted by Ethereum Dapps: direct, indirect, and mixed. In a direct architecture, the client directly interacts with the smart contracts deployed on the blockchain (in this case, Ethereum). In an indirect architecture, the client interacts with smart contracts through a centralized server hosting the back end. Finally, a mixed architecture combines the direct and indirect architectures, where the client interacts with smart contracts both directly and through a back-end server (Wu et al., 2019).

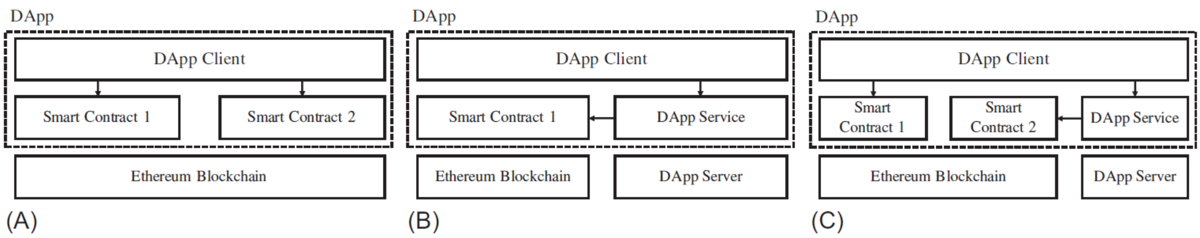

Figure 1.6: Possible architectures of decentralized applications by Wu et al.

Other peculiarities of decentralized applications are access and data management. To interact with a Dapp users need a wallet, a peculiar application managing the users' pair of cryptographic keys and blockchain address. The wallet communicates with the blockchain and is required to invoke, execute, and receive transactions from other users or smart contracts. Wallets provide users' pseudonymity, enabling interaction with the blockchain network on which the dapp runs without explicating personal data.

Despite the fact that the code of smart contracts is immutable by default, it might be set to change behavior according to predetermined conditions, in response to a vote, after a certain action occurs, or after a certain period of time has passed. Moreover, when building a decentralized application, a certain degree of upgradeability might be desired to fix bugs, improve security, or add other features. OpenZeppelin, a company that provides widely used tools, libraries, audited contracts, and other products to build and manage Ethereum projects, offers a mechanism to upgrade smart contracts. The process makes use of proxy contracts, i.e., abstract contracts implementing the core delegation functionality, which act as intermediaries, directing users' calls to implementation contracts that contain the code and logic. Proxy contracts hold the state and are upgradeable, enabling the proxy administrator to point and redirect calls to a new implementation contract containing the desired changes. The proxy contract does not change its address, therefore users interacting with it do not need to make adjustments on their end.

Scholars, blockchain enthusiasts and developers alike have proposed different requirements to classify a blockchain application as decentralized. Johnston et al., among the firsts to make a proposal of such kind, suggest the following three criteria:

1. The application must be completely open source, it must operate autonomously, with no entity controlling the majority of its tokens, and its data and records of operation must be cryptographically stored in a public, decentralized blockchain.
2. The application must generate tokens according to a standard algorithm or set of criteria and possibly distribute some or all of its tokens at the beginning of its operation. These tokens must be necessary for the use of the application and any contribution from users should be rewarded by payment in the application's tokens.
3. The application may adapt its protocol in response to proposed improvements and market feedback, but all changes must be decided by majority consensus of its users.

While many in the blockchain community believe these features should be possessed by a decentralized application to be considered such, the development of the industry shows that dapps may possess and show only some of the features above.

With a different perspective, developer and entrepreneur Siraj Raval suggests four features that any profitable dapp should have. The author places the focus on profitable applications as he expects them to have more chances of being successful, long lasting and attractive. The four features presented by Raval (2016) are:

1. Open Source. A closed source application would likely encounter users' aversion as it would require them to trust the developers on the application actually being decentralized and on developers not having access to users' data through a central source. Consequently, users tend to favour open-source applications especially when monetary assets are involved. Open sourcing a decentralized application makes it trustable and transparent attracting developers, contributors and users and thus positively effecting the eventual token's value.

2. Internal currency. To monetize a dapp traditional revenue models are not ideal. Open sourcing the code can also prevent certain forms of monetization. Indeed, there is no formal mean to prevent a hard fork cloning the application while removing or lowering fees and commissions (although such revenue streams are widely adopted). A solution consists in allocating scarce resources in the network through a native scarce token. Such token would be needed to use the network and to incentivize and pay the actors supplying other scarce resources such as computing power, capital, storage and or other assets. The value that people place in the dapp and in its utility ultimately determines the value of the tokens. Developers can retain a stake of the token supply as a form of remuneration for their work. Besides native tokens other sources of revenues could derive from the sale of digital assets.

3. Decentralized consensus. Through consensus mechanisms blockchain technology enables agreement on the state of the system in a decentralized way. The parties involved independently agree on transactions, data and

application-level constructs without the need to trust the other nodes. Applications requiring different parties to agree on something should use a blockchain.

4. No central point of failure. Decentralized applications cannot be shut down because they run on a peer-to-peer network, therefore they are resistant to the failure of one or more nodes.

The characteristics identified by Raval are representative of most, if not all, applications deployed on blockchain networks, with some features being direct consequences of running on the blockchain itself. The list proposes suggestions rather than establishing requirements; as a result, it is better suited as a guideline for developers instead of being used as a classification system to discern decentralized applications from those simply utilizing blockchain technology.

Moreover, according to both Johnston and Raval, public blockchain protocols meet the requirements, features, or criteria to be classified as decentralized applications. What this study addresses, however, are platforms built at the application level rather than at the infrastructure level, as distinguished by Chen (2020), who categorizes blockchain-based platforms into infrastructure and application-layer platforms:

- *Blockchain-Infrastructure Layer*: The infrastructure layer of a blockchain refers to the blockchain itself. A blockchain can be a platform, and we refer to such a platform as the infrastructure layer. At the infrastructure layer, a project needs to secure its distributed ledger, establish distributed consensus, and offer developer tools.
- *Blockchain-Application Layer:* A blockchain application is a project that is built on top of an existing blockchain to serve end-users with specific needs. An application can also be a platform, and we refer to such a platform as the platform of the application layer. At the application layer, a project often

focuses on creating business logic and user interfaces that can serve end-users with specific needs.

DApps inherit the typical characteristics of blockchain: they are non-censurable, distributed, globally accessible, permissionless, interoperable, i.e., they can be combined to create other DApps, their code is inherently open source, and the upgrade rules are clear and defined. One important implication and novelty of DApps is that governance can be decentralized so that the users of the application participate directly in their management. This is achieved through the issuance of governance tokens, which entitle token holders to participate in protocol governance via voting and possibly propose protocol updates. (Curve, n.d.; 1inch Network, n.d.; MakerDAO, n.d.; Yearn, n.d.).

Based on the governance role played by token holders, a classification of decentralization level of governance system has been defined (World Economic Forum, 2021):

- Completely centralized: only the development team that built the protocol can change any aspects of the system.
- Partially decentralized: only some aspects can be altered by governance token-holders; the threshold for proposing governance change is low.
- Completely decentralized: all aspects can be altered, and any token holder can propose changes.

There are now an increasing number of applications being developed in the DApp space. Finance, marketplaces, gaming, social networks, and gambling are the most widespread and have the largest user base. Other categories, which represent new DApp designs, have fewer users and transactions, and include identity, media, storage, security, and more.

1.2.6. Governance definition

The notion of governance is very broad and contains different facets often depending on the field in which the concept is used, with the most prominent being the public sector.

A general definition provided by the UNESCO International Bureau of Education states that "Governance has been defined to refer to structures and processes that are designed to ensure accountability, transparency, responsiveness, rule of law, stability, equity and inclusiveness, empowerment, and broad-based participation. Governance also represents the norms, values, and rules of the game through which public affairs are managed in a manner that is transparent, participatory, inclusive, and responsive".

Similarly, there is not one conclusive definition of corporate governance. Governance Institute, for example, defines it in these terms:

Governance encompasses the system by which an organization is controlled and operates, and the mechanisms by which it, and its people, are held to account. Ethics, risk management, compliance and administration are all elements of governance.

An alternative definition provided by Organization for Economic Co-operation and Development (OECD) asserts:

Corporate governance involves a set of relationships between a company's management, its board, its shareholders and other stakeholders. Corporate governance also provides the structure through which the objectives of the company are set, and the means of attaining those objectives and monitoring performance are determined.

The definitions agree on the fact that at its core, governance is more than the administration of human, financial, and physical resources to achieve concrete outcomes; it is a mechanism, a social construct concerning a variety of different issues inherent to collaborating as a community, shared by the parties involved.

Blockchain has emerged as an innovation capable of redesigning interactions and coordination in business, politics, and society, appearing to be a solution to problems requiring coordination across heterogeneous stakeholders in a way that challenges traditional hierarchical structures. As a result, understanding how blockchain affects governance systems and how it is governed is critical.

1.2.7. Blockchain governance

If blockchain technology fulfils even partially its potential to transform all human systems requiring record keeping, then it might eventually underpin many essential infrastructures in our society. Accordingly, the governance processes for creating, maintaining, and modifying the technology warrant close examination, as these processes will affect the resilience of the technology and any infrastructures that come to rely on it. (Walch, 2019)

Open Source Software governance

The governance of blockchain systems may differ from traditional governance structures, sharing instead similarities with Open-Source Software (OSS) projects. Many blockchain projects, including the two main protocols Bitcoin and Ethereum, were released as OSS. Both blockchain and OSS systems involve the contribution of a range of external parties in the development, which is often volunteer-based, they share political motivations, have openly visible and modifiable code and share similar challenges in achieving direction and coordination. Due to these similarities OSS literature provides a starting point to study blockchain governance (Pelt, Jansen, Baars, & Overbeek, 2021).

Markus (2007) defines OSS governance as "the means of achieving the direction, control and coordination of wholly or partially autonomous individuals and organizations on behalf of an OSS development project to which they jointly contribute."

Different frameworks have been crafted in literature to analyze Open-Source Software governance. Pelt et al. (2021), who propose a framework to study blockchain governance, found of interest the matrix proposed by de Noni, Ganzaroli and Orsi (2011), that addresses different configurations of governance based on seven variables, namely: the presence of a *foundation, the type of license, membership, changes to the source code, sub-projects, release authority, leadership and decision-making,* and *access to the code and bug reporting.* Another list of OSS governance dimensions on which the authors focus is defined by Markus (2007) who identifies *ownership of assets, chartering the project, community management, software development processes, conflict resolution and rule changing* and *use of information and tools.*

Some of these identified governance dimensions are also applicable and useful in the analysis of governance of blockchain projects, as it will be illustrated in the following paragraphs.

However, blockchain projects also differ from traditional open-source software ones due to the presence of ownership, whether of tokens or computational power, which can be used to exert power or signal intent.

Governance layers

As de Filippi and Mcmullen (2018) assert, a blockchain system does not exist in a vacuum; any blockchain system is composed of multiple technology layers forming a stack. Therefore, a project built on the application layer, such as a Dapp, is not only directly subject to its own governance rules but also indirectly affected by the rules of all the different underlying technology layers, including the blockchain network and internet infrastructure, that both enable and constrain the application. Given that blockchain networks run on top of Internet, they fundamentally depend on the suite of Transmission Control Protocol and Internet Protocol, which lay at the bottom of the stack, to route, transport and reassemble data between nodes in a proper manner. The principle of net neutrality should grant equal priority to all data transmissions, but ultimately, internet service providers (ISPs) control the transport layer and could discriminate against traffic originating from or destined for a blockchain network. Therefore, potential discrimination from ISPs or censorship by nation-states would impact the functioning of blockchain systems whether deliberately or as an accidental consequence of unrelated Internet management practices (Geere, 2012).

On top of the Internet's policies, blockchain networks implement their own governance systems and operational structures that define the p2p infrastructure and determine who can have access to it, who can read and write transactions, and how these are validated and recorded according to the consensus mechanism that enables nodes to reach agreements on the network’s state. As a result, even if a Dapp can be completely decentralized and autonomous, its operations can be altered by changing the state of the underlying blockchain network or by amending the code it relies on, such as a smart contract library or a proxy contract.

Ultimately, the bottom layers of the technology stack implement their own governance systems without considering what happens on the layers above, while directly affecting them. As a result, builders of blockchain applications must consider the governance structures and implications of Internet and blockchain governance when designing their projects.

Anyhow, of particular interest are not the mutually agreed upon rules and algorithms that specify and enable the proper functioning of public blockchain protocols but rather how the different stakeholders of an ecosystem agree on changes, developments, and upgrades to the operational structures and how they deal with unforeseen and unexpected events. In contrast to the Internet, the blockchain community has no official governing groups such as ICANN, the Internet Engineering Task Force, or the World Wide Web Consortium to identify development needs and steer their resolution, which creates uncertainty (Tapscott & Tapscott, 2016). Those who wish to preserve the blockchain decentralized, accessible, and secure often find it difficult to agree on a course of action to face the countless issues arising. Blockchain networks could break into warring groups if governance is not properly addressed.

Private and permissioned blockchains are governed by the companies that develop the infrastructure in ways that may resemble traditional systems, as such they are not the subject of this study. Instead, this research focuses on governance in public blockchains, where the lack of a central entity and administrator necessitates coordination and collective action from the network's diverse members to pursue collective goals. As these systems have become more widespread, questions about their governance have multiplied, and attention has been drawn to what the governance of these protocols looks like, how social order is maintained, who holds power, how this is exercised and limited while ensuring the legitimacy of actions taken, and what are the paths forward. Governance structures are strictly tied to the issue of trust, which is a central aspect of social coordination. Online socio-technical systems combine informal human relationships, formal regulations, and technical solutions in a variety of ways to solve the issue of trust (De Filippi & Loveluck, 2016 citing Kelty, 2005). Two important characteristics determine the governance structure of online peer-production communities: the fact that they are volunteer-driven and their desire to self-organise. As a result, they frequently need to employ alternate modes of coordination and incentive mechanisms compared to more conventional types of organisations such as enterprises and corporations.

Types of governance

Studies on blockchain governance have intensified following two major contrasting events: the DAO attack on Ethereum and the dispute on the block size of Bitcoin, both of which led to hard forks and splits of the respective ecosystems in 2016. Blockchain governance now refers to two related but distinct concepts: governance of the blockchain and governance by the blockchain (Olnes et al, 2017; de Filippi & Mcmullen, 2018).

Governance of the blockchain involves the processes and structures determining the development, execution, maintenance, and operation of the technology and how users can engage with it. It addresses the specific question of making consensus-relevant changes to the software running a blockchain, i.e. changes of internal rules applied by all relevant participants of the network (Fischer & Valiente, 2021).

On the other hand, governance by the blockchain, or by the infrastructure, refers to governance by hard-coded rules directly embedded in a blockchain system. Governance by the blockchain mainly concerns the process of rule enforcement, rather than the decision-making itself. It leverages on the ability of the blockchain technology to enable systems in which adherence to rules encoded in smart contracts is automatically enforced at the occurrence of pre-determined conditions. As a result, governance by the infrastructure is not limited to decision-making related to blockchain protocols but extends to other domains and existing governance processes, where the technology provides a supporting role to improve their efficiency. Consensus mechanisms used by blockchain networks to agree on a common state are forms of governance by the blockchain.

Both kinds of governance include endogenous rules coming from within the reference community and exogenous rules imposed from outside the reference community (de Filippi & Mcmullen, 2018). From the perspective of a decentralized application built on a public blockchain network like Ethereum the processes and decision-making procedures embodied in the smart contracts governing the dapp would qualify as endogenous, whereas the rules governing the Ethereum network would qualify as exogenous.

Blockchain researcher and author Shermin Voshmgir (2020) distinguishes two spheres of Web3 and decentralized applications' governance: "social governance" and "algorithmic administration of governance". The first refers to the human decision-making processes around the development and release of potential protocol upgrades. It is the process of finding collective position on future projects and evolutions, including how different stakeholders receive the necessary information to make educated decisions. The latter instead refers to machine-readable governance rules directly encoded in the blockchain itself and automatically enforced by the network, similarly to the previously reported definition of governance by the blockchain. Consensus protocols and smart contracts are examples of automated steering and computational constitution enabling algorithmic administration of business logic and governance.

Despite blockchain technology enables the automation of certain bureaucratic functions and formalization of institutional rules, the continuous adaptation of protocols, upgrade and improvement of the code is still prerogative of collective human action. Voshmgir (2020) states that in the current form blockchain protocols and smart contracts are insufficient tools to confront "unknown unknowns" arising in complex multi-stakeholder environments due to changing conditions over time, human errors, or information asymmetries among the variety of actors involved.

The social process of finding consensus about policy upgrades can be conducted either off-chain or on-chain. "Off-chain governance" describes a protocol upgrade process where decision-making first takes place on a social level and is then encoded into the protocol by developers (Reijers et al., 2018; Voshmgir, 2020). Discussions and improvement proposals take place on different channels among developers and communities and upgrades are eventually implemented following institutionalized procedures according to the specific protocol. "On-chain governance" instead refers to the decision-making processes and mechanisms that have been encoded in the infrastructure enabling the proposal, voting and implementation of upgrades directly on the blockchain (Reijers et al., 2018; Voshmgir, 2020; Wright, 2020). The decisions taken and successfully agreed upon are usually tested on the network for a certain amount of time and then deployed on the main network. Economic incentives in forms of tokens enable coordination in the autonomous setup.

Various authors (Filippi and Loveluck, 2016; de Filippi and Mcmullen, 2018; Voshmgir, 2020) agree on the fact that blockchain networks involve political and social dimensions which cannot be dealt with the sole reliance of technological tools and the use of algorithmic governance because, while being predictable and fair in execution, it lacks the flexibility needed to face unforeseen circumstances and does not resolve the human factor and broad involvement. A combination of on-chain and off-chain governance, each with its own advantages and drawbacks which make them suited for specific situations, would likely be the best approach to regulate and resolve the decision-making process in blockchain systems.

Governance of blockchain networks

Other studies address how public blockchain networks are governed and whether they are actually decentralized. De Filippi and Loveluck (2016) examine the political economy of Bitcoin, shedding light on its highly technocratic power structure. The authors state that, on the one hand, as an attempt at self-governance and self-sufficiency, the Bitcoin network exhibits a market-driven approach to social trust and coordination that is embedded directly in its technical protocol. On the other hand, despite being an open-source project, the development and maintenance of the Bitcoin code ultimately rely on a small group of highly skilled developers who play a crucial role in the platform's design. Specifically, they stress that while anyone may submit a network improvement proposal, the final decision is made alone by the core development team.

Likewise, Angela Walch (2019) argues that certain developers of public blockchains, intended as those making and encoding decisions about the policy choices to be embedded in the operating software, act as fiduciaries of those who rely on these systems, de facto exercising powers without corresponding accountability. Within this group of contributors, the team of core developers, even if not structured as a formal entity, generally acts as the leaders and decision-makers in relation to the code, thereby limiting the stated decentralization of public blockchains.

Hacker (2017) also makes similar observations by stating that imperfect governance structures of blockchain systems become evident in those situations that lead to hard forks. According to the author, what is most noteworthy about the constructive aspect of cryptocurrencies is the opacity and informality with which the protocol itself is updated, rather than the high level of specificity in applying the protocol rules to transactions. There are no clear standards in place that describe how the protocol itself may be amended, especially when opposing viewpoints must be reconciled. In sharp contrast to the protocol's operating rules precision, governance mechanisms are almost totally absent when it comes to modifying the “rules of the game” in times of disagreement.

While the development of blockchain protocols is often driven by user feedback, Hacker (2017) finds an increasingly presence of a central steering element. The standard implementation of the Bitcoin protocol, for example, is maintained by a small number of people, the "core devs". While anybody can propose modifications to the code, only the core developers have the authority to implement them (Gervais et al, 2014). Nonlinearity and unpredictability in protocol modifications are undoubtedly the outcome of a lack of a method to handle dissent within the development community and, more widely, among users and stakeholders. Core developers rely on informal methods that depend on approximate conceptions of consensus and that are subject to no defined legal or organizational framework (Bayern, 2014).

As a result, despite the promises of decentralization and the decentralized infrastructure, blockchain networks currently show a concentration of powers in the hands of few operators as it happens on the Internet. Indeed, a decentralized infrastructure does not necessarily entail a decentralized governance structure, on the contrary the lack of a central authority leaves the system to be more easily co-opted by external forces (de Filippi, 2020).

The majority of studies on blockchain governance focus on the administration and law of blockchain networks and their communities, while no proper studies have instead addressed governance of decentralized applications built on top of them. There is no clear picture or established theory on the practices and models used to govern Dapps and whether they are subject to similar pitfalls of blockchains’. Some tools, such as tokens, or organizational forms, like Decentralized Autonomous Organizations, that are strictly connected to the topic have been subject of analysis, but not in the specific context of Dapps governance systems.

Only the work of De Filippi and Mcmullen (2018) titled *Governance of blockchain systems: Governance of and by Distributed Infrastructure* makes a consideration on the governance of decentralized applications when discussing on-chain governance. The authors assert that the majority of existing on-chain governance methods resemble plutocracies rather than democracies. In the case of Dapps, this comes into play when the decision-makers, which are often individual token holders, engage in governance by burning tokens or by casting a vote, the weight of which is determined by the quantity of tokens that each individual owns at any particular moment. Thus, a small number of token holders with large holdings, defined as whales, will have disproportionate control over the system making it susceptible to manipulation. Certain parties may attempt to collude or just acquire the required resources to influence the vote in a manner that promotes their own interests over those of the greater community. If token holders' interests do not precisely line with those of decentralized applications’ users, then this governance mechanism becomes problematic. This conflict is ordinary in many Dapp designs: token holders are typically more interested in seeing the price of their tokens increase, whilst users would prefer to see the price decline in order to minimize the expenses of using the Dapp. As a result, on-chain governance suffers from the exact issue that it was intended to solve: individuals acting in their own self-interest can exploit Dapp regulations technically or economically, regardless of whether they are malevolent (de FIlippi and Mcmullen, 2018).

1.2.8. Blockchain governance frameworks

Few conceptual frameworks to analyze blockchain governance have been developed by academia. Drawing from IT governance literature, Beck, Mueller-Bloch, and King propose a novel governance framework based on three dimensions: *decision rights, accountability*, and *incentives*. Decision rights concern the rights governing control over certain assets, determining the degree of centralization of a system; accountability refers to the degree to which actors are responsible for their actions and subject to consequences; finally, incentives represent the rewards and benefits that motivate agents to act. Their governance framework assesses the degree of centralization of decision rights, the enactment of accountability either through institutional or technical means, and the alignment of incentives among the parties of a blockchain system and how their effective combination can overcome the issues related to the principal-agent theory.

The *decision rights* and *incentives* dimensions are also present in other studies on blockchain governance even if not structured in frameworks. According to multiple authors decisions rights stand for the authority and ability of blockchain participants in choosing how decisions are taken, executed, and monitored (Allen and Berg, 2020; Mosley et al.,2020; Pelt et al, 2021). Incentives or disincentives impact participants' behavior and motivating individuals to participate in governance matters and driving stakeholders in making collective decisions. (De Filippi and Loveluck, 2016; Wright, 2020)

Carter (2017) conducts a cross-sectional survey of the most popular cryptoasset projects at the time. Among different economic and technical variables, the author analyzes the governance structures of these systems classifying eight different models: *benevolent dictator, corporate control, foundation control, core consensus, loose consensus, master nodes, delegated staking* and *Tezos-style*, according to "who ultimately makes decisions over the system". Ziolkowski et al (2019) illustrate core governance decisions of fifteen blockchain systems which include *demand management*, i.e. who decides and how decisions are enacted, *data authenticity*, i.e. who writes data and validates transactions, *system architecture development*, i.e. who decides requirements and functionalities of the system, *membership*, i.e. decisions on who can join the network, *ownership disputes*, i.e. resolution of conflicts, and *transaction reversal*, decisions pertaining the reversion of unintended transactions.

Finally, building on the existent literature, Pelt et al. (2021) develop a comprehensive blockchain governance framework identifying three governance layers and six governance dimensions, hereby fully reported.

Table 1.2: Pelt et al. (2021) blockchain governance framework dimensions.

Governance dimension	Description	Inspired by
Formation and context	This dimension captures the relevant background information of a blockchain. Examples of aspects to look into include the purpose of a blockchain, its launch style, formative ideology and the type of license used.	Carter (2017), Gasser et al. (2015), Hsieh et al. (2017), Markus (2007)
Roles	This dimension identifies the different roles present on each of the three layers of governance. Examples of roles on the three different layers include a foundation, developers and miners.	Beck et al. (2018), de Laat (2007), Izquierdo and Cabot (2015), Jensen and Scacchi

	Furthermore, the aim is to describe observable hierarchical structures between them. Other aspects to look into include responsibilities assigned to the roles and whether they are held accountable for their actions.	(2010), van Deventer et al. (2017)
Incentives	This dimension captures the motivational factors involved for the roles specified in the roles dimension. This is done by looking at the incentives present on the three layers of governance. Examples of questions include what the intrinsic sources of motivation are for community members, how developers are funded, and why node operators want to participate.	Gasser et al. (2015), Hsieh et al. (2017), Jensen and Scacchi (2010), Lattemann and Stieglitz (2005), Lerner and Tirole (2003)
Membership	This dimension focuses on the way participation and membership are managed for the available roles. It captures whether a blockchain is open for anyone to join and participate. Questions asked here include the process to enable new members to join the network and whether new contributors can directly become involved in the development process.	de Laat (2007), de Noni et al. (2011), Hsieh et al. (2017), Izquierdo and Cabot (2015), Midha and Bhattacherjee (2012), van Deventer et al. (2017), Ziolkowski et al. (2019)
Communication	This dimension captures the formal and informal ways of communication between the stakeholders of a blockchain. It includes the available communication tools such as coordination systems and tracking systems, but also looks at discussions	de Laat (2007), Gasser et al. (2015), Izquierdo and Cabot (2015), Markus (2007), van Deventer et al. (2017)

	done in the open, such as meetings and working groups.	
Decision making	This dimension highlights how decisions are made, monitored and agreed upon on the three layers of governance. Furthermore, it looks at the way in which the decision making processes are set in place. Relevant aspects to look at include available voting mechanisms, release decision processes, the consensus mechanism used and procedures to solve arising conflicts.	Beck et al. (2018), Carter (2017), de Laat (2007), de Noni et al. (2011), DiRose and Mansouri (2018), Filippi and Loveluck (2016), Gasser et al. (2015), Hsieh et al. (2017), Izquierdo and Cabot (2015), Jensen and Scacchi (2010), Markus (2007), Ziolkowski et al. (2019)

Table 1.3: Pelt et al. (2021) blockchain governance framework layers.

Governance layer	Description	Inspired by
Off-chain community	As the highest of the three layers, the off-chain community layer encompasses the governance matters taking place in the real world with a focus on the wider community of a project. It highlights how a project is defined more generally and captures the ties of the community to the governance layers below.	Off-chain community level (Carter, 2018), Organizational level (Hsieh et al., 2017), Off-chain (Finck, 2019; Reijers et al., 2018)
Off-chain development	The off-chain development layer encompasses the governance matters taking place in the real world with an explicit focus on the software development process. For example, it looks at how roles related to development interact and decisions are	Off-chain implementational level (Carter, 2018), Individual participants and project teams (Jensen & Scacchi, 2010), Off-chain (Finck,

	made in the maintenance of the protocol.	2019; Reijers et al., 2018)
On-chain protocol	The on-chain protocol layer comprises all the governance matters taking place on the blockchain through its underlying protocol. Examples include the decision making processes, voting mechanisms and rules of interaction encoded directly into the infrastructure of the blockchain.	On-chain (Carter, 2018; Finck, 2019; Reijers et al., 2018), Blockchain and protocol levels (Hsieh et al., 2017)

By crossing the six governance dimensions on the three layers, questions are identified to assess governance of blockchain protocols.

The framework provides an easy-to-use, simple, and clear structure for stakeholders to better understand blockchain governance by allowing different aspects and constructs to be organized into distinct categories. Specifically, experts who evaluated the validity and usefulness of the framework describe three main uses for it: (i) as a starting point for a debate for new blockchain projects, when it must be determined how to design the project's governance; (ii) as a schema for evaluating the governance of a pre-existing blockchain, like the comparison of Bitcoin's governance against Ethereum's; (iii) as a checklist after the conclusion of a situation involving blockchain governance-related matters. For instance, to ensure that no feature of governance has been overlooked. (Pelt et al., 2021)

The framework does not, however, provide support in drawing conclusions or understanding the implications of the variables' design on governance itself, that task is left to the interpretation of the person using the model.

1.2.9. Decentralized Autonomous Organizations

As illustrated in the previous chapters, blockchain technology enables new ways of global collaboration and the institution of new organizational structures and distributed governance models, which culminate in the form of decentralized autonomous organizations (DAOs).

A DAO is an organization run by pre-programmed algorithms and rules encoded in smart contracts and executed on the underlying blockchain network that all members must abide by (Chonan, 2017). These deterministic rules facilitate coordination between unknowing agents in a trust-minimized setting (Wright and de Filippi, 2015). To adjust the code and modify the DAO's pre-programmed running protocols, user consensus is required (Dwivedi et al., 2021).

Instead of having a hierarchical structure, the participants of a DAO collectively control the organization and define the course of action towards a shared mission through proposals and voting systems specified by the code. In contrast with traditional organizations requiring human handling, all decisions happen and are implemented transparently on-chain, removing the need to trust a benevolent central entity to enforce them and manage the organization's assets and operations. As such, decentralized autonomous organizations represent a paradigm shift in the concept of economic organization, providing transparency, shareholder control, flexibility, and self-government.

Similar to decentralized applications, the backbone of a DAO is a single or a set of smart contracts that specify the organization’s rules and typically hold the group’s treasury (Ethereum). Contrary to dapps, however, DAOs are organizations and thus collectivities that are geared toward the achievement of very specific goals and possess formalized social structures; they are not software applications that provide users with one or more services. Moreover, according to Buterin (2014), a DAO has internal capital, meaning that it contains some form of internal property that is valuable in some way, and it has the ability to use that property as a mechanism for rewarding certain activities. Because the smart contract defining a DAO typically establishes a treasury, decentralized autonomous organizations enable a set of people to operate towards a specific social, economic, or political purpose by collectively managing funds or other assets, where no one may spend the money without the group's agreement. Examples of how a DAO could be used include:

- A charity that can take donations from people all over the world and vote on which causes to support.
- Collective ownership that purchases physical or digital assets and allow members to vote on how to use them.
- A venture fund that pools investment capital and votes on which projects to support. Investment returns could then be shared among DAO members. (Ethereum)

Once the contract defining the DAO is deployed on a blockchain network, only a vote may modify its rules. If somebody tries to perform actions that are not covered by the code's rules and logic, it will fail.

DAO governance is typically enacted through the distribution of native governance tokens that grant holders decision-making rights and voting power based on the quantity detained. Even though the smart contracts and the protocol on which they are instituted define their modus operandi, DAOs are not entirely autonomous, as the name suggests. Indeed, they still require human involvement, in particular token holders and curators that make the decisions concerning their operations, which also involve off-chain activities (de Filippi and McMullen, 2018). Contrary to traditional organizations where decisions are taken by one or a few individuals, DAOs enable broad participation in the decision-making process, encouraging large communities to have a say on all matters.

The DAO experiment

The first widely known example of a DAO, named The DAO, originated in April 2016 as a venture capital fund based on a framework designed by a small blockchain company called Slock.it with contributions from the open-source software community. The DAO was designed to enable cryptocurrency "investors" to directly finance and administer new projects built on the Ethereum network. Unlike traditional funds governed by powerful institutions, The DAO enabled individual investors to vote on proposals based on pre-set rules. Because the organization runs on Ethereum, intricate business logic could be coded, and once activated, it would be essentially unstoppable. The blockchain would guarantee that all transactions and organizational changes performed by The DAO would be immutably recorded on a public ledger authenticated by a huge, decentralized network of computers. Furthermore, because the organizations backed by The DAO were directly funded by token holders, each enterprise would be effectively administered by its investors based on each individual's investment position (DuPont, 2018).

In the 28 days following the launch, The DAO received the equivalent of about US$160 million in ETH in funding from an estimated ten to twenty thousand investors. The capital collected represented around 14% of the total ETH supply. However, just after the necessary two-week "debate" time, on June 17, 2016, an unidentified user exploited The DAO's code, utilizing an unforeseen behavior of the code's logic, to rapidly deplete the fund of an amount of ETH tokens valued at millions of dollars. Immediately, Slock.it, the influential voices of the Ethereum network, multiple cryptocurrency exchanges, and other informal technical leaders intervened to staunch the bleeding by closing exits through exchanges and launching counterattacks. According to DuPont (2018), it was at that precise moment that the vision of future governing structures pioneered by The DAO disintegrated and devolved into traditional forms of sociality, leveraging existing strong links to negotiate and influence, debate and disagree—without a single line of code. Indeed, when the code failed, people started looking for leadership and human intervention, as exemplified by the fact that even short posts by Buterin on Twitter were interpreted as decisions. In the end, the entire DAO project was scrapped with a disgraceful hard fork that reversed what should have been an "immutable" ledger, splitting Ethereum into two different networks: Ethereum Classic, which did not invalidate the blocks where the hack happened, and Ethereum, which moved The DAO’s funds into a withdraw-only contract for participants to redeem them. "Moderates" regarded the hard fork as confirmation of Ethereum's adaptability and pragmatism, while the more “orthodox” considered it to be censure by a powerful cabal or proof that blockchain technology was unable to live up to its utopian promises. (DuPont, 2018).

The failure of The DAO experiment demonstrated the downsides of the lack of a central authority needed to make quick decisions to face unforeseen circumstances and the DAOs’ inability at that point in time to substitute corporations. According to de Filippi and Mcmullen (2018), The DAO incident leads us to reconsider what defines good blockchain governance. First, it emphasizes the limitations of endogenous on-chain governance: even if precise governance rules can be encoded into smart contracts, it is not possible to ensure that they will operate as intended or that a series of events will not render these rules obsolete or even undesirable. Consequently, there is a need for a mechanism to change the protocol of a blockchain network if judged essential by relevant parties. Second, these incidents (along with Bitcoin's block size dispute) demonstrate that the administration of a blockchain system cannot rely solely on traditional external law enforcement processes. Even if a court were to order the alteration of a specific smart contract to comply with legal requirements, it is unclear how and against whom such an order might be implemented. Even if the developers within the court's jurisdiction were compelled to comply with the ruling, the smart contract would continue to exist so long as the majority of miners in the underlying blockchain network refused to accept the fork (de Filippi and McMullen, 2018).

Despite their limitations, and the risk of being inefficient due to the trivial task of coordinating multiple individuals, crypto libertarians advocate for DAOs as the means to a more decentralized and democratic society by promoting coordination in an open and transparent way. As societies increasingly rely on virtual organizations, so too must organizational structures adapt to reflect and promote this virtualization trend for the good of their users (Chohan, 2017). While traditional organizations and structures may be obsolete for such purposes, blockchain may help to handle the evolving organizational design needs of modern situations (Dwivedi et al., 2021) and could emancipate individuals from the grips of governments and corporations and help them build better systems.

On the other hand, critics of The DAO's utopia argue that human sociality emerges whenever humans are involved and that existing governance structures have been fine-tuned over thousands of years of social commerce, governance, and exchange rather than the idealistic, pre-social vision that arguably never existed (DuPont, 2018).

DAOs today

In any case, the potential of decentralized autonomous organizations to build organizational forms that defend self-sovereignty and lead to a more free, open, and fair society has not vanished, but it is now clear that it is not enough to simply trust the code and algorithmic governance.

As the Web3 ecosystem grows and blockchain technology evolves, learning from experience, greater attention is being placed on the safety and auditing of smart contracts. More communities are recently self-organizing in Decentralized Autonomous Organizations to experiment with this new form of collaboration, thanks to the diffusion of suites of tools and services for creating and managing decentralized organizations, such as those provided by Aragon. Yet, their adoption is still early on the adoption curve, not only due to the technical hurdles present but also because of the uncertainty concerning regulations imposed by financial authorities.

A blog post on Alchemy (2022), a specialized blockchain developer platform, defines eight main types of DAOs:

1. Protocol DAOs: decentralized autonomous organizations designed to govern a decentralized application.
2. Grant DAOs: DAOs designed to facilitate non-profit donations that deploy capital assets across the web 3 ecosystem to fund ideas and projects.
3. Philanthropy DAOs: organizations aiming to help progress social responsibility and have a social impact.
4. Social or creator DAOs: DAOs bringing together builders, artists and creatives in self-organized communities.
5. Collector DAOs: DAOs for individuals to collectively invest in and manage digital assets and collectibles.
6. Venture DAOs: DAOs that pool capital to invest in Web3 projects, startups, and protocols.
7. Media DAOs: DAOs reinventing traditional media platforms where content creation is driven by the community which are also rewarded for doing so.
8. SubDAOs: subset of DAO members that manage specific functions such as operations, partnerships, marketing and treasury.

1.2.10. Literature gap

Blockchain has emerged as an innovation capable of redesigning interactions and coordination in business, politics, and society at large (Atzori, 2015). Because of its transparent and automated nature, it is often depicted as a solution to problems requiring coordination across heterogenous stakeholders, challenging traditional hierarchical structures and replacing centralization with distributed consensus (Lumineau et al., 2021).

The implications and advantages stemming from the adoption of large-scale blockchain solutions across various domains have received a fair amount of attention from academia. Increasing interest is now being placed in gaining a deeper understanding of how blockchain systems are governed and by whom. According to Tapscott and Tapscott (2016), effective governance results from a multistakeholder approach in which transparency and public participation are prioritized and weigh more heavily in the decision-making process. For the first time in human history, non-state multistakeholder networks are arising in order to solve global challenges. Since its inception, blockchain has promised to make trusted third parties redundant, eliminating the need for trust in agreed-upon contracts. In practice, however, whether blockchain is actually decentralized depends on what is governed and how this governance is enacted (Halaburda & Muller-Bloch, 2019). Moreover, there is not a clear understanding of an ideal system of governance for complex socio-economic systems enabled by blockchain technology. Few scholars have tried to capture governance mechanisms and determine who has authority in blockchain networks, while little focus has been given to decentralized applications.

This paper intends to study how changes and upgrades to the protocol and operating processes of decentralized applications are performed to adapt to specific needs and evolving circumstances while ensuring fairness and social order for the multiple stakeholders involved. All the different types and functions of governance just described are of interest in this study, on the one hand to investigate how and to what extent different stakeholders cooperate to guide the development and operation of dapps, and on the other hand, to determine whether and how governance processes can be executed and enforced automatically on-chain.

Given the current lack of empirical evidence and studies of governance systems adopted by decentralized applications and how decentralization is enacted, this study aims to shed light on the topic through case studies on various Dapps structuring the analyses in a framework deriving from that developed by Pelt et al. (2021).

2 Methodology

In relation to the aforementioned dearth of research, the literature review reveals a scarcity of available tools for better understanding the governance of decentralized applications and a substantial absence of studies addressing the topic. Having a solid grasp of how decentralized application governance is structured would be beneficial for both stakeholders in the ecosystem and regulators, given its central role in the ongoing development and long-term sustainability of the applications.

2.1. Approach

The objective of this study is to understand how decentralized applications model their governance and how decentralization is attained. The proper methodology to be adopted to address the research question has been picked among qualitative research methods as the study attempts to describe and interpret some complex human phenomenon, in the words of informants (Heath, 1997). Indeed, as the knowledge in the domain is still limited, it is critical to collect data from those who are experiencing the phenomenon under investigation (Gioia et al., 2013) "within its real-life context" (Yin, 2013). As a result of the phenomenon driven (Eisenhardt and Graebner, 2007) nature of the research purpose, multiple exploratory case studies have been conducted (Yin, 2013).

This step also included the research of a suitable framework to define, analyze and compare decentralized applications' governance models. The framework defined by

R. Pelt, S. Jansen, D. Baars & S. Overbeek, adapted to better fit the purpose of the research, has been considered for structuring the analysis.

2.2. Framework of Analysis

The framework developed by R. Pelt, S. Jansen, D. Baars & S. Overbeek (2021) aims to improve the lack of understanding and tools available on the topic of blockchain governance by capturing its dimensions and layers in order to guide businesses, regulators, users, and other relevant stakeholders to analyze the governance of blockchains in a structured way. Specifically, it answers the question: How can governance structures of blockchains be defined and compared?

The scheme they designed addresses blockchains intended as networks. While the framework is also basically applicable to applications built on blockchain infrastructure, some modifications to the dimension's description have been made to better fit the context. Given the dynamicity of the Dapps' environment, to the six dimensions already present, evolution has been added to capture how the governance model itself changes in time. The modifications have been done after testing the original framework by interviewing the exponents of two blockchain networks, namely Fantom Opera and Polygon. These examinations enabled to understand how to use and adapt the framework due to the differences among blockchain networks and applications and whether the networks' governance had any substantial impact or influence on that of Dapps.

The resulting framework and its components are reported in the tables below.

Table 2.1: DApps governance framework variables

Governance dimension	Description
Formation and context	This dimension captures the relevant background information of a decentralized application. Examples of aspects to look into include the sector of an application, its purpose, its launch style and the formative ideology.
Roles	This dimension identifies the different roles present in each of the three layers of governance. Examples of roles on the three different layers include a foundation, developers, users, and governance-token holders. Furthermore, the aim is to describe observable hierarchical structures between them. Other aspects to look into include the responsibilities assigned to the roles and whether they are held accountable for their actions.
Incentives	This dimension captures the motivational factors involved in the roles specified in the roles dimension. This is done by looking at the incentives present in the three layers of governance. Examples of questions include what the intrinsic sources of motivation are for community members, how developers are funded, and why governance token holders want to participate.
Membership	This dimension focuses on the way participation and membership are managed for the available roles. It captures whether an application is open for anyone to join and participate. Questions asked here include the process to enable new members to join the network and whether new contributors can directly become involved in the development process.
Communication	This dimension captures the formal and informal modes of communication between blockchain stakeholders. It includes the available communication tools, such as coordination systems

	and tracking systems, but also looks at discussions done in the open, such as meetings and working groups.
Decision making	This dimension highlights who has the power to make decisions and how decisions are made, monitored, and agreed upon on the three layers of governance. Furthermore, it looks at the way in which the decision-making processes are set up. Relevant aspects to look at include the available voting mechanisms, the release decision processes, the mechanisms used to implement decisions and changes, and procedures to solve arising conflicts.
Evolution	This dimension captures the evolution of the governance of the decentralized application from its inception to its current state and provides insights on its future plans. It also looks at how and to what extent governance itself is the subject of proposals and changes, and the reasons behind the adoption of a certain governance mechanism.

The second building block of the framework, the three governance layers, have also been revised as reported in the table below.

Table 2.2: DApps governance framework layers

Governance layer	**Description**
Off-chain community	As the highest of the three layers, the off-chain community layer encompasses the governance matters taking place in the real world, with a focus on the wider community of a project. It highlights how a project is defined more generally and captures the ties of the community to the governance layers below.
Off-chain development	The off-chain development layer encompasses the governance matters taking place in the real world. with an explicit focus on the software development process. For example, it looks at how roles

	related to development interact and decisions are made in the maintenance of the protocol.
On-chain protocol	The on-chain protocol layer comprises all the dapp's governance matters taking place directly on the blockchain through its underlying protocol, including how the technology is used to implement and automate governance processes and the way in which off-chain decisions are deployed on the blockchain itself. Examples include the on-chain decision-making processes, voting mechanisms, and rules of interaction encoded directly into smart contracts and off-chain proposals deployed on the blockchain.

Crossing the seven governance dimensions on the three layers, questions are formulated for each formed cell to assess the governance of decentralized applications. The *formation and context*, and *evolution* dimensions are cross-sectional, meaning they are unified for the three layers and placed at the edge of the framework. The reasoning follows that of Pelt et al. (2021) in that both the context of how a decentralized application was founded and how the governance structure evolves are applicable to all three layers without distinctions or peculiarities.

Table 2.3: Dapps governance framework questions

		Governance Layers		
		Off-chain community	Off-chain development	On-chain protocol
Governance dimensions	Roles	What roles are defined within the community? Is a foundation present? Are there observable hierarchical structures between	What are the available roles related to development? Are there observable hierarchical structures	Are there specific roles related to on-chain governance? Are there observable hierarchical

		these roles? Are there accountabilities assigned to the roles?	between these roles? Which responsibilities and accountabilities are assigned to these roles?	structures between these roles? Who deploys off-chain decisions on-chain? Are there accountabilities assigned to the roles?
	Incentives	What are the associated incentives for the available community roles? Do these incentives include monetary or non-monetary rewards?	What are the associated incentives for the available development roles? Are developers paid? How is funding arranged for developers? Are developers hired to work on the project?	What are the associated incentives for the on-chain roles? Do these incentives include monetary or non-monetary rewards?
	Membership	Is the community open for anyone to join and participate? Who can join the available community roles? Are there available processes or rules for community management? How are borders of the	Is the developer's community open for anyone to join and participate? Who can join the available development roles? What are the rules and	Who can take part to on-chain governance? What is the process to enable new members to join on-chain roles? Is there a structure or voting mechanism to

		community defined? Is there any locked-in period?	processes for participation management? Is training necessary for developers? How is the source code access management arranged?	control the addition of members?
	Communication	What are the media used for community discussion? How does the community achieve agreement? Is there a way to coordinate actions?	What are the media used for development discussions? How do developers achieve agreement? What are the coordination systems used?	How does the communication among the available roles take place? How does communication with other layers take place? How are actions coordinated?
	Decision making	Does the community have input on development decisions? Are there any signaling systems such as voting mechanisms for the community? Are there processes for dispute	How does generation of decision proposals work? How are decisions executed and implemented? Who has release authority? What are the procedures to	How are decisions encoded and deployed on-chain? Who holds the final implementation decision? Are there voting mechanisms determining the autonomous

		resolution within the community?	solve arising conflicts?	execution of proposals? What are the processes for conflict resolution?
	Formation and context	What is the purpose of the decentralized application? What was the launch style of the application? Who was in charge of the original design and deployment? What is the formative ideology of the application?		
	Evolution	Why has this mode of governance been selected? How has it been chosen? Is the governance of the dapp itself subject of proposals and changes? Are there clear guidelines describing the governance mechanisms and how the protocol can be changed?		

While structuring the interviews' answers and secondary data in the framework, it emerged that the decision-making variable alone was not sufficient to grasp the complexities of decision-making systems in decentralized applications and was not able to provide a clear picture of how different participants were involved so as to enable comparisons among the cases. Given that the roles of stakeholders and their involvement in the decision-making processes are central to determining how powers are distributed and exerted within governance systems, an additional framework has been developed specifically aimed at understanding who the actors involved in each step of the decision-making process for different kinds of decisions are. Despite being simple, the framework enables a deep-dive into the decision-making system to determine the importance of each stakeholder and how power is distributed among them. The framework is fully described in the *Decision-making framework* paragraph.

2.3. Case selection

2.3.1. Database and preliminary analysis

As a starting point for the case selection, dappradar.com, a comprehensive database of decentralized applications, has been consulted to identify the target population of Dapps from which to choose those to analyze. First, the database was analyzed using variables provided by the dappradarar.com website itself (e.g., balance, users, transaction volume), identifying the subset of dapps that have significant activity in a specific period of time, which were then extracted to map and understand the ecosystem surrounding the examined topic.

The analysis, which began on March 19th, 2022, includes the top 150 decentralized applications ranked by the number of Unique Active Wallets (UAW) interacting with the smart contracts of the dapps in the thirty days preceding data extraction. The choice of a 30-day time horizon has been constrained by the maximum time frame offered by the resources selected. As decentralized applications are still in their early stages, the level of user adoption has been considered the decisive parameter for making assumptions about the development directions of the ecosystem. Indeed, it is assumed that the best-designed and best-performing applications are the ones able to attract the highest number of users.

Variables description

The variables analyzed are the following:

Name: The name of the decentralized application that allows observations to be distinguished.

Category. The Dapps within the dataset were divided according to the category they belong to and the service they offered. The classification process was carried out in a qualitative way according to the distinctions made by DappRadar and crossreferenced with other sources such as DeFi Pulse, State of the Dapps, and Dapp.com. DappRadar distinguishes between DeFi and Exchanges, but the latter is merely a subcategory of the larger DeFi category. As such, both have been labelled as "DeFi." The categories are:

- DeFi: a variety of non-custodial financial protocols, platforms, and services built on top of blockchain technology that aspire to reinvent elements of traditional financial services and address their challenges.
- Gambling: applications offering any kind of gambling activity or game.
- Games: applications incorporating gaming components ranging from simple card games to complex interactive gaming platforms.
- Marketplaces: blockchain-based platforms where users buy, sell, and exchange goods, usually in the form of NFTs.
- Social network: social media collectively managed by contributors and aiming to solve the critical issues of traditional counterparts.
- Collectibles: applications that create NFTs out of images, cards, video clips, gifs, or other forms of digital art. They offer benefits to holders of the collection, often aiming to create a community and ecosystem around it.
- High-risk: Most likely fraudulent applications that do not fully state risks and rules and are frequently based on Ponzi schemes or game theory.
- Others: all verticals are not widespread enough to be considered standing categories and therefore grouped.

Network. The variable lists all the blockchain networks on which the decentralized application is deployed.

Number of networks. number of networks on which the smart contracts are deployed.

Number of users. number of unique monthly users interacting with any of the decentralized application's smart contracts. It is a key metric for measuring the adoption of a given protocol and an indicator of its level of success. The number of users is cumulative for the different chains on which a dapp is deployed.

Transaction volume. The variable represents the monthly amount of value flowing into the dapps' smart contracts, expressed in US dollars. It is also a very important metric as it gives a different perspective on dapps' adoption by showing where the most value is exchanged and, as such, which apps could have more potential for monetization.

Proprietary token. This is a binary variable recording the presence of a native fungible token directly issued by the decentralized application. Native tokens can either function as utility tokens, governance tokens, or both.

Token name. In case the decentralized application issues a proprietary token, its name has been recorded.

The complete analysis is illustrated in the chapter "*Preliminary Analysis of the Dapps' Ecosystem.*"

Sampling

Starting from this database, multiple cases have been selected using a theoretical sampling method. According to Eisenhardt and Graebner (2007) *"Theoretical sampling simply means that cases are selected because they are particularly suitable for illuminating and extending relationships and logic among constructs. Again, just as laboratory experiments are not randomly sampled from a population of experiments, but rather, chosen for the likelihood that they will offer theoretical insight, so too are cases sampled for theoretical reasons, such as the revelation of an unusual phenomenon, replication of findings from other cases, contrary replication, elimination of alternative explanations, and elaboration of the emergent theory".* Theoretical sampling better matches the needs of the present research. Cases have been selected based on the following criteria. To begin, only projects that have been running for at least a year have been deepened to ensure the integrity of the evidence. Then the focus was solely placed on projects that had issued a native governance token. Finally, the cases have been selected only among the DeFi and Gaming sectors, given their consolidation and prominent role in the ecosystem as evidenced in the preliminary ecosystem analysis.

Then, the next step consisted in contacting representatives for each initiative, asking for their availability to be interviewed. The selection process ended with the identification of 7 cases, shortly introduced and resumed in Table 2.6. An additional interview has been carried out with a “governance liaison” from GFX Labs, an independent group of developers contributing to the development of the Web3 ecosystem and collaborating with numerous Dapps that also serves as a delegate on a few well-established Dapps. This interview allowed for insights into governance systems reflecting the community point of view rather than the core teams’ one.

1inch Network is a combination of decentralized protocols co-founded by two engineers at the ETHGlobal New York hackathon in May 2019. The idea was to create a tool that could act as the Google of decentralized finance providing a one-stop access to the entire ecosystem, finding ways to trade assets more efficiently across various DEXs.

Today 1inch Network includes an aggregation protocol, sourcing liquidity from multiple DEXs to ensure the best swap rates, a limit-order protocol for crypto trading, and an AMM liquidity protocol, all combined into a single dapp. On top of that 1inch also provides an easy to use crypto-wallet offering an entry point to the dapp and to DeFi as a whole.

Curve is a leading AMM decentralized exchange founded by Michael Egorov in November 2019. It was originally designed for efficient stablecoin trading on Ethereum and later expanded to include other volatile assets and features such as staking, while also being deployed on other blockchain networks. Hundreds of liquidity pools have been launched through Curve's factory.

Furucombo is a DeFi aggregator founded by a company named Dinngo in 2018. It enables users to create investment strategies across DeFi protocols with a drag-and-drop tool that bundles different actions into one single transaction. Users also have the chance to use pre-existing strategies or have their money managed by more experienced traders in return for a fee.

Maker Protocol is a decentralized credit facility that provides anyone with access to the Internet and the crypto economy with the possibility to borrow Dai against collateral. Dai is the leading decentralized stablecoin that is soft-pegged to the US dollar. The project was originally founded in 2017 as a traditional tech company, the Maker Foundation, by two Danish co-founders. The Foundation designed and bootstrapped the application, created its backbone and infrastructure, and drafted the roadmap for decentralization. MakerDAO is now in charge of the protocol and its operations, while the Foundation still supports the protocol and its governance.

SpookySwap is an automated market-making decentralized exchange founded in April 2021 as a fork of Uniswap V2 on the Fantom opera Network. The team of eight behind the Dapp's original development took advantage of the fact that no DEX was yet present on Fantom, thus creating the application with a focus on decentralization, anonymity, and excellent user experience. A lot of effort has been placed on developing a fast and intuitive UI that provides an excellent UX, which is now a strength of the protocol. In addition to the DEX, the protocol has since added farms, a built-in bridge, its own NFT line, a marketplace, and the ability to stake NFTs, thereby expanding its offer.

The Sandbox is a community-driven gaming ecosystem or metaverse platform where users and creators can build, play, share, and monetize their own digital assets and gaming experiences on the Ethereum blockchain. The Sandbox ecosystem includes three integrated products: the voxel editor, marketplace, and game maker, which together provide a comprehensive experience and inclusive tools for generating content to be used in the game. Originally, the Sandbox was a 2D game for smartphones; in 2018, publisher Pixowl brought the virtual gaming platform on the blockchain to disrupt existing game makers like Minecraft and Roblox.

Yearn Finance is a security focused yield aggregator that reliably delivers a good return on crypto assets. It does not aim to have the best returns on the market but to provide good yields in a simple, trustless, and secure manner. The dapp was originally designed and developed in 2020 by Andre Cronje with the initial goal of investing his funds and those of people close to him. The first version of the product was quite simple: it would select the best interest rate on the lending protocol market and deposit the users' funds. Every time a user would deposit or withdraw additional funds, the app would revalue the interest rates in the market and move the assets accordingly.

Table 2.4: Cases selected

DApp	**Foundation year**	**Category**	**Native token**
1inch	2019	DeFi – Aggregator - DEX	1INCH
Curve	2019	DeFi – DEX	CRV
Furucombo	2018	DeFi – Aggregator	COMBO
Maker Protocol / DAO	2017	DeFi – Lending	MKR
SpookySwap	2021	DeFi –DEX	SPOOKY
The Sandbox	2018	Game - Metaverse	SAND

Yearn Finance	2020	DeFi – Aggregator	YFI

2.4. Data collection

To limit potential biases (Eisenhardt and Graebner, 2007) and gather stronger insights (Eisenhardt, 1989), the study relied on multiple sources of evidence: as summarized in Table 2, it drawn on primary data, namely, semi-structured interviews, and secondary data, such as reports, whitepapers, social networks posts, online news-articles and websites.

The primary data consisted of seven semi-structured interviews, one for each Dapp, conducted between July 2022 and September 2022. The interviews began by asking informants to briefly describe the Dapp and their role to then proceed asking the questions of the framework of analysis to investigate the Dapp governance. Data was simultaneously collected and analyzed. This cyclical process allowed to gather new information based on the evidence arisen from previous interviews (Gioia et al., 2010) and, following where the informants led the interview, the framework was adjusted during the research. Each interview lasted at least one hour, was conducted using online tools (Microsoft Teams, Zoom or Google Meet) by the author, and was recorded and transcribed verbatim.

Table 2.5: Case interviews and data sources

Case	Primary data	Secondary data
1inch Network	Business development manager	1inch website, 1inch blog, 1inch governance forum, 1inch guides, 1inch documentation portal, 1inch Snapshot, twitter
Curve	Founder	Curve website, Curve blog, Curve governance forum, Curve resources,

		Curve documentation portal, Curve whitepaper, Curve DAO portal
Furucombo	Chief Operating Officer at Dinngo	Furucombo website, technical docs, Medium, forum, Snapshot, twitter.
Maker Protocol	Core Unit facilitator	MakerDAO website, MakerDAO whitepaper, blog, forum, MakerDAO world community portal, Maker operational manual, Maker Improvement Proposals webpage
SpookySwap	Head of Business Development	SpookySwap website, technical documentation, Medium, Twitter, Snapshot, Fantom Foundation blog
The Sandbox	Community manager for Italy	The Sandbox whitepaper, website, documentation and help resources, Medium
Yearn Finance	Business Development manager	Yearn blog, Medium, Yearn technical documentation, Yearn governance forum, Yearn improvement proposals webpage, Yearn whitepaper, notion webpage

2.5. Data analysis

The grounded theory approach was used in the data analysis process (Glaser and Strauss, 1967). Within-case and cross-case analyses were carried out in accordance with the principles for multiple case study theory development (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). Primary data was independently analyzed and triangulated with secondary sources (Jick, 1979). The material collected has been organized to answer the questions of the governance and decision-making frameworks and shed light on how each decentralized application structures its governance model.

At this point, The Sandbox has been omitted from the examination as it was the only application belonging to the gaming category and skewed the results. First, because the scope of the decisions taken was quite different from those taking place in DeFi applications, it created problems in deriving a unique framework for the decision-making process. Secondly, the application's native token, SAND, does not yet grant its holders participation in the governance of the ecosystem. The distribution of decision-making powers is planned, but it is far from being enacted, and its extent and functioning are not yet defined. The Sandbox’s community is involved in the creation of the game experiences and assets but within the limits and structures centrally defined by the company, which still governs the protocol independently.

The interviews were then coded using an inductive technique (Saldana, 2013) to discover early themes and then clustered together in second-order themes using replication logic across cases.

The process cycled between case data, emerging concepts and dimensions, and academic literature to improve the emerging construct definitions, abstraction levels, construct measurements, and theoretical relationships while the cross-case research was underway (Gilbert, 2005). To converge on a condensed collection of constructs, the focus was placed solely on the most robust findings (Andriopoulos and Lewis, 2009).

3 Preliminary analysis of the Dapps' ecosystem

3.1. Introduction and overview

The census includes the top 150 decentralized applications by monthly unique active wallets (UAW). Despite accounting for only 1.43% of the total number of Dapps tracked by DappRadar across 49 different blockchain protocols, the sample can be considered a good representative of the market in terms of users.

As evidence, the number of daily users connected to the top dapps has been compared to the total number of daily UAW to show the relevance of the sample. The comparison has been made using daily values since the total number of monthly Unique Active Wallets across all applications and protocols is not available. Instead, the total number of unique addresses connecting daily to a dapp hosted on the protocols tracked by DappRadar is provided and adjusted every twenty-four hours. On March 19th, this value amounted to 2.35 million unique addresses. Note that even though the terms are being used interchangeably, the number of wallets and addresses is just an estimator of the number of users, since an individual might own different wallets to interact with different blockchain networks. Another limitation of the approach is a single user may connect to multiple decentralized applications during a single day and thus is counted in each Dapp's daily users count but only once in the total daily amount. Still, it gives a good understanding of the usage of decentralized applications and is the only viable procedure with the data available.

The application that attracts the most unique users on a daily basis is Splinterlands, a collectible trading card game that counts 345.68 thousand different wallets, or 14.71% of the daily total. Coming in second place, PancakeSwap, an automated market maker (AMM), counts 271.42 thousand unique users, equal to 11.55% of the daily value. Following in third place, 182.45 thousand daily wallets, corresponding to 7.76% of the total, connect to Alien Worlds, an NFT metaverse. At fourth and fifth place, respectively, there are Farmers World with 5.39% and Atomic Assets with 3.08% of the total daily unique addresses. These top five applications already account for 42.50% of daily active users, despite the limitations discussed above.

For this reason, the sample is used to provide a global representation of the decentralized applications ecosystem and to analyze the sectors in which such applications are being developed and which are able to attract more users.

3.2. Analysis

3.2.1. Categories

The sample of applications is classified into 8 categories according to the sector they operate in.

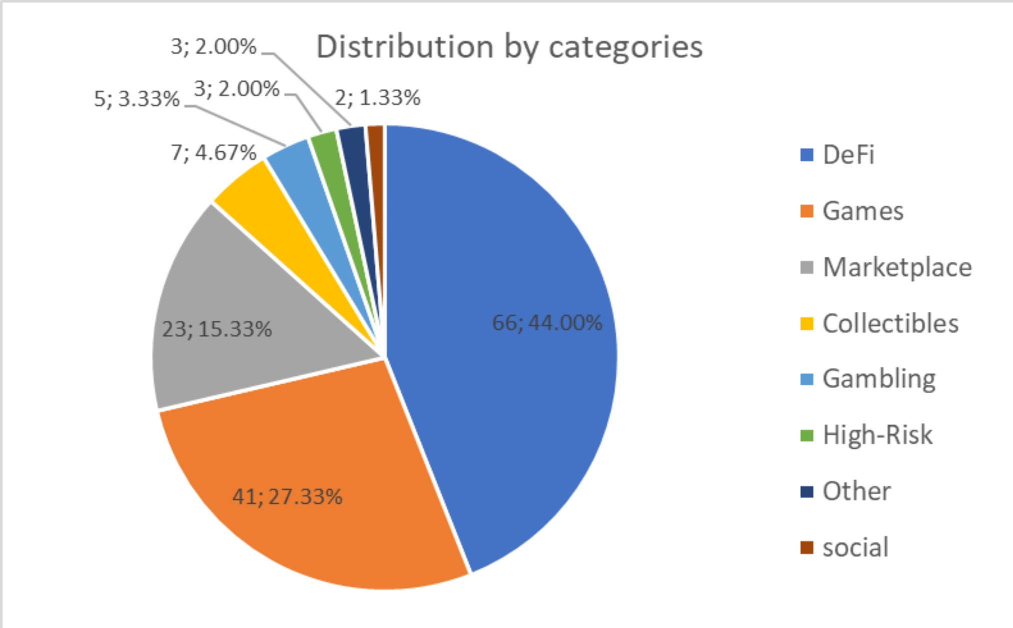

Figure 3.1: Distribution of Dapps by the category/sector they belong to.

Analyzing the distribution of the top decentralized applications in the different categories shows that most fall within one of the two categories of DeFi or games, with 44% and 27.33% of the total, respectively, followed by marketplaces (15.33%) and collectibles (4.67%). Gambling dapps account for 3.33% of ecosystems, while high-risk and other dapps (applications that do not fall into any of the other categories) account for 2%. Finally, social networking applications only represent 1.33% of the ecosystem. It is surprising to find three applications labelled as high-risk in the top 150 applications by monthly unique active wallets. It is possible that such applications, often based on a pyramid or Ponzi scheme, are able to attract a conspicuous number of inexperienced users in the short term by promising high returns with little risk. However, they are often short-lived as users realize the fraud and abandon them.

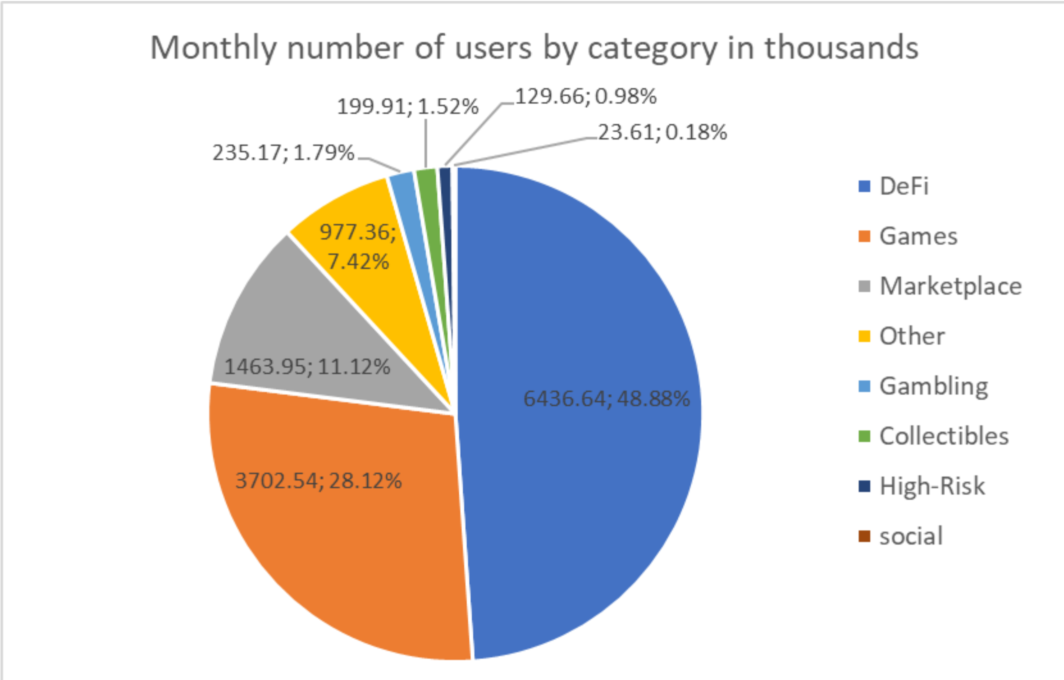

Figure 3.2: Distribution of unique monthly users by Dapp's category.

Analyzing the distribution of the number of unique monthly active users among the eight categories, we find a ranking similar to the previous one. Again, DeFi applications and games dominate the ecosystem with 48.88% and 28.12% of the total number of users, respectively. Marketplaces still follow in third place. The only two applications belonging to the "other" category attract 7.42% of all users thanks to the presence of Atomic Assets and PrimeLab. The first is a platform enabling the creation, trading, and sale of NFTs; PrimeLab is an ecosystem of web3 experiences built on the NEAR protocol. In the census ranked by number of monthly unique active wallets, the two apps rank at third and fifth place, respectively, and cumulatively have slightly less than 960 thousand users. This explains the category's unexpected result. Gambling, collectibles, high-risk, and social networking applications cumulatively draw less than 5% of total users.

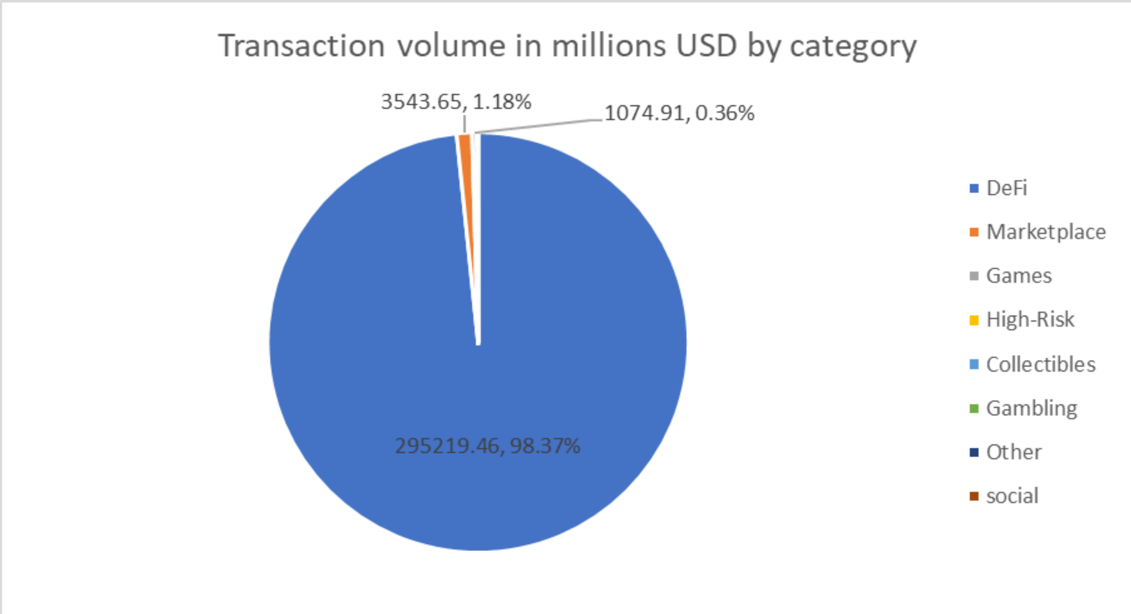

Figure 3.3: Transactions volume of decentralized applications grouped by category.

In terms of monthly transaction volume, expressed as the total amount of incoming value to a Dapp's smart contracts in US dollars, DeFi leads the pack with 98.37% of the total, followed by marketplaces (1.18%) and games (0.36%). All other categories do not have significant amounts of value transacted through them. The results are understandable; financial applications by nature involve flows of money between individuals and the management of financial assets, allowing users to trade, lend, borrow, and invest in cryptocurrencies, other tokens, and more asset classes. More than 295 billion USD have been exchanged in a month in the top DeFi applications, showing the significance of the sector both within the blockchain space and in the broader sector of financial services.

Marketplaces take the second place with 3,544 billion USD in transaction volume. The platforms enable users to sell, buy, trade, and even rent digital assets, mainly in the form of artwork. Non-fungible tokens have gained a lot of traction in the market during the end of 2021, when top collections were selling for various thousands and even millions of American dollars, generating billions of dollars in transactions. The market has lately cooled down, but as the graph shows, a lot of value is still being exchanged across marketplaces.

The top gaming applications generated 1,705 million USD in transaction volume, showing the emergence of the sector and its ongoing development. The transactions mainly represent rewards attributed to players, purchases, and trades of in-game assets.

The three graphs pictured above clearly show decentralized finance's dominant positions in the environment across all key metrics. In particular, among DeFi applications, decentralized exchanges occupy the top spots in the ranking. Decentralized exchanges are financial applications that enable users to swap and trade different tokens without relying on a centrally trusted party to process transactions. The other relevant category is that of games; the sector has a high potential as it enables players to earn and own game assets thanks to the introduction of financial elements such as native tokens, tradeable goods, staking, and remuneration systems.

3.2.2. Blockchain Networks

Analyzing the distribution of decentralized applications across blockchain networks depicts which environments are favored by developers to deploy the apps. It has also been investigated whether the smart contracts of a Dapp are stored on a single blockchain network or on multiple ones.

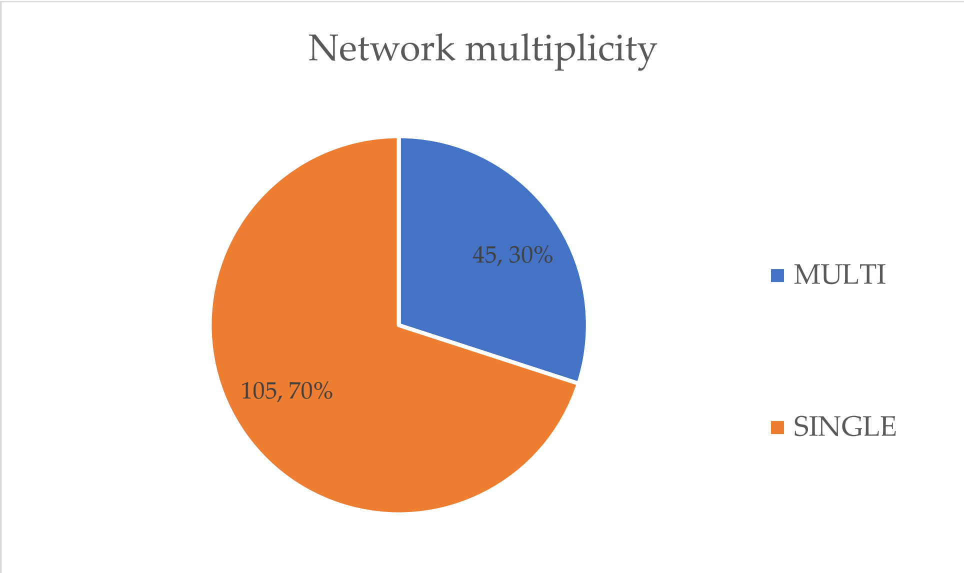

Figure 3.4: Distribution of Dapps among a single or multiple blockchain networks.

The figure above shows the number of applications deployed on a single chain or on multiple chains. The majority (70%) of decentralized applications recorded in the census operate on a single blockchain network. Several decentralized applications (30%) instead deployed their smart contracts on different blockchains to reach a larger user base or exploit the benefits provided by different infrastructure layers. As the graph suggests, decentralized applications are mostly developed and launched on a single network. This is mainly the result of the decision to focus resources and efforts in one place and get the application running in the first stages.

The decision on which blockchain network to develop the decentralized application has fundamental importance for the success and future development of the app itself. Different blockchains use different consensus mechanisms and thus inherit different characteristics such as transaction speed, costs, and security, which in turn influence the functioning of applications running on top of them. Indeed, decentralized applications do not exist in a vacuum. They operate within a larger ecosystem according to their own protocol rules while also inheriting the protocols and rules of the underlying layers.

As the Dapp gets traction in the market and matures, the developers' team and the community itself might propose to deploy the application on other networks as well. Such a decision is often related to the choice of the first chain. Many older applications were first developed on Ethereum, the first programmable blockchain infrastructure, that has a large community of both users and developers. However, the increased popularity of the network combined with the PoW consensus mechanisms it used led to scalability problems, higher transaction fees, and lower speeds, negatively impacting the usage of Dapps. This encouraged builders to explore different chains to provide a better user experience. The existence of Ethereum Virtual Machine-compatible chains facilitated the expansion. EVM compatibility means that the chain is Turing complete and uses the same logic of Ethereum to maintain the network's canonical state. This ensures a similar level of programmability and programming code, access to Ethereum's development tools, and the ability to port most of smart contracts' components without the need to rewrite them. Porting smart contracts onto a non-compatible chain would instead require rewriting the smart contracts' logic and using different languages and programming tools.

Deploying a decentralized application on different blockchains can also result from the willingness to attract a larger user base that might favor a particular network or to integrate different tokens, especially in the case of DeFi. Certain token types are blockchain-specific and thus not available on another network unless in the form of a derivative.

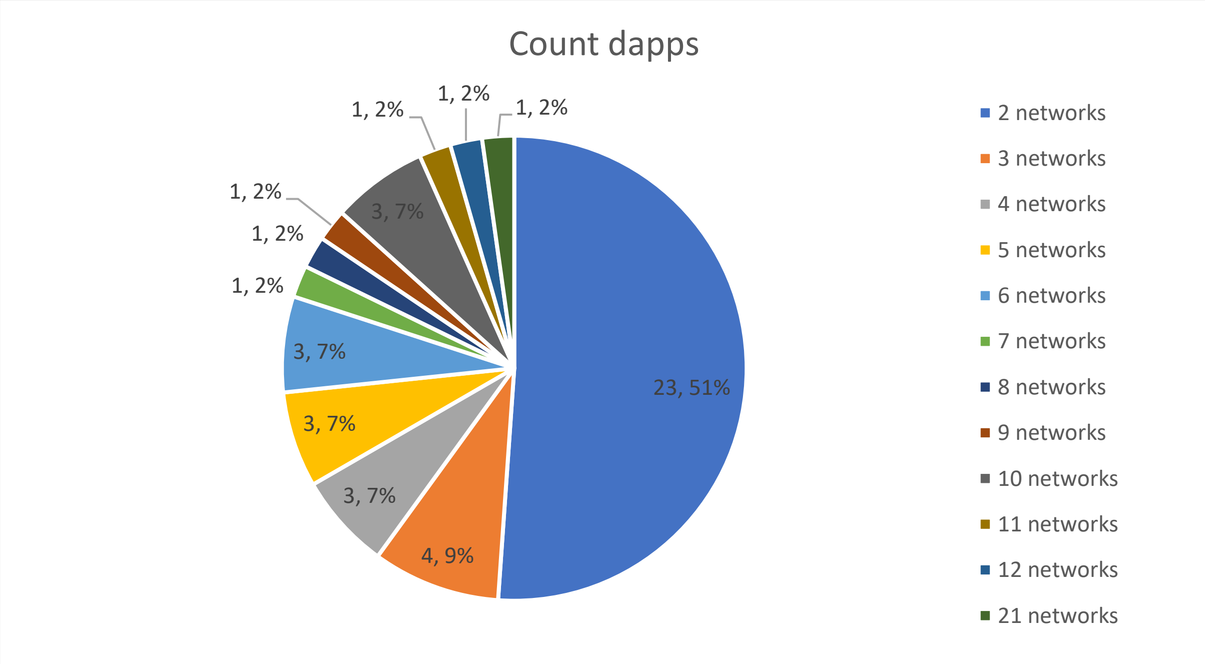

Figure 3.5: Distribution of decentralized applications by number of blockchain protocols on which they are deployed.

This chart shows how many different protocols multi-chain decentralized applications' smart contracts are deployed on. Most multi-chain dapps operate on two networks (51%), followed by three networks (9%). 28% of decentralized applications are equally distributed among those using 4, 5, 6, and 10 networks. Interestingly, one decentralized application, tofuNFT, is deployed on 21 different blockchain layers.

As previously said, EVM-compatible chains enable the porting of smart contracts developed for Ethereum, typically requiring only a few adjustments. Adopting multi-chains opens many possibilities for decentralized applications to enhance speed and exposure to different features and tokens. However, for the time being, there is no definitive solution enabling the interoperability of different blockchains, and thus workflows can be fragmented.

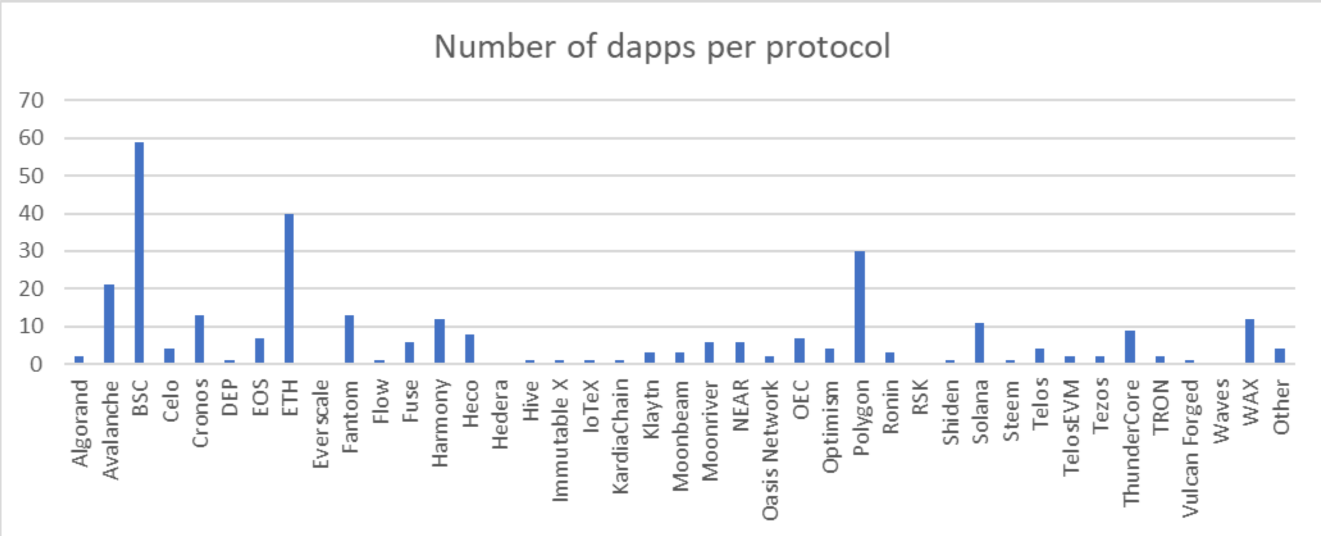

Figure 3.6: Number of decentralized applications deployed on each blockchain network.

In recent years, a plethora of public blockchains have been developed, each trying to overcome some technological limitations or inefficiencies while providing practical value and tools for developers looking to build applications. Each network might offer different features and meet different business requirements.

The distribution of applications across blockchains is not uniform; the two blockchains dominating the ecosystem are Binance Smart Chain (BSC) and Ethereum (ETH), followed by Polygon and Avalanche.

BSC is a blockchain network that is part of the BNB Chain, developed by Binance, a leading centralized exchange, and its developer community. BNB Chain can be thought of as a network of two distinct subchains. Binance Smart Chain brings programmability and interoperability to the BNB ecosystem and runs in parallel to Binance Chain, which supports voting and governance mechanisms. BSC is compatible with the Ethereum Virtual Machine. The chain allows for very low transaction costs and fast transaction speeds, which come at the expense of a lower level of decentralization. BSC uses a Proof of Staked Authority consensus, which combines Delegated Proof of Stake and Proof of Authority. The set of validator nodes is governed through staking on Binance Chain, and one is elected every day. The chain relies on only 21 validator nodes, which is expected to be increased to 40 in the near future.

BSC has grown rapidly thanks to the recent surge of DeFi, the category representing the majority of the Dapps on the chain. Its low transaction costs and high speed of processing make it particularly suitable for decentralized finance. This is particularly true when compared with the second-most-adopted blockchain, Ethereum, which has been facing scalability issues, currently making it cost prohibitive to use given the high gas fees.

Ethereum is one of the oldest and most established blockchains. It introduced the notion of state and the capability of executing code on chain with the Ethereum Virtual Machine. As such, it was the first blockchain to enable developers to create applications on top of it. It is a mature ecosystem supported by a large community of developers who are constantly updating the protocol. These characteristics, coupled with its reliability, explain why Ethereum is still largely popular.

Ethereum has recently switched its consensus mechanism to proof-of-stake after a long period of testing on a subchain. When the database was analyzed, Ethereum was still using proof-of-work and the following description is based on that. Sending transactions through the network, whether to other users or smart contracts, incurs a set amount of fees determined by the operations to be performed, plus "gas" fees required by miners in exchange for their computing power. The cost of gas is thus determined by free market interactions among miners and users. Paying more gas usually results in a faster transaction speed because miners have higher incentives to validate the transaction.

Anyone can open a node, verify transactions on Ethereum, and also participate in the mining process. However, it is unlikely that a solo mining activity could be profitable unless professionally undertaken with significant capital investments, and thus miners aggregate their computing power in pools. Quite recently, cloud mining has been introduced, in which an individual pays a miner an upfront amount to mine coins on his behalf. This has obviously lowered the barrier to entry for mining, but it does not increase the number of nodes or the computational capacity of the network. As of April, 5785 full nodes are active on the Ethereum blockchain, but they are not necessarily participating in mining activities.

The third and fourth blockchains with the highest number of decentralized applications are Polygon and Avalanche, with 30 and 21 applications, respectively. Both are open, programmable smart contract platforms using proof of stake consensus mechanisms. Polygon is a network of different chains specifically developed to provide scalability to Ethereum. In particular, Polygon PoS is a layer-2 scaling solution working as a sidechain. Indeed, despite having its own validation process, Ethereum has regular checkpoints at which information is transmitted to the blockchain. Polygon PoS can process thousands of transactions per second, compared to 15 on Ethereum, at a much lower cost. Many Dapps originally developed on Ethereum have been subsequently ported to Polygon PoS thanks to the easy deployment of smart contracts from the main chain.

Avalanche also aims to create a fast, low-cost ecosystem that processes thousands of transactions per second and is compatible with Solidity, the Ethereum programming language. It also enables the launch of both private and public blockchains on top of it, with the possibility to customize the virtual machine, i.e., the runtime environment, and dictate how it should operate.

Both Polygon and Avalanche have been working on the interoperability of blockchains and have developed bridges to easily transfer assets from and to Ethereum.

3.2.3. Native tokens

As seen in the literature review, the possibility to issue tokens on chain using programmable smart contracts and distribute them relatively effortlessly over a public infrastructure represent unique innovations of the blockchain space. This section of the analysis describes the use and role of tokens in the operations of decentralized applications.

All decentralized applications necessarily involve the use of tokens to have transactions validated and included in the underlying blockchain infrastructure. Not all dapps, however, need or implement a proprietary token. The term "proprietary token" refers to the fungible utility tokens native to the decentralized applications that are built on top of the underlying blockchain protocol. Native tokens have different functions within the ecosystem, usually providing access to a service, incentives to users, enabling the payment of protocol fees, or granting governance rights. NFTs representing unique assets in the form of digital art, game assets, or securities are not considered in this analysis to be proprietary tokens.

Table 3.1: Issuance of a native token by Dapps

Category	Dapps % with own token	Dapps % without own token	Grand Total
Collectibles	0.00%	100.00%	7
DeFi	80.30%	19.70%	66
Gambling	0.00%	100.00%	5

Games	46.34%	53.66%	41
High-Risk	33.33%	66.67%	3
Marketplace	30.43%	69.57%	23
Other	0.00%	100.00%	3
Social	100.00%	0.00%	2
Grand Total	**54.67%**	**45.33%**	**150**

Table 3.1 highlights the issuance of proprietary tokens among the Dapp categories. Out of the 150 decentralized applications in the database, 82, corresponding to almost 55% of the total, adopt the use of a native token, while 68 dapps, corresponding to 45%, do not issue one.

None of the applications in the collectibles category make use of a proprietary application token. Instead, all these applications issue non-fungible digital assets representing artwork, trading cards, video clips, or music. Each asset has unique properties and can be bought, sold, and exchanged with other individuals. Eventually, an NFT might bring the owner other advantages, such as the possibility to win prizes and rewards, privileged access to future collections, or participation in various experiences. The most popular application in the collectibles category is NBA Top Shot, which turns NBA and WNBA fans' most loved and "epic" highlights with related descriptions and game statistics into officially licensed NFTs with different degrees of scarcity.

DeFi applications are powered by tokens and cryptocurrencies, which are used for trading, lending and borrowing, investing, and representing derivatives. Indeed, all DeFi applications in the studied ecosystem fall into four main sub-categories: exchanges, credit, derivatives, and asset management applications. As previously said, exchanges enable traders to swap pairs of digital assets, both stablecoins and value-floating tokens, made available by liquidity providers in exchange for a fee. Exchanges are the most diffused applications in the ecosystem since they are one of the first use cases of decentralized applications. Credit applications involve the issuance of interest-bearing crypto financial instruments among borrowers and lenders in a peer-to-peer fashion. Intermediaries are replaced by automated, non-custodial protocols and pools of capital provided by individual lenders. Similar to traditional finance, derivatives represent contracts whose value is based on one or more underlying assets. Derivatives create synthetic financial assets that can be programmed and compounded in virtually any configuration using smart contracts and oracles, i.e., entities connecting the blockchain to external systems. Finally, asset management applications seek to maximize the value of a portfolio of financial assets by constantly moving and staking capital across different DeFi applications based on different conditions.

Other than using layer-1 tokens, such as Ethereum, Matic, and BNB, and stablecoins, most DeFi applications also adopt and use their own and other application tokens. Indeed, eighty percent of the applications in the decentralized finance sector issue a proprietary token. The functionality of tokens issued by DeFi applications varies depending on the type of service provided and the protocol. For example, in decentralized exchanges and lending dapps, native tokens are used to reward liquidity providers who stake their capital in the applications' smart contracts, making it available for other users to trade or borrow. Native tokens may also be used to pay fees, gain access to additional services such as lotteries, back algorithmic stablecoins, or grant governance rights. Some DeFi applications also use another type of token, the liquidity provider token (LP), which represents the share of liquidity in a pool provided by an individual. This enables liquidity providers to retain control of the assets staked on the platform. However, DeFi apps do not necessarily need a native token if there is no natural utility for it. Applications such as bridges, for example, are used solely to transfer assets among different blockchains, so a native token would likely not add utility to the platform. Often, the native tokens are used to distribute some governance powers and thus provide holders with certain participation rights.

Instead, none of the five gambling applications present in the database issue native tokens. These dapps provide games, services, and gambling activities in which users bet cryptocurrency to win prizes. The tokens used are the protocol tokens of the blockchain on top of which the app is built. All five gambling applications analyzed are deployed on a blockchain network named Thundercore and employ its layer-1 token, TT.

Decentralized gaming applications have introduced the play to earn paradigm. According to the in-game mechanics, players can complete missions and quests, solve puzzles, fight, battle, and participate in tournaments to earn crypto assets. Thus, a consistent number of gaming applications have implemented their own native token to fuel their activities. Such tokens are like traditional in-game currencies, with the difference that they have real world value. At any time, players could sell their tokens to other players for other cryptocurrencies. The tokens can also be used to buy other in-game assets and NFTs, such as characters, skins, land, cards, armors, and accessories. While in traditional games the assets remain in the game with no real value, NFTs used in decentralized games are the owner's property and can be traded and sold for crypto tokens on marketplaces.

As explained in the methodology, decentralized applications falling in the marketplace category allow users to mint, i.e., deploy on the blockchain, sell, buy, trade and eventually even lend and rent non fungible tokens. Around 30% of these applications issue a native token, which can be used to access the application, pay transaction fees reward users for their trading activities. Some marketplaces, such as

LooksRare, Neftyblocks and X2Y2 respectively issuing RARE, NEFTY and X2Y2 native tokens, distribute the secondary market fees among the token owners who stake their assets in the protocol.

Finally, tokens issued by social applications are used to reward content production.

4 Decision-making framework

After having completed the literature review on blockchain governance, conducted interviews with protocol representatives, and consulted additional documentation, a good knowledge base has been built on the topic. This served as a theoretical foundation for designing the decision-making framework within DeFi applications. Indeed all the cases that have been selected belong to the DeFi sector due to its prominent role in the ecosystem and the need to draft a single framework that could be used for all the cases analyzed. First, all kinds of relevant decisions that are being made in relation to a DeFi application's development and operations have been identified, captured, and organized in a synthesis matrix. Overlapping and related decisions have then been grouped together through an iterative process to derive the most important types of decisions. The listed types can contain smaller topics.

The decision types identified have been divided into two distinct categories:

- off-chain decisions: decisions involving the decentralized application or its ecosystem that do not affect the code base and smart contracts nor need to be deployed on the blockchain.
- on chain decisions: decisions that need to be deployed through a new smart contract and enforced on the blockchain or that impact the existing code base, encoded rules and processes.

This distinction should not be mistaken with that of off-chain and on-chain governance provided in the literature review. On chain decisions, as the analysis will illustrate, are often first debated on a social level among stakeholders, and then voted and deployed on the blockchain; they are not agreements automatically executed by the code itself according to predetermined rules and mechanisms.

Table 4.1: Decision-making framework: types of decisions

	Decision type / scope	**Description**
Off chain	Front end	All decisions pertaining to the official front end of a dapp, such as those involving the design, the user interface, and user experience of the website used to interact with the application.
	Documentation, articles & newsletter	Decisions concerning drafting official documentation related to the protocol, such as the whitepaper, guides and technical docs, and releasing official articles, blog posts and news.
	Branding, IP & marketing	Decisions related to the brand, name, logo, eventual trademarks and intellectual property rights and marketing activities not tied to the governance token, like partnerships or sponsoring of events.
	Managing teams and groups	Decisions connected to managing official groups on various communication channels such as Discord, Telegram and forums and to the structuring of the workforce.
On chain	Tokenomics	All decisions tied to the token supply and allocation, including minting new tokens, distribution, inflationary mechanisms, etc.
	Treasury	Decision pertaining to the management and expenditure of protocol's funds. Examples include which tokens to keep in the reserve, investment

		strategies, issuing grants, listing the token on CEXs and more.
	Pool creation	Launch and setting up of new liquidity pools where to trade tokens.
	Farm / vaults creation	Launch and setting up of farms receiving token allocations <u>even from other protocols</u> and of vaults and routing strategies for aggregators.
	Adjusting products parameters	Decisions concerning adjusting fees, revenues distribution, risk factors and other parameters
	Smart contracts maintenance and definition	Decisions concerning tuning, bug fixes, and changes to the algorithms enabling the functioning of the protocol or other processes.
	Deployment on other chains	Developing and deploying the smart contracts on another blockchain network
	Governance changes	Decisions concerning the governance system itself such as delegation of authority and distribution of powers, voting mechanisms, quorum, proposal process and more
	New products	Decisions concerning the development and deployment of new products or features for the protocol.

It should be noted that given the differences in the value propositions and services offered by the decentralized applications, not all protocols face all the different kinds of decisions.

The second block needed in the framework consisted in determining the phases of the formal decision-making process, which arose in the interviews and were confirmed in the technical documentation of various protocols. The framework only considers the phases that are ruled and required by the governance systems in place. It does not take into account informal and unstructured processes aimed at improving the decision making process itself which may or may not happen, such as gathering all available information to address an issue or weighing the evidence.

Table 4.2: Decision making framework: phases

Decision making phase	**Description**
Initiation / proposal process	This phase consists in the drafting of a formal and detailed proposal to address an issue or driving a change and presenting it for approval or rejection. For a decision to be executed a specific proposal needs to be implemented, especially if the change needs to be encoded.
Voting	This step entails the voting mechanisms used to come to a final decision and accept or reject a formal proposal.
Implementation	The process by which agreed decisions are put into effect and possibly deployed on the blockchain.

The *initiation / proposal process* does not include the preliminary phases of ideation, discussion, and research of the different ways and alternatives in which an issue can be addressed and the policy enacted. This is due to the absence of formal and regulated processes to perform such activities, their non-binding nature, and the fact that, essentially, they can be done without any permission. Furthermore, it has been deemed to be somewhat overlapping with the pre-existing *Communication* variable in the Blockchain Governance framework, which already captures coordination tools and methods for stakeholders to reach agreement.

As it will be discussed in the following chapters, once a decision is implemented, it does not mean that it is automatically executed, as some agreements require the assignment of tasks and activities to be executed by some human actors.

Lastly, a matrix is formed by crossing the decision types with the steps of the decision-making process. The resulting cells are then filled with the decentralization level of each step-decision-type arrangement according to the actors who can participate and have authority in it.

For greater clarity and reconciliation between the different applications, the involvement of the different actors who interact with the decision-making process has been divided into four groups:

- anyone: any individual from the larger community can participate in the process without restrictions;
- token holders: only the individuals who own the governance token can take part in the step of the decision-making process. To participate token holders might need a minimum number of tokens or have to lock them;
- core team: only the members of the core team, company or foundation have access to the step;
- multisignature: only the signers of a dedicated multisig wallet can participate in the decision. Signers could be part of both the wider community and core team. A multisignature wallet is a specific type of wallet associated to and requiring the digital signature of more users.

Accordingly, the steps open to anyone or token holders have been classified as decentralized; those reserved to the core team have been labeled as centralized; and finally, those requiring a multisignature or carried out by both the core team and the community have been classified as semi-decentralized.

The resulting framework and its application are visible in the within case analysis.

5 Results

This section exhibits the results that were obtained from the analysis of the six cases operating in the DeFi sector.

Continuing with the analysis, after supplementing and verifying the informants' responses with information from secondary sources, the study of each individual case was set up by structuring and evaluating what emerged from the interviews in the two frameworks described in the methodology paragraph.

First, the formation and background of the application were assessed to gain an understanding of the general context and ideology that led to the development of the protocol, which have been illustrated in the chapter devoted to the methodology.

The focus was then placed on comprehending who all the different actors operating in the ecosystem are, as well as the possible relationships between them and the roles that they play. Likewise, the incentives present for each role were assessed to determine what motivates each actor to participate in the decentralized application. The analysis then proceeded to identify the communication channels that the various participants in the ecosystem utilize to chat, interact, and discuss governance matters. An overview of the existing means and tools available to distribute information, coordinate action, and reach agreements is particularly important to unravel potential knowledge disparities among the stakeholders, which can lead to privileged positions in the governance system. Indeed, addressing issues and driving change necessitates the development of specific proposals as well as the investigation of enactment choices and connected results, which require expertise and specialized information.

Most importantly, the analysis aimed to understand how the different stakeholders are involved in the decision-making process for the relevant changes that are made regarding the protocol's operations, development, and governance. In this regard, with the support of the appropriately crafted framework, the study illustrates how and to what extent the community, token holders, and core teams take part in the proposal process to suggest an action or change, in the voting system to express a preference, and in the implementation of the outcome.

Lastly, based on the within-case analysis and the evidence collected for each case, the cross-case analysis examined how the framework variables identified by Pelt et al. interact with one another and how they influence the decision-making process, the distribution of decision-making power, and the effectiveness of the decentralization in the governance system.

5.1. Within case analysis

5.1.1. Curve

Roles and membership

Like typical DEXs and DeFi apps, the Curve community is formed by users, liquidity providers, token holders and other protocols interested in the use of any of Curve's features. Additionally, there is an independent risk assessment team that voluntarily works to check the safety of the tokens listed in the pools so to prevent possible scams. As said above, token holders need to stake CRV in return for veCRV, which grants holders participation to the DAO and governance. Tokens can be staked for a maximum of 4 years to get maximum voting power. The DAO has no hierarchical structure and does not support delegation. However, there are secondary platforms, an example being Convex, which can aggregate users and work as a coordinated group.

Membership and access to the off-chain community is permissionless, as anyone can use Curve, provide liquidity to pools, or become a token holder by acquiring tokens on the market or staking LP tokens.

Actors overseeing the off-chain development include Curve core team and external contributors. The Curve team is a proper company with a fairly flat hierarchical structure and employees working at different projects. Eventually other protocols contribute to development, especially when they need something specific, as modifying a pool.

Incentives

The incentives in place for the community are both functional and monetary. The AMM algorithm behind the pools enables efficient trades with low fees and slippage, especially for pairs of stablecoins, attracting a high number of users. Liquidity providers are the most incentivized actor. Early liquidity providers received an original CRV allocation amounting to 2.15% of the total supply, while currently they receive half of the fees charged by the pools and additional CRV emissions when they stake LP tokens in gauges. The allocations are distributed across gauges as voted by the DAO, with the weight mainly depending on the importance, volume and volatility of the connected pool. Totally 62% of the entire CRV supply is reserved to liquidity providers.

Curve DAO participants are incentivized by the allocation of the other half of the fees collected by the protocol, which are distributed among the members proportionally to their holdings. Vote-locking CRV also entitles holders to a boost up to 2.5x on the CRV rewards obtained on the eventual LP tokens staked. Even though these incentives are aimed at inducing individuals to participate in governance, they do not effectively ensure participation in discussions, cooperation, or voting but rather promote the locking of tokens in the vote escrow contract.

Developers are typically employed by the company and get a combination of Fiat and CRVs depending on their preferences. The company and eventual external investors are entitled to 30% of the token allocation with a 2-4-year vesting period. Thus, the incentive for both the company and its founder is to contribute code that helps the ecosystem grow and thrive. Therefore, the incentive scheme enables alignment between the vision of the core team and the other stakeholders.

Communication

Community members communicate and discuss on the governance forum, Telegram and Discord, whereas the core team internally uses Slack to debate around operational plans and current development activities. In particular, the governance forum is used to discuss and share ideas concerning all the different kinds of decisions illustrated in the previous paragraph. It acts as a coordination tool for the community to know and understand what proposals are about, what they seek to change and even possible associated risks. An important source of information comes from the risk assessment group, which shares its opinion and research on the topics discussed.

"The community usually works fairly decentralized. There are some coordination tools like a forum where governance discussions happen, for example, because people really need to know the proposals they see what it is about. Also there is some independent group which assesses the risks of different things proposed to keep the governance informed.

"They (community and DAO) can of course use the Governance Forum. Or they could write on Telegram or Discord, or some other groups can be created on Telegram and stuff like that. But yeah, there are multiple things. Few good discussions happen on the governance forum like even fairly technical ones."

Decision making

Table 5.1: Curve decision-making framework.

		Initiation / proposal process	Voting	Implementation
Off chain	Front end	○ Decentralized	● Centralized	● Centralized
	Documentation, articles & newsletter	○ Decentralized	● Centralized	● Centralized
	Branding & marketing	○ Decentralized	● Centralized	● Centralized
	Managing teams and groups	○● Semi-decentralized*	○● Semi-decentralized*	○● Semi-decentralized*
On chain	Tokenomics	○ Decentralized*	○ Decentralized*	○ Decentralized*
	Treasury	○ Decentralized*	○ Decentralized*	○ Decentralized*
	Farm / vaults creation	○ Decentralized	○ Decentralized*	○ Decentralized*
	Pool creation	○ Decentralized	ND	○● Semi-decentralized*
	Adjusting products parameters	○ Decentralized*	○ Decentralized*	○ Decentralized*
	Smart contracts maintenance and definition	○● Semi-decentralized*	○● Semi-decentralized*	○● Semi-decentralized*
	Deployment on other chains	○● Semi-decentralized*	○● Semi-decentralized*	○● Semi-decentralized*
	Governance changes	○ Decentralized*	○ Decentralized*	○ Decentralized*
	New products	○● Semi-decentralized*	○● Semi-decentralized*	○● Semi-decentralized*

* token holders need to lock their CRV tokens in vote escrow contracts to get veCRV and obtain voting power.

Curve decision-making starts off-chain on the governance forum and eventually on Telegram channels and Discord. The community is fairly active in proposing and discussing ideas, and even raising rather technical proposals. A voting power of 2500 veCRV is required to post an official proposal. There is no off-chain voting; encoded proposals are voted on chain by the DAO over the course of a 7-day voting period. To acquire voting power token holders, need to vote lock CRV tokens. Voting power linearly decays to zero after three and a half days, so to partially prevent last minute changes and flips that have created controversies in the blockchain space. In order for a proposal to be approved, the votes cast needs to pass the quorum equal to 30% of the total amount of veCRV in circulation, in addition to a simple majority.

Decisions pertaining to the off-chain realm mostly happen in a centralized manner. This results from the front end and intangible assets being owned by Curve (the company). Indeed, the front end is a traditional web interface that does not reside on the blockchain, and as such, it has traditional ownership and is subject to current Internet regulations. Similar considerations apply for the brand, official news, and documentation posted on the website or GitHub. Anyhow, the community can approach the company through the communication channels in place to suggest any welcome change, but its involvement doesn’t go further. Each party is in charge of its own groups, teams, and roles, while they share Telegram and Discord groups that are jointly managed.

On-chain decisions are far more complex. The token holders forming the DAO oversee CRV and its tokenomics. Therefore, they control to which farm contracts (called gauges in the Curve protocol) token emissions are allocated and in what relative quantities, whether to implement deflationary mechanisms or adopt other kinds of monetary policies. The DAO also administers the protocol treasury, deciding not only how to spend shared resources but even which tokens to hold in reserve to diversify their holdings.

Pool creation is permissionless, as anyone can deploy a pool that is not yet existing on Curve. By using preset factory contracts, any individual can set up a pool of liquidity by simply depositing the pair of tokens not yet jointly listed through the UI. Still, the process needs to follow certain requirements concerning the tokens involved, the setting of fees and few other parameters. Not all kinds of pools can however be created through the factory contract. Thus, contracts can be created from scratch if the creator has specific needs, but the code is checked by the core team to ensure there are no risks associated with it prior to its implementation. Once a new pool is created, it is possible to also create an associated gauge. Nevertheless, it can only be integrated into the protocol after a successful DAO vote. The DAO also controls the setting of the products' parameters, such as fee collection and fee distribution once they have been deployed.

Decisions pertaining to the development of new products are quite trivial. Token holders can suggest, propose officially, vote, and even establish that a new product or feature should be built. However, what usually happens is that token holders only ask for new features and express their ideas to the development team, not in a formal way but rather through different communication channels. Despite anyone could develop a contract, the token holders are often not capable of developing the features themselves and do not have the power to force the development team to do so either, as the DAO has no control over them. Indeed, even if the decision were taken without having code or smart contracts ready to be deployed and enforced, it would merely set a direction that would require further action. The product development could then pass into the hands of the core team, or, alternatively, the DAO could issue a grant to external contributors to have it done.

On the other side, the Curve core team can independently decide to build new features, either following the community's requests and suggestions or according to what they deem fit and valuable. Once a newly developed product is ready, the company proposes it to the DAO, which votes and decides whether to implement it or not. The company could deploy the product autonomously, but it would be an independent stand-alone feature not integrated into the DAO and Curve ecosystems and thus would not receive CRV.

"Well, I mean, they (token holders) can ask for new features, of course. But really, it doesn't happen this way. When it comes to the DAO, it's controlling things on chain […] Usually, you already have the code developed and deployed. […] We just listen for users and develop things, but that's not formally required by the DAO. It's not necessarily going on the governance forum; it's just expressed in how it could be expressed when talking to users in chats or whatever. […] Formal things with the DAO come when you actually connect the newly developed things to the Curve DAO ecosystem. And you cannot really bypass it; nobody can."

Smart contracts deployed by Curve are non-upgradeable, and thus changes would require deploying new versions. Likewise, configuring the smart contracts on other networks possibly requires fixes to the code base. As such, they both follow a similar process to the development of new things.

"Upgrades are impossible. It's impossible to upgrade the code. You can contribute new things, but you cannot upgrade old things. Well, you can propose a new version, and if the governance accepts, this new version gets deployed, but the old version stays."

5.1.2. SpookySwap

Roles and memberships

SpookySwap ecosystem is quite heterogeneous involving different actors in the off-chain community and in the development too. Anyone can use the protocol to perform swaps, trading tokens via automated liquidity pools both at market price and setting price limits; participation is encouraged by a fast and intuitive user interface and the possibility of exchanging or bridging assets from or to other protocols. The protocol is also permissionless for what concerns contributing liquidity. Other actors are present, like community mods that help manage the community, solve its problems and answer questions, acting as a sort of intermediate layer between the community itself and the SpookySwap team. Then there are owners of the NFTs released by SpookySwap and more importantly BOO token holders. SpookySwap community also involves other protocols and partners that would like to introduce pools for their tokens, and even some companies from web2.

Concerning development roles, SpookySwap team constitute the most prominent actor. The team consists of eight people without an established hierarchy, four of which were also among the founding members. In addition, external collaborators are present and those other protocols who have an interest in entering the exchange. Memberships are selective, as they are controlled by the central team, which decides whether to bring in new members and manages the hiring process. External developers may contact the team to see whether positions are open, but most likely they have the chance to participate as "freelance" contributors when grants are assigned.

Incentives

The initial BOO mint allotted 7% of the total supply to community airdrops.

Liquidity Providers are rewarded with 0.17% out of the 0.2% trading fees collected by the protocol and also earn an annual percentage rate from BOO emissions if they stake their liquidity tokens in farms. As much as 72.3% of total BOO emissions is allocated to farm rewards. Community Mods have associated monetary incentives to their roles paid with developer funds.

NFT owners and token holders both earn from the appreciation of the owned assets; additionally, those who own one of the official NFTs will receive a boost on their staking. BOO can also be staked in the buy-back single-stake pool to receive xBOO tokens as a proof of deposit; ; xBOO can be in turn staked in other pools to earn more tokens. A small part of trading fees are used to buy back BOO from the market, which is sent to the single-stake pool, increasing the value of xBOO token. BOO holders also have the chance to participate in the governance of the dapp.

The team received an initial assignment of tokens for the development of the dapp equal to 5% of the supply, released in tranches. An additional 5.3% of BOO supply will be issued to it, released with a rolling distribution to ensure that the team continues to work on the project. As a result, the team benefits from the overall expansion and improvement of the SpookySwap ecosystem, providing an incentive alignment. Moreover, the team earns money from the ecosystem products that are centrally controlled, like the sale of the Magicats or the fees charged to Bridge assets from or to Fantom Network.

External collaborators receive BOO grants for their contributions and support on different projects. Finally, other protocols do not have other incentives than “listing” their tokens to enable further liquidity, diffusion, and adoption in an effort to grow and scale their ecosystems.

Communication

Communication tools that are used by the community to discuss, coordinate, and reach agreements are Telegram and Discord. Spookyswap also has a proper governance forum where to share ideas about the protocol’s evolution, but it is basically unused. Moreover, only three thousand members are active on Snapshot, signaling a general lack of participation in governance from the community, whose engagement also tends to be dependent on economic cycles and market trends.

The core team often communicates to the community about current proposals, development and roadmap via Twitter and Medium, other than being present in Telegram channels.

"In our in our community there's really two or three ways to interact with spooky swap outside of the DEX itself. And that would be either through our Twitter, through our Telegram group, or through our Discord."

Decision making

Table 5.2: SpookySwap decision-making framework.

		Initiation / proposal process	Voting	Implementation
Off chain	Front end	● Centralized	● Centralized	● Centralized
	Documentation, articles & newsletter	● Centralized	● Centralized	● Centralized
	Branding & marketing	● Centralized	● Centralized	● Centralized
	Managing teams and groups	● Centralized	● Centralized	● Centralized
On chain	Tokenomics	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized
	Treasury	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized
	Farm / vaults creation	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Pool creation	○ Decentralized	ND	○ Decentralized
	Adjusting products parameters	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Smart contracts maintenance and definition	● Centralized	● Centralized	● Centralized
	Deployment on other chains	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Governance changes	○● Semi-decentralized	○● Semi-decentralized	● Centralized

	New products	○● semi-decentralized	○● semi-decentralized	● centralized

As with Curve, governance discussions are usually handled in Telegram, Discord, or the appropriate governance forum. Voting happens on Snapshot; a minimum of 1.3k SpookyVotes are needed to raise an official proposal that can be voted by any BOO holder. Voting power is not linear, as the weight of 1 BOO is different depending on what form the token is in: 1 BOO in a single stake or resting in a wallet equals 3 vote points, whereas 1 BOO in liquidity pairs grants 5 vote points. As all decision-making happens off-chain, proposals are usually in the form of plain text containing the desired suggestion and a somewhat detailed program. The core team is needed to work on the development, encode proposals, and finally implement them on chain.

All decisions not directly impacting the protocol and thus pertaining to the off-chain realm, such as web development, user interface and experience, design, marketing, are entirely made by the core team, which owns the brand and intangible assets.

On chain decisions impacting the protocol are taken in a quite centralized manner as well. BOO holders have an input on decision-making as they can discuss and raise Snapshot proposals substantially on any subject matter. Anyhow, the community cannot autonomously pass a proposal and enforce it, as the deployment of smart contracts on-chain is done exclusively by the core team. The code base is even checked by external auditors prior to being published to prevent possible bugs or security risks that would harm the protocol.

Nevertheless, community proposals are often limited in scope and mainly concern farms, BOO emissions, partnerships with other protocols, or listing the token on centralized exchanges. They rarely deal with SpookySwap's operations and product development. Possibly more complex proposals could arise; however, the average token holder does not have enough technical know-how, resources, and information to make proper decisions or is not interested in changing how the protocol works. As a consequence, most of the proposals on Snapshot have been raised by the core team, who uses the mean to gather community feedback. The community generally trusts the developers to care about operations and ordinary protocol development. Changes impacting the protocol's operations, like fine-tuning, fixing bugs, contract development and product design are indeed often implemented without even asking the community for approval.

Given the absence of an automated implementation process, the protocol needs a central entity to execute decisions and deploying code on the blockchain. While this enables faster decision making, most likely more efficient operations and lower risks of incurring in security issues, it does greatly reduce the decentralization level. The governance process is not completely transparent and not explained on the official website; the role of the community in the decision making is not well defined. It is not clear, for example, what would happen if the community proposed something that would impact the core team or the governance itself; BOO holders have the power to pass a proposal on Snapshot but it only acts a signal, not being able to implement it and execute it.

Only the creation of a new pool is permissionless. Using factory contracts, the setup is simple and convenient, requiring the liquidity provider to provide the tokens addresses through the webpage if they are not yet present on SpookySwap.

5.1.3. 1inch Network

Membership and roles

1Inch Network encompasses different actors and roles: users, community managers, liquidity providers, token holders, 1INCH Network DAO, core contributors, corporate investors, and the 1inch Foundation. The latter is the legal and financial entity with ownership and control of the 1inch.io domain name, the 1Inch front-end, and the

Crypto DeFi Wallet, and is entitled to the aggregation protocol Pathfinder's proprietary algorithm. It also takes on the legal responsibilities for everything that could happen to the network. As such, the Foundation represents the organization with whom external parties can do business and which backs and promotes 1INCH Network. In its legal form, only the two cofounders are part of it. Together with core contributors, it is involved in the development of the ecosystem. Core contributors are a group of individuals, including business developers, IT developers, designers, lawyers, and others, working as contractors, who are committed to building and maintaining the 1inch Network, making general software development, and keeping the 1inch Pathfinder algorithm and API smoothly running. The largest contributor is 1inch Labs, which is a coordinated team with a set organizational structure to work more efficiently.

"Legally we (contributors) all are individual contractors of the foundation. We have our contracts to deliver certain services, but unofficially, without actual legal documents there is a hierarchy. There are chief officers, middle, there are juniors. Otherwise, it just doesn't work."

The community is open, as anyone can become a user or provide liquidity to the protocol, and 1INCH tokens can be obtained through exchanges or even some Fiat on-ramp gateway partners. To be able to participate in governance token holders must stake their assets. To guarantee that those with direct control over the protocol have a stake in its long-term success, while limiting the influence of funders and key contributors, various voting weights were allocated to each type of governance token:

- **st1INCH:** Non-transferable ERC-20 token representing 1INCH staked within the 1inch protocol's governance contract. It has a Voting Weight of 100%.
- **v1INCH:** ERC-20 token representing 1INCH tokens that are currently locked in the vesting contract. These tokens are held by backers, advisors, and core contributors but are not yet fully-vested. Each v1INCH has 20% Voting Weight.

Finally, to become a collaborator, one must go through a hiring process or apply for a grant, which restricts participation in off-chain development.

Incentives

The use of 1INCH is favored by an extremely efficient and fast protocol that helps save on gas costs and by the absence of transaction fees for users of the Aggregation and Limit Order Protocol. Liquidity providers to the AMM pools earn from the swap fees collected, but there are no active farming or staking programs that can boost LPs' rewards. Token holders obtain partial or total reimbursement of gas fees based on their holdings. However, unlike other protocols, there are not additional incentives or a comprehensive token economy.

Token distribution is not much oriented towards the community, with only 30% of the total 1.5 billion supply destined for community incentive programs. Most have been distributed to an original airdrop and through liquidity mining programs along 2021. A share equaling 14.5% of the total supply will form the growth and development fund, which will be used to issue grants and incentivize developers to build on 1inch protocols. The remaining tokens will be shared among various backers (33%) and core contributors (22.5%).

The Foundation earns money by cooperating with liquidity sources and monetizing the aggregation of proactive market makers (PMMs). Additionally, the company issued a 1 INCH token and raised 195 million USD in two investment rounds, in which it sold 1 INCH tokens to cooperating investors. The foundation also finances the developers' work.

Communication

Discord and the governance forum are the main channels for community discussion; users are also present on Telegram and Reddit. The Foundation releases updates and news directly to the community via Twitter and Medium. It also hosts monthly calls with the community managers to get aligned on community needs. 1Inch front-end also hosts a webpage in which anyone interacting with the protocol can provide feedback or ask for improvements and integrations of the products. Internal development discussion are carried out across various groups among the Foundation and contributors.

Decision making

Table 5.3: 1inch Network decision-making framework

		Initiation / proposal process	Voting	Implementation
Off chain	Front end	○ Decentralized	● Centralized	● Centralized
	Documentation, articles & newsletter	○ Decentralized	● Centralized	● Centralized
	Branding & marketing	○ Decentralized	● Centralized	● Centralized
	Managing teams and groups	● Centralized	● Centralized	● Centralized
On chain	Tokenomics	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized
	Treasury	○ Decentralized	○ Decentralized	○● Semi-decentralized
	Farm / vaults creation	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Pool creation	○ Decentralized	ND	○ Decentralized
	Adjusting products parameters	○ Decentralized*	○ Decentralized*	○ Decentralized*
	Smart contracts maintenance and definition	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Deployment on other chains	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized

	Governance changes	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized
	New products	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized

*Some decisions are taken by 1INCH token holders, other by LP providers.

As for the other protocols the decisions regarding off-chain elements are taken by the core team. Potentially anyone could ask for upgrades to the UI and UX or other feature requests, but it is up to the Foundation and its contributors to decide the advancements to put forward.

1Inch Network has two separate on-chain governance systems: instant governance and DAO governance. Instant governance enables users that stake their 1INCH tokens to vote directly for 1Inch Liquidity Protocol and 1Inch Aggregation Protocol's parameters setting with instantaneous effects.

On the Aggregation Protocol, 1INCH holders can vote on the distribution of the swap surplus (the positive slippage) between the treasury and the referrers. The liquidity protocol has more variables to be set. Factory governance is responsible for parameters common to all pools: the default swap fee, the default price impact charge, the default decay time, the referral incentive and the governance or treasury reward. These general settings are voted by 1INCH token holders. The setup of pool-specific parameters, except for the reward distribution, can be changed within the defined ranges through voting by liquidity providers of the pools; the default values are set for those liquidity providers who do not cast their votes. Instant governance uses a weighted average of all votes and applies it linearly over 24 hours.

DAO governance instead goes through a lengthier process. Like the other decentralized applications, prior to the decision-making process itself, the community shares ideas and suggestions about the 1inch ecosystem in Discord or the Governance forum. Anyone can sign up and engage in the conversations with the goal of gaining a rough consensus to then formalize a proposal. Proposals must meet all the requirements in the 1IP proposal template, describing the concept in detail. After gathering community feedback and eventually adjusting the proposal, the author can at any time finalize the IP and initiate a 5-day forum poll to evaluate community sentiment. The voting options are only in favor of or against the proposal. If the proposal appears to be favored, token holders with a minimum voting power of 25,000 can move 1IPs to Snapshot for an official DAO vote to confirm or reject the change. The voting period lasts seven days. Successful votes require both of the following: (i) a minimum quorum of 10 million weighted votes, (ii) a simple majority for the proposal. After the voting session, the off-chain Snapshot vote can be executed on-chain through a tool and the use of an oracle. Finally, there is a 72-hour escalation period where the IP can be challenged, followed by another 72-hour time-lock period prior to the incorporation of the 1IP into the protocol.

Despite the well-established process, 1INCH Network DAO has the power to execute only decisions overseeing the Treasury, which manages the holding and spending of community funds earned by the protocol through positive slippage on trades. Funds could also be used to sponsor the development of modules/contracts and deploy them (e.g., alternative front-ends, new network deployments, new API integrations, etc.). Still, during the time-lock period, 1Inch Network DAO Treasury multisig owners can veto malicious transactions in a 7 of 12 fashion.

All other kinds of decisions involve the core team. Indeed, the technology is hard to understand for most of the community, and as such, their proposals are non-technological. Improvements initiated by the community generally lack participation and hardly reach quorum. Most of the proposals, especially the technical ones, arise from the Foundation and its contributors and are then eventually voted on by the DAO. The core team can indeed introduce changes without formally going through the whole process needed for the community to raise proposals. For general maintenance and fine tuning or bug fixes, smart contracts are developed, generally audited by external firms, and then deployed on-chain by the Foundation. Whereas more wide-encompassing solutions, such as those concerning governance changes or new products, are usually proposed to the community for approval prior to the execution.

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

"Actually, we also need to understand what the main thing is that bothers them or that actually they (community) care about. Essentially, if we set everything else aside, it is the price of the token. This is what 99% of the community care about. So when they care about 1inch token price, they don't really care about the technology because it is already good for them. I mean, they are already using it. And I would say that 90% of the proposals of the Community are heavily 1 inch token oriented."

Pool creation in the liquidity protocol is instead permissionless as the other protocols previously analyzed. Farming is instead currently suspended, and it is up to the Foundation to decide whether to reinstate it.

5.1.4. Yearn Finance

Membership and roles

The Yearn community, devoid of formal hierarchies, includes users, token holders, strategists and contributors who work on the off-chain development and maintenance of the protocol. The community is open, as anyone can use Yearn to invest his own crypto assets, become a token holder by acquiring YFI tokens on the market and propose a strategy using existing repositories. Yearn's main product, yVaults, are capital pools that route users' deposits into the DeFi ecosystem through strategies seeking out the highest yield available in the market. Vaults automatically shift capital and rebalance the asset portfolio so that even inexperienced users can invest their crypto holdings and passively exploit market opportunities.

There is no company or legal entity backing Yearn. Contributors operate in a horizontal structure with fluid roles in the so-called yTeams overseeing different operations. Originally, individuals contributed on a voluntary basis with Yearn founder, Andre Cronje, who later issued YFI tokens to distribute control over the protocol. There are no managers administering teams, but leaders naturally arise in different fields of expertise. Moreover, there are no formal responsibilities assigned to each role; instead, accountabilities are self-assigned according to specific projects but also shared by all teams. Anyone can become a contributor, but they need to propose and offer something of value to the team and ecosystem. Consequently, an informal selection procedure is in place. Nonetheless, it is always possible to work independently and propose production to the protocol's governance for consideration.

"We don't have any company at all. We don't have any legal structure anywhere in the world; no legal structure at all. There is a group of people that is more involved in the day-to-day operations of Yearn. But actually, anyone can get in and start contributing."

"We don't assign responsibilities to people. It's self-assigned responsibilities. Like I am responsible for the docs because I said so […]. And let's say a problem occurs, a hack, an incident, whatever, […] We're a team so if there's trouble, it's all our responsibility. Because when there's a hack like the one that we had, there were multiple decisions made so it's not one person responsibility. Maybe a few persons are going to be more involved in solving the problem somehow, but the responsibility is ours. Then the responsibility of something working, we take it ourselves. It's like I said, I'm going to be responsible for this, and if I'm not, somebody will tell me, hey, what's going on? What's wrong with this?"

Finally, multisignature signers are usually suggested by yTeams and elected by YFI token holders. At the time being two members are contributors part of the yTeams while the other seven are renowned figures in the blockchain space, such as developers of other protocols or engaged members of the DeFi ecosystem.

Incentives

Users are interested in using Yearn to earn a return on their crypto assets. The protocol might not have the best returns on the market, but it provides good yields in a simple, trustless, and secure manner. Strategies are not performed if they do not generate yields higher than the fees, so that there is no risk of incurring in losses. Strategists are rewarded with a portion of the strategy's performance fee. Up to 10% of the generated yield fees by a specific strategy (performance fee) goes to the strategist. Another 10% of the generated yield fees by all strategies goes to the Yearn DAO treasury plus an additional 2% of the vault's total assets are taken as fees over the year which go to Yearn to pay for expenses like gas, developer grants, and other services. The remaining yield goes to users weighted for the capital they have poured into vaults. Going forward fees will be adjusted by the appropriate team to enable more flows of capital across pools.

Discussions are also in place to introduce rewards to YFI token holders staking YFI, such as distributing them YFI bought from the market with a share of the treasury funds, reducing fees or using a buy and burn model to reduce the supply of YFI and thus increasing its price.

Contributors in yTeams receive economic incentives in the form of one-time or monthly grants according to their work and support, which could be sporadic, part-time, or full-time. According to the interviewee, working with a high degree of flexibility and being surrounded by smart people in a respectful and meritocratic environment can be considered additional non-monetary incentives.

"The team is super smart. This may be a little bit off topic, but I would say it anyways; we conducted an internal research, like interviews with everyone, and most of the people said that before Yearn they felt they were the most intelligent person in the room. After working at Yearn they feel like they are not the most intelligent person in the room, which is cool because it means that every single person respects each other, and they can still like the different types of intelligence. So, I think for me, one of my personal reasons is the team. I think that's a plus."

The original nine signers received 1 YFI out of goodwill, but mainly perform their duties to support the protocol and its decentralization. The incentive would be that of actively contributing to keeping safe and advancing the ecosystem.

Communication

Community discussions are held across various channels including Discord, Reddit, Telegram, Governance Forum and even a Pool of Ideas to make suggestions to the yTeams. YTeams and even multisig signers interact with the community through the same channels, plus they use Medium and Twitter to reach the external audience and communicate the roadmap and evolution of the protocol. Additionally, the team uses internal chats and meetings to hold development discussions and decide on operational action plans.

Decision Making

Table 5.4: Yearn finance decision-making framework.

		Initiation / proposal process	**Voting**	**Implementation**
Off chain	Front end	○ Decentralized	● Centralized	● Centralized
	Documentation, articles & newsletter	○ Decentralized	● Centralized	● Centralized
	Branding & marketing	○ Decentralized	● Centralized	● Centralized

	Managing teams and groups	● Centralized	● Centralized	● Centralized
On chain	Tokenomics	○ Decentralized	○ Decentralized	○● Semi-decentralized*
	Treasury	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized*
	Farm / vaults creation	○ Decentralized	● Centralized	○● Semi-decentralized*
	Pool creation	ND	ND	ND
	Adjusting products parameters	○ Decentralized	○ Decentralized	○● Semi-decentralized*
	Smart contracts maintenance and definition	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized*
	Deployment on other chains	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized*
	Governance changes	○ Decentralized	○ Decentralized	○● Semi-decentralized*
	New products	○ Decentralized	○● Semi-decentralized	○● Semi-decentralized*

*Done by a multisig.

Yearn's governance shows some differences from the other protocols studied, deriving from the different way it was conceived and developed during its early stages. Indeed, Yearn Founder created and distributed the YFI token to hand over the governance of the protocol without minting a share of tokens for himself. The token was meant to be valueless, and it could not be sold or bought. Instead, it was only distributed to people providing liquidity to some pools and having money deposited on the platform.

"All the YFI was distributed as a fair launch. It was the first fair launch ever. There was no pre- mint, no presale to VCs or anything, only farming."

Yearn's governance model has evolved in time and is now based on delegated powers, where YFI holders, yTeams, and the multisignature control different facets of the protocol in what they call a "multi-DAO structure". Decision-making powers are organized as discrete transferrable objects managed by YFI holders. In this vest, YFI holders vote for changes to the protocol, to YFI tokenomics, or to the governance structure, while delegating decision-making powers over the protocol's operations to yTeams and the signing and execution of on-chain transactions to multisig members. This system should enable protocol development with a sufficient level of decentralization without slow bureaucratic procedures; however, it is not without shortcomings. In such setup, token holders have the final say on the other groups' operational control and limitations. Nonetheless, the power to execute smart contracts, and thus changes, is held by the multisignature; the signers should follow the community's will, but there is no formal way to force them.

The decision-making process starts with discussions on various channels about future releases, possible protocol developments, implementation of new features, changing of vaults' parameters and strategies, acceptance of tokens within the ecosystem, the governance structure, delegation of powers, and more; anyone can freely suggest ideas. The community is active on Discord, Telegram and on the governance forum while, yTeams usually discuss in Telegram groups.

Off-chain decisions that are executed without needing to be deployed on the blockchain network are autonomously taken by those who hold the associated power. All the front-end, official communication, documentation, marketing, and team management decisions are executed by the yTeams.

Polls on the governance forums are used to test the sentiment of what the community feels about a certain proposal. Proposals are formalized in a standardized structure called YIP, i.e. Yearn Improvement Proposal. After a three-day discussion period, anyone holding YFI can move to Snapshot for off-chain voting which lasts five days. Anyone holding YFI tokens or staking them across various DeFi protocols is entitled to vote on Snapshot. No quorum is needed for a proposal to pass; a simple majority is sufficient. Once a vote has passed, it becomes binding and needs to be implemented by yTeams if it affects operations and is then deployed on chain by the multi-sig if necessary.

While token holders can eventually write the code and submit it, it is mainly yTeams who are responsible for the encoding of the proposals passed by the community. However, formally, there are no obligations to do so, which is a common inconsistency in the governance processes of decentralized applications observed.

Anyhow the YFI token holders control the YFI minting address and thus its tokenomics, the setting of the fees of yVaults, which however has recently been voted to be transferred to a newly formed team, so to adjust fees dynamically to stay competitive with higher yields. YFI holders also control governance changes, overseeing the governance system in use and deciding on eventual shifts and distribution of decision-making powers among the different actors. This also grants token holders power to ratify yTeams and the multisignature singers.

The treasury fund is controlled together with the core teams, which need to present budgets on a bi-annual schedule and publish quarterly reports and any monthly adjustment to the token holders for approval. The teams actively manage the funds to cover operations expenditures, security costs, pay contributors and diversification of the portfolio as they deem efficient.

Any individual can develop one or more yVaults' underlying strategies, thus becoming a strategist. To add a strategy to a yVault, however the strategist must pass it via the strategy vetting procedure, which includes concept vetting, code review, and security review performed specifically by Yearn strategy team.

The proposals advanced by yTeams that needs to be deployed on-chain follow the same path as the community ones, whereas decisions affecting the operations, which they have control on, that do not need to be encoded in smart contracts are carried out autonomously.

Again, the deployment of code on the underlying blockchain network is carried out exclusively by the multi-signature wallet, where six out of nine signatories are required to execute the proposal. However, once again, there is no formal mechanism to prevent signers from executing the code they want without going through the entire governance process or posing a veto to successfully voted proposals and not executing them. Although YFI holders manage the distribution of powers, how it flows within Yearn and can limit and replace the multisig wallet, it is not clear how they do so, effectively not being able to control on chain execution. This could represent a major issue of the governance model in place which could place limits on the degree of decentralization of the dapp if not properly addressed. Currently, the problem is addressed by including community members in the multisignature signers.

The Yearn staffer interviewed says that there is a lack of community participation, which is not particularly active. One possible explanation lies in the shortcomings just mentioned. Another reason may also lie in the governance system in place. Some of the community members who were most active in governance, previously operating independently, in an unstructured manner, are now part of yTeams. Indeed yTeams, contrarily to other dapps' development teams, should not be seen as a central entity but rather as collective groups of contributors empowered by token holders to act in the best interest of Yearn within a constrained domain of action. Initially they were formed by early volunteer contributors who were later joined by specialized figures. Finally, a plausible explanation of the lacking engagement could be that the community does not have time and knowledge to follow the protocol development and trusts the yTeams to do what is best for the ecosystem.

5.1.5. Maker Protocol

Membership and roles

MakerDAO has a highly diverse ecosystem. Users, who visit MakerDAO to apply for credit or simply use DAI outside of the protocol, are the first set of stakeholders. Frequently, they are also active community members who may not hold MKR tokens but take part in discussions. Keepers, i.e., individuals or protocols that exploit arbitrage opportunities in collateral auctions, and oracles, which provide market price information of collateral assets and assist with protocol maintenance, make up the second group. A third set of stakeholders consists of external partners, such as integration partners who wish to adopt the use of DAI or another Maker product in their protocols, and collateral applicants who wish to onboard a new collateral type in Maker vaults. Then there are MKR token holders, who are either investors or passive MKR token holders who primarily hold the tokens as speculative assets, and governors and delegates, who actively participate in the governance of the ecosystem by raising proposals and voting as a way to contribute to the project.

Then there are the Core Units, the workforce paid by the Maker protocol to fulfill a variety of tasks. Their structure is relatively flat, organized in seventeen different teams: Risk, GovAlpha, Protocol Engineering, Growth, Sustainable Ecosystem Scaling, Oracles, Governance Communications, Dai Foundation, StarkNet Engineering, Collateral Engineering Services, Development and UX, Data Insights, Deco Fixed-Rate, Immunefy Security, Sidestream Auction Services, Strategic Finance, and TechOps. Each Core Unit has its own mandate and set of responsibilities, a budget to fulfill them, and a so-called facilitator, who is essentially the person in charge of the unit. Mandates are intended to be wide, open-ended, and high-level directives that allow for creativity and flexibility. Mandates from distinct Core Units may overlap, resulting in redundancy. This aids in the parallelization and decentralization of labor within the

DAO. Finally, there is, or better there was the Maker Foundation which developed and launched the protocol but now only acts as the Dai Foundation Core Unit facilitating dialogue with the proper Dai Foundation, which has been 'spun-oof' and owns intangible assets such as the IP, brand and trademarks.

Maker governance is quite accessible meaning that anyone could create a forum account and start participating in discussions and create proposals even without owning MKR tokens. Also, MKR tokens can be acquired on the open market and enable holders to participate in voting. When it comes to joining the workforce, there are more restrictions. Typically, a hiring process exists for the Core Units and, by extension, the Maker Foundation. However, there are numerous examples of people who were hired after hanging out in the Discord server and gradually becoming useful through active participation. Therefore, the hiring process is more accessible and transparent than traditional organizations, but still not permissionless.

Incentives

The first incentive for the community is the value provided by the product itself, whether through lending vaults that give access to credit or simply using DAI as a stable crypto asset. As engagement and discussions around governance are crucially important for the evolution of the protocol and the long-term viability of MakerDAO, any community member who participates in discussions and raises proposals can be rewarded for the effort. Based on the score members receive for their positive interactions, 2500 DAI per week is distributed among active participants in the MakerDAO forum. For the same reasons, delegates passing through a KYC process and adhering to the code of conduct also receive DAI compensation depending on the number of tokens they receive in delegation and their engagement on the governance forum. Rewards addressed to delegates amount to 1,000 DAI per week. Additionally, a pool of 6000 DAI per month is distributed to authors of successful MakerDAO governance proposals, given that they provide measurable impact to the protocol.

Individuals working for the core units are not eligible for the rewards; instead, they get a salary paid by the protocol, the specifics of which might vary across teams. This salary is made up of a base amount of pay in addition to any performance incentives and MKR bonuses that may be awarded.

Communication

There are many different avenues available for community participation, as was alluded to in the paragraph discussing the decision-making process. The Governance Forum is the most significant one. People from the community gather together in this space to discuss about anything and everything that has to do with the governance of the Maker ecosystem or the products it develops. Equally as significant are the Governance and Risk calls, which are held so that the official proposals that are being examined during the governance cycles can be presented and evaluated by the Core Units and the community as a whole. In addition, there are channels on Telegram, Reddit, WeChat, and Discord where members of the community can freely speak with one another. Moreover, there is a blog that informs both the local community and the outside world; however, it is not maintained up to date. At long last, the MakerDAO team has an official Twitter account from which they post official updates.

Decision Making

Table 5.5: Maker Protocol decision-making framework.

		Initiation / proposal process	**Voting**	**Implementation**
Off chain	Front end	ND	ND	ND
	Documentation, articles & newsletter	○ Decentralized	○ Decentralized	○ Decentralized
	Branding & marketing	● Centralized	● Centralized	● Centralized

	Managing teams and groups	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized
On chain	Tokenomics	○ Decentralized	○ Decentralized	○ Decentralized
	Treasury	○● Semi-decentralized	○● Semi-decentralized	○● Semi-decentralized
	Farm / vaults creation	○● Semi-decentralized	○ Decentralized	○ Decentralized
	Pool creation	ND	ND	ND
	Adjusting products parameters	○● Semi-decentralized	○ Decentralized	○ Decentralized
	Smart contracts maintenance and definition	○● Semi-decentralized	○ Decentralized	○ Decentralized
	Deployment on other chains	○● Semi-decentralized	○ Decentralized	○ Decentralized
	Governance changes	○● Semi-decentralized	○ Decentralized	○ Decentralized
	New products	○● Semi-decentralized	○● Semi-decentralized	○ Decentralized

Prior to the formal decision-making process, off-chain governance happening on the forum may be utilized in a variety of ways and for a plethora of purposes, including gathering input to support and inform forthcoming on-chain governance, freely exchanging ideas to enhance the protocol, and approving or rejecting formal processes. Discussion and debate are the most informal and unstructured methods of off-chain governance, but they still represent the cornerstone of decision-making. Through the forum's poll creation functionality, informal polls present the community with a range of options to vote on. Although more formal than debates, they cannot immediately effect protocol changes or activate processes; they are widely used to gauge community sentiment on issues affecting the MakerDAO ecosystem. Anyone can construct informal polls, and the only rules for their widespread use are civility and common sense. Signal requests are the most immediate way to impact change off-chain. These tools are structured polls whose structure and necessity are determined within the MIPs Framework. They are used to reach agreement on an issue before moving it to on-chain governance.

For ideas and well-reasoned arguments to have tangible effects they need to be structured into Governance Polls and Maker Improvement Proposals (MIPs), standard documents approved and voted upon by Maker Governance that regulates and defines the functioning and behaviour of the Maker Governance itself, MakerDAO, or the Maker Protocol. MIPs can be added, changed, replaced, or deleted through the governance process in place. MIP0 establishes the Maker Improvement Proposals (MIPs) Framework to be used by all subsequent MIPs: the core principles that any MIP should follow are specificity, completeness, avoid overlap, clarity, and brevity.

MakerDAO formal on-chain governance articulates in two well defined cycles. The Monthly Governance Cycle outlined in MIP51 establishes a consistent monthly schedule for planning governance decisions. It is primarily used to incorporate new MIPs or MIP subproposals into the Maker Protocol. Examples include adding a new Core Unit or adjusting the operating budget.

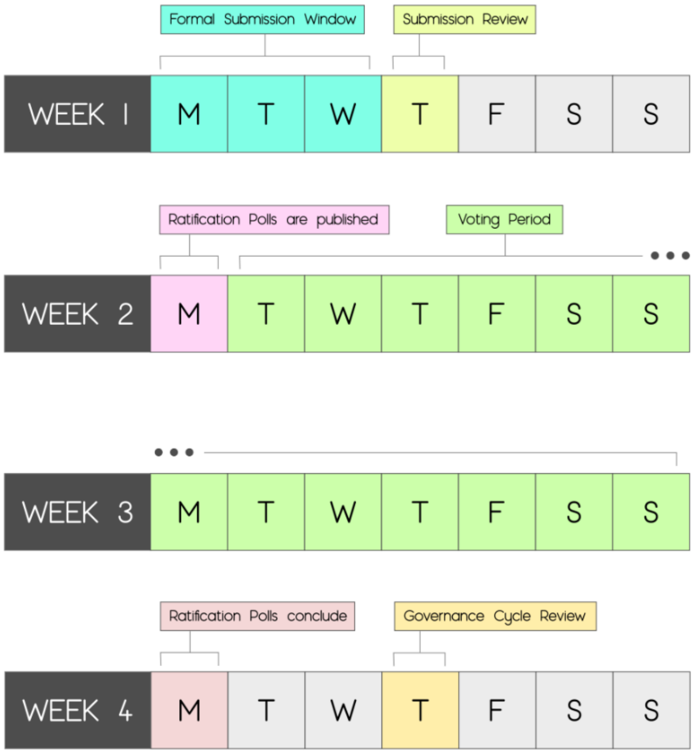

Figure 5.1: MakerDAO Monthly Governance Cycle.

The Monthly governance cycle is broken down in weeks, beginning on the first Monday of each calendar month. During the first week, from Monday to Wednesday, MIP authors submit proposals in a formal manner on the MakerDAO official forum, in the proper subcategory. On Thursday, Governance Facilitators assess submissions as part of the weekly Governance and Risk meeting. The Governance Facilitators must agree on whether each proposal that respects the MIP guidelines should be subjected to a Ratification Poll. If they deem that proceeding with a ratification poll will impair community cohesion, they may consider blocking it, explicitly explaining the reason via the official forum. Maker Governance can remove facilitators from their positions whether it suspects an abuse of power.

Proposals that conform with the rules and are not deemed undesirable will advance to the Ratification Poll stage where they are voted on-chain in a two-week timespan. Ratification Polls are used to measure the sentiment of the MKR holders giving them the opportunity to signal their support or opposition to a variety of topics, like protocol changes, improvements, goals and targets, governance processes, core units, system parameters, collateral types, etc. Polls ensure that governance decisions are carefully considered prior to being executed. Indeed, they do not yet contain executable code which, if needed, will be compiled by Core Units after the polls have been accepted by token holders and included into Executive Votes.

Monday of the fourth week, the ratification polls conclude, each proposal or bundle of proposals is either accepted or rejected. On Thursday, the Governance Facilitators perform a Governance Cycle Review as part of the weekly Governance and Risk meeting, in which they summarize and discuss the Governance Cycle with the community and discuss the forthcoming one and planned or potential submissions.

The second existing cycle is the Weekly Governance Cycle which serves as a predictable framework for Maker Governance decisions to be made on a weekly basis and works in tandem with the Monthly Governance Cycle. It allows for recurring decisions that necessitate quicker action than what happens on the Monthly Governance Cycle.

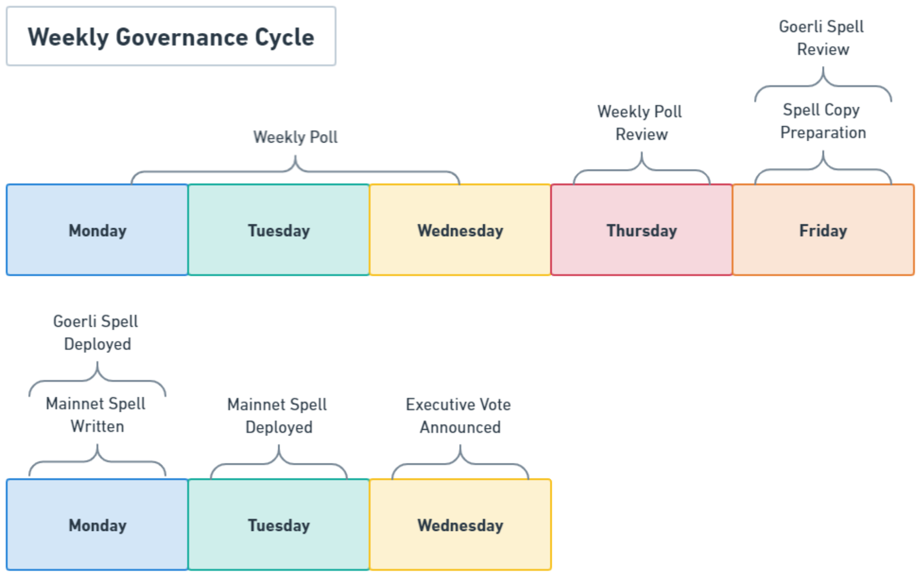

Figure 5.2: MakerDAO Weekly Governance Cycle.

Every Monday, the Weekly Cycle begins and features common recurring decisions proposed through Weekly Polls, non-binding governance polls that determine the weekly Executive Vote's contents to implemented. Weekly polls cannot modify system parameters independently (MakerDAO); they set what will be included in the next Executive Vote. Non-Standard Weekly Polls can also be drafted, which are non-binding polls with arbitrary time-sensitive decisions requiring a separate vote to speed up their execution. Facilitators are the only ones allowed to create Non-Standard Weekly Polls because they have already earned the community's trust. Non-Standard Weekly Polls are utilized only when the Weekly Governance Cycle is deemed too slow for the proposed solutions to have the desired impact or to respond to sudden changes. For example, the Risk Core Unit Facilitator can require immediate parameter changes for a collateral type due to a sudden shift in market conditions or a detected vulnerability. Ratified Facilitators may submit Non-Standard Weekly Polls related to their Core Unit mandate. If necessary, they could also skip the Non-Standard Weekly Polls and enter rationale directly into the weekly Executive Vote.

The weekly polls are open until Thursday before the Governance and Risk Call, where the results are reviewed. Every Friday, successful Weekly Polls are included in the Executive Vote content.

Successful polls, pertaining to both weekly and monthly governance cycles, are encoded by the Engineering Core Unit in so-called "spells" and released on a test net first and then on the main net. Finally, the Executive Vote required to execute the spells and thus technical changes to the Maker Protocol is put to a seven-day vote on Wednesday of the following week. Governance Facilitators may decide to skip the weekly Executive Vote if it doesn't offer any changes to the Maker Protocol that are important or compelling.

Voter-approved modifications are not immediately effective. Instead, a Governance Security Module, established by the governance itself, delays changes up to 24 hours to grant the opportunity to token holders to protect the system against malicious proposal.

Both Executive Votes and Ratification Polls are voted on the Maker Foundation Governance Portal by MKR holders. To be eligible to vote it is necessary to temporarily lock up MKR tokens into the Voting Contract.

Maker governance somewhat resembles Yearn's one, where core teams are contracted by the token holders to provide specific services to the ecosystem and carry out the operational tasks. Procedures are in place enabling token holders to adapt the workforce and their structure to the specific needs required based on real-world performance and emerging challenges. MakerDAO however is able to enforce changes through their on-chain execution, whereas Yearn necessitates the multisignature signers to do so.

As for who participates in the different decision types, starting with off-chain decisions, the Maker Protocol does not have an official front end to interact with. Instead, access to the set of Maker smart contracts that enable Dai Lending is offered by third parties that have built UIs on top of them. The most important one is the Oasis app, a DEX created by the Maker Foundation in 2016 to enable the exchange of MKR and Dai with other tokens. The app was then split off into its own entity and now operates independently. MakerDAO websites only host the documentation, blogs, the forum, developer guides, and links to other apps and services using Dai; they are administered by the token holders through the appropriate Core Unit. Finally, the official governance portal used to vote for both polls and executive votes is hosted by the Foundation. Alternative UIs could be eventually developed by the DAO.

To a large extent, permission is not required to write documentation, resources, or newsletters; rather, any individual is free to do so on a voluntary basis as long as they adhere to the structures established by token holders.

Token holders together with the Core Units are responsible for managing teams and groups throughout all of the available communication channels and within the Core Units themselves. The token holders are the ones who validate the existence of the different teams, while the Facilitators are responsible for managing the Core Units and hiring and firing their members.

Off-chain decisions do not necessarily need to go through the lengthy process previously described; on-chain decisions instead do. Anyone can propose decisions pertaining to all the different scopes defined in the decision-making framework, whereas, as said above, only MKR token holders have the power to vote and implement changes on chain. Operational choices linked to them that are mandated for the different Core Units make an exception. The teams are indeed given flexibility to operate within their mandates to reach the agreed objectives and performances; still, they need to go through the governance cycles to make changes affecting the underlying smart contracts or processes in use.

A couple of clarifications are needed regarding the treasury and tokenomics. Core Unit budgets allotted by the Maker Protocol treasury need approval from the token holders. Once the budgets have been validated, the teams can manage them as stated in their plan without having to ask for other permissions on each expenditure. Tokenomics of the Protocol is peculiar as MKR supply is dynamic: tokens are created and destroyed to keep the stability of the Dai peg and ensure the Protocol is always solvent. MKR is destroyed when the Maker Protocol's system surplus exceeds a minimum threshold; excess Dai deriving from the interest paid by borrowers is auctioned for MKR that is then burnt. Inversely, when the Maker Protocol is running a deficit and the system debt exceeds a maximum threshold, MKR is created and auctioned for Dai to recapitalize the system (MakerDAO). MakerDAO launched with one million MKR tokens at its inception and the supply oscillates around that value. The smart contracts regulating MKR are controlled by the token holders.

5.1.6. Furucombo

Membership and roles

Furucombo community is substantially formed by users, fund managers, few individuals contributing to certain projects, COMBO token holders and external protocols. There is no hierarchy within the community, but there are some more involved individuals that contributed to certain projects to support the protocol. One has engaged in marketing activities to spread the protocol awareness and attract more users, a second has helped building a dashboard on Dune Analytics regarding activity conducted on Furucombo, finally a third member is helping the team to manage a sort of governance coordination tool. Moreover, there are Discord community moderators operating on a voluntary basis.

Individuals who have an extensive knowledge of decentralized finance and the crypto economy and are contracted to manage the assets and portfolios of other users are referred to as fund managers. The application to become a fund manager is open to anyone, but to be granted the role, it is necessary to go through a know your customer process. The procedure entails filling out a Google form and having an interview with a representative from Dinngo. This is done so that the organization can verify that the applicants are actual people and not bots or potential fraudsters. The core team has introduced some verification in order to ensure greater security in light of the fact that the crypto economy space is home to a large number of scams and custody risks, many of which are aimed specifically at inexperienced individuals.

Token holders own COMBO either as a speculative assets or to participate in governance. Although the influence in the governance is currently limited Dinngo is planning to shift more powers to the community in the near future.

A few external protocols also interact with Furucombo to integrate their features expanding their accessibility and user base. Finally, there are Dinngo, the company behind the protocol ideation and development who still manages most of the processes and is focused on improving the protocol, and a few venture capitals backing the project.

Incentives

Incentives for users are to be found in Furucombo's value proposition of being a comprehensive aggregator helping users to navigate and work with DeFi protocols in a single place. Thanks to the composability offered by the Furucombo, users can bundle several different actions to perform complex transactions crossing many DeFi products, like using flash loans to exploit arbitrage opportunities, swapping tokens before depositing them in a specific protocol or automatically staking LP tokens after providing liquidity to a pool. Reversely, Furucombo also gives builders a platform to express the potential of their product. COMBO holders do not receive incentives as there is no opportunity to stake COMBO tokens to earn rewards nor other allocations.

Instead fund managers can charge management and performance fees respectively on the assets they administer and the returns they generate.

Finally, Dinngo is paid with the treasury funds to cover the development and administrative costs. Moreover, it raised money through a funding round backed by venture capitals and the COMBO token launch sale on Balancer, another DeFi protocol.

Communication

Discord, Telegram and the governance forum are used by the community to gather together, chat and discuss. The forum however is not very bustling and mainly sees posts from Dinngo members. Medium and Twitter are also used to communicate news and plans with the external audience. Finally, the company hosts community calls with the community to align them on development.

Decision Making

Table 5.6: Furucombo decision-making framework

		Initiation / proposal process	**Voting**	**Implementation**
Off chain	Front end	• Centralized	• Centralized	• Centralized
	Documentation, articles & newsletter	• Centralized	• Centralized	• Centralized
	Branding & marketing	• Centralized	• Centralized	• Centralized
	Managing teams and groups	• Centralized	• Centralized	• Centralized

On chain	Tokenomics	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Treasury	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Farm / vaults creation	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Pool creation	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Adjusting products parameters	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Smart contracts maintenance and definition	● Centralized	● Centralized	● Centralized
	Deployment on other chains	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	Governance changes	○● Semi-decentralized	○● Semi-decentralized	● Centralized
	New products	○● Semi-decentralized	○● Semi-decentralized	● Centralized

Most decision-making powers in Furucombo are still exercised in a centralized fashion. This is due to the fact that a partial distribution of decision-making powers has been only recently enacted with the introduction of Snapshot voting. Activity on the voting portal however has only witnessed two official identical proposals posted by Dinngo to introduce a protocol fee as a percentage of the initial funds invested by users performing transactions with the create mode. The proposal has been posted twice since it did not initially meet the quorum.

The decision-making process is not very open and transparent and lacks a clear structure and definition of the community's role within it. Indeed, the various stakeholders are not provided with any documentation that is available to the public explaining the governance system in place. Nonetheless, any member of the community is free to use the governance forum to take part in discussions, make suggestions regarding governance, or make requests regarding the addition of new protocol features and integrations with other protocols. Despite this, there is a low level of participation in the forum, and the majority of the few topics that have been posted are requests for assistance with the operation of the application or problems that users have encountered.

On Snapshot, the ability to launch official polls is restricted to individuals who hold a minimum of 30 thousand COMBO tokens and to members of the core team. Community participation is lacking: less than 50 members have subscribed to Furucombo's Snapshot page and cast a vote, and no proposals have been initiated by the community as of yet. All COMBO token holders can vote on active proposals during a seven-day period. There is a quorum of 6 million COMBO and a simple majority of yes-votes is needed for the proposal to pass. Eventually, token holders can already encode proposals but need the team to review and deploy the code as voting happen off-chain. Indeed, Dinngo is responsible for the implementation and execution of all decisions made by both the team and the community. In any case, given the limited participation of token holders and the knowledge required, it is highly unlikely that code will be developed by token holders themselves. The only exception happens with builders of Furucombo cubes, i.e., blocks containing customized transactions or investment strategies, who develop the contracts themselves.

Currently, the core team has the power to decide what and when to release new features, make modifications to the protocol and the product, adjust parameters, introduce governance changes, and more without confronting the community. Still, Dinngo usually listens to the community about what to build and release, seeking support from the ecosystem. Anyhow, there is no formal obligation for the company to post polls on Snapshot, and operations are usually carried out autonomously.

The treasury managing fees collected on swaps is controlled by a multisig wallet; at present all the signers are part of the Dinggo team although the company plan is that of transferring some to the token holders and to partners from other protocols.

All decisions pertaining to the off-chain realm are centrally made by Dinngo. The front end is not public and can only be modified only by the protocol engineers. The company is focused on improving the UX and UI so that it is easier to build on top of the protocol and to attract more users. The company also manages the branding and marketing of the protocol, incentive activities, as well as the teams and official documentation and communication.

5.2. Cross case analysis

Leveraging on the existing literature on the topic of blockchain governance, the study aims to investigate the factors and elements that influence the effective distribution of powers in public blockchain-based decentralized applications and enable true decentralized governance. Hence, the cross-case analysis has been performed by crossing the results stemming from the blockchain governance framework and the decision-making framework for all cases to depict the role and impact of the different variables on the governance models.

The results are structured in paragraphs that shed light on how the governance variables identified in the framework derived from that developed by Pelt et al. affect governance practices and influence the effectiveness of decentralization in the cases under analysis in this paper.

5.2.1. Communication and information systems

As stated in the literature, blockchain networks involve political and social dimensions that cannot be addressed by relying solely on technological tools and algorithmic administration of governance, which lack the flexibility needed to face unforeseen circumstances and do not account for the human factor and broad involvement. Indeed, the improvement and development of protocols and the underlying code base require consensus-seeking and human intervention to adapt to evolving needs and market dynamics.

For decisions to be implemented and executed, specific proposals must be developed. The wide variety of decisions to be made with respect to the application's operational structures and development need to align with the interests of multiple stakeholders and might concurrently require specific knowledge and proprietary information, which frequently resides with the development teams. Indeed, there is usually a disparity of knowledge and possession of information between development teams and the rest of the community. Numerous decisions require deep technical or economical knowledge that the average token holder does not have.

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

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

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

because he likes the projects or because he wants to speculate."
(MakerDAO)

Prior to the formal proposal and voting processes, governance of decentralized applications usually begins off the blockchain on various communication channels, where all members of the community and development teams have the chance to interact in a permissionless way. Discussions and debate can be used in a variety of ways and for a plethora of purposes, such as freely exchanging ideas to improve the protocol, seeking consensus and agreements to support and inform changes, gauging community sentiment on existing issues, and approving or rejecting formal processes and structures in place. Possibly, discussion topics can be better structured and detailed in proposals. Some protocols then move motions that seem to have ecosystem support on Snapshot, where token holders have the chance to cast their vote for or against the change. As the voting happens off-chain, the outcome mainly acts as a signaling system, given that there is no code to be executed.

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

"There are some coordination tools, like a forum, where governance discussions happen. […] People really need to know what the proposals they see are about. […] there is also an independent group that assesses the risks of different proposals to keep the governance informed. Who really knows that the code proposed in the governance, like that of a pool to get CRV incentives, is correct? Even if the pool code is standard, who really knows

that a stable coin is really stable and that it is not a scam coin? There is some risk assessment required." (Curve)

"They (community and DAO) can of course use the Governance Forum or they could write on our Telegram and Discord channels. Some other unofficial groups can be created on Telegram and stuff like that […]. Few good discussions happen on the governance forum […]" (Curve)

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

However, aside from a few exceptions, the asymmetry in information leads the community to primarily consider in its discussions aspects that are elementary or pertaining to a few limited areas, such as token allocations and protocol fees. What frequently happens is that the community just makes suggestions without first structuring their ideas into a problem or identifying what viable data-driven solutions might be. These factors in turn tend to leave community members out of the process of formulating complex decisions.

"We also need to understand what the main thing that bothers the community is or that actually they care about. If we set aside everything else, essentially what 99% of the community care about is the price of the token. So, when they care about 1Inch token price, they don't really care about the technology because it's already good for them, since they are

already using it. I would say that 90% of the proposals from the community are heavily 1inch token oriented." (1inch Network)

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

"Very often people use factory pools where they don't need to write the code, but they do propose pools to get CRVs. That happens very often." (Curve)

"[…] a user could indeed write on the governance forum, and then multiple people can discuss over there, but it's just a user expressing an idea. It's nothing formal; it's not that there is some vote necessary, and if the vote happens, somebody has to follow it; nothing like that. It is more like people interacting with each other, coming up with whatever suggestion, […]. When it comes to the code deployed, perhaps governance can step in and accept it or not in the DAO. But before that it's more like interaction between people, and there is no predefined structure" (Curve)

Despite being scattered, unstructured, and non-binding, ideas arising from the various stakeholders are often taken into consideration by the core teams. In most cases, however, they just serve as inputs for their decisions; development units do indeed have separate conversations from the rest of the community where they identify the changes that need to be made and determine how to address the issues that are being experienced.

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

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

"For example, if you want to change the AMM formula it probably requires some thoughtful descriptions. So, a user could of course just express it publicly and we would pick up this thought […]. […] ideas are usually heard, that's the thing." (Curve)

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

As a result, what is observed is that token holders are mainly confronted with yes-or-no proposals that external partners and protocols suggest or that the community contributes itself such as: "Should we list token X?" Should we set parameter X in way Y? Should we pay for X? Should we add X feature? Etc." or with already drafted solutions and policies offered by core teams.

Example of community proposals:

"Deploy a "tricrypto3" pool (wBTC + wETH + FRAXBP).

This is a proposal to create a new tricrypto pool, called "tricrypto3", which will consist of wBTC + wETH + FRAXBP. Motivation: the FRAXBP is quickly becoming one of the pillars of the Curve ecosystem and Frax Finance plays an integral part […].This *proposal requires the Curve core dev team to launch the "tricrypto3" pool, as this cannot be done from the factory contracts as you can only pair 1 token with the meta fraxbp."*

"[1IP-3] Snapshot Proposal: VOTE to make $1INCH deflationary!

Summary: Implementing a strong deflationary mechanism to the 1inch token. Abstract: Removing Single-Asset-Staking & Farming Completely. Replace with a deflationary mechanism."

Example of external partner proposal:

"[Proposal] Mean - DCA Buyback Pilot Program.

The objective of this pilot program is to provide a better understanding through example that DCAing is a better way to execute buy-backs within the treasury. Allocate $1M worth of ETH (249.376559 ETH @ $4010 per ETH) towards this buyback program. Create a 30 days position YFI to ETH within Mean Finance at a rate of 8.31255197 ETH per day"

Examples of core team proposals:

"Ownership Vote 217 proposes to add the GaugeManager extension to both the stableswap and crypto factory ownership proxies, enabling permission-less reward management for factory gauges.

Abstract: Currently, the only way third-party rewards can be added to factory deployed gauges is via a governance vote or with the assistance of a core team member. Adding this contract will enable gauge creators to bypass both, and simply manage gauge rewards themselves. Note: the gauge manager will only be able to add new rewards, and grant distribution rights. Gauge managers do not have control over the distribution period, or the ability to claw back rewards once given to the gauge."

"YIP-65: Evolving YFI Tokenomics.

Summary: Evolve the role YFI plays in Yearn over four distinct phases, cementing the vision of the token as the fundamental foundation of governance.

Abstract: If adopted, this proposal seeks to:

Direct a portion of YFI that is bought back by the Treasury as a result of BABY (buy back and build) as rewards to those YFI token holders who actively participate in Yearn Governance.

Evolve the role YFI plays in Yearn Governance through four distinct components. These build on top of each other and thus come in a particular order:

1: xYFI. Distribute YFI that's been bought back with Treasury tokens as rewards in a YFI vault.

2: Vote-locked YFI. Introduce ve-style locking of YFI (veYFI) for up to four years (exact max duration tbd), where a longer locking duration gives a greater share of voting power and share of YFI rewards. An early exit from the lock is possible by paying a penalty that is rewarded to the other locked token holders.

3: Vault Gauges + Voting. Introduce vault gauges where vault depositors stake their vault tokens and earn YFI rewards according to their veYFI weight. YFI are allocated to gauges based on weekly governance votes.

4: "Useful work" features. Expand the duties and responsibilities of veYFI voters, and their locked YFI, in exchange for earning additional protocol rewards. Pending the tbc v3 vault design.

Give the mandate to Yearn Developers to roll out the above components at their discretion as and when they become feasible.

Restrict the YFI eligible to vote in Yearn Governance as only those staked in xYFI (from Phase 1 and onwards) or vote-locked in Yearn (from Phase 2 and onwards).

As the proposals above suggest, the community is generally left out of the problem identification and strategy formulation processes, and even the determination and assessment of the alternatives that could be pursued to address an issue. In most cases, before the community has the chance to express their views or while they do so in unstructured ways, the core teams have already determined the policy details, what the improvements should look like, and why the solution proposed would benefit the ecosystem.

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

"There are two or even three people at 1Inch Foundation who are community managers, who try to help and guide the 1inch DAO participants in their voting. However, again we come back that they are people who essentially are working for a centralized entity which is 1Inch Foundation. Within 1Inch Network there is no hierarchy, there's just a wonderful bunch of people with 1inch tokens. Sometimes they offer something themselves without intervention of community managers but then it's extremely hard for them to reach the quorum, because it's hell of a job." (1inch Network)

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

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

The structures that decentralized applications have set in place could be adequate enough to make complex decisions and answer complex questions, but the problem lies in how such systems are used, often in a way that does not involve the whole ecosystem. Instead of a real decentralization, it seems that the dispersion of decision-making power is fictitious: decisions are taken by a small number of more powerful individuals and then they are proposed to the wider community, which only expresses its approval or rejection. Therefore, token holders and DAOs tend to have a decision-making power that they are unable to fully exercise; instead, they often rubber stamp centrally made decisions or exercise veto power when granted by the governance system in place.

To fully involve the wider community, or just the token holders, in the governance of decentralized applications, proper processes need to be used to foster constructive and transparent discussions, enabling stakeholders to coordinate and identify the changes that are needed or desired. The governance debate needs to become a consensus-seeking exercise to reach an optimal compromise, where communication channels force participants to focus on the underlying reasoning, causes, theories, and data rather than polarizing contests about the integration of specifying tokens, creation of new pools, setting of fees, or other parameters that miss the big picture and the important issues.

Proposition 1: *Granting token holders the possibility to raise and vote on improvement proposals for the protocol is not enough to have an effective decentralized governance. The* *governance system should have well-functioning communication and information structures and use them properly to provide stakeholders with the proper data and knowledge to make decisions and include their views.*

5.2.2. Roles

Off-chain governance is generally permissionless as it consists in the discussions surrounding protocol operating processes and development that take place on various communication channels where anyone can join and participate. The stakeholders involved are not bound by code to perform specific actions, but rather they freely operate as they deem fit and determine what is in their best interest. Despite the fact that these are not formal processes and do not directly impact the protocol, they remain the bedrock of the decision-making process. The previous paragraphs show how the proposals put forward by the development teams tend to be held in higher regard and given more consideration than those arising from the community. This is due to the level of recognition and trust they have established within the ecosystem and the information asymmetry already described.

A second consideration to be made is that decisions pertaining to the off-chain realm tend to be made by a central entity, which once again is represented by the company or, if there is no formal entity, the core team backing the application. There is a technical motivation behind this, which can be used to explain why this is the case. Off-chain decisions, as should be obvious, are not implemented and executed on the blockchain, which is the only place where token holders have the ability to exercise power that is both significant and effective. Anything that needs interaction with Web 2 and the non-crypto world cannot be governed by code. A legal entity or some other type of business organization may be required to comply with pre-existing national and supranational regulations when making decisions concerning such activities as registering intellectual property rights, brand ownership, or raising capital.

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

"We have 1inch Pathfinder that is proprietary and that belongs to 1inch foundation. And this Pathfinder is the key to the success of 1 inch. And you cannot copy the pathfinder [...] and actually even myself I am not allowed to look at the code, I wouldn't understand anyway. There are only a handful people who can modify the Pathfinder and who can work with it" (1inch Network)

Regulatory frameworks for blockchain-based applications and organizations are still a grey area under development, although governments are working towards statutory provisions, as demonstrated by the recognition of blockchain-based limited liability companies in Vermont and DAOs in Wyoming. Despite being interesting, the question of what type of business organization would best suit the needs of protocols to interact with the external environment and how they could even include some community representatives, as in a cooperative, is beyond the scope of the research. This research also did not take a deep dive on the process by which decisions are made within the core teams themselves. Anyhow, the teams that have been investigated tend to have an organizational structure being described as flat.

"Yeah, well, there is a company which is developing the code. There are employees of that company […] It's not very hierarchical, so it's a fairly flat structure, I would say. But of course, there are things some people work on, and other people work on different things, so that's pretty much it." (Curve)

“It’s a relatively flat organization built up out of multiple teams that we call Core Units. I think there’s now 16 of them and they all have their own mandate.” (MakerDAO)

Partnerships with actors external to the blockchain also require an organization to do business with, in order for them to be well defined and successful. Indeed, it would be difficult to make arrangements and come to business agreements with a diverse community without official representatives. Even in decentralized applications that do not have a legal entity representing them, such as SpookySwap, it is the core team that manages relationships with other organizations outside the blockchain, but also with other blockchain protocols, unless the partnership specifically involves the governance token.

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

“Partners and actors external to the DAO are controlled by team members. […] I talk almost daily to protocols both within Fantom and outside of it. These would be big things like Chainlink, Anchor, maybe other layer 1s like Optimism or Arbitrium […]. There is constant talking to protocols that want to partner with us, that want to do some kind of coordination, or want to get their tokens whitelisted, including Web2.” (SpookySwap)

“Well, there is a company that develops the code.” (Curve)

Although the smart contracts on public blockchains are universally accessible and can be triggered by sending transactions via a node, a user interface greatly improves accessibility for non-technical users and enhances the user experience. Front ends are provided on traditional web interfaces and need to be hosted on servers, thus requiring someone to operate them—something that cannot be easily done by a group of token holders. Moreover, front-end development needs designers and developers to build the interface users interact with, which again makes Dapps dependent on core teams. It could be possible, however, to build parallel front ends interacting with the same set of smart contracts, but if users are not capable of understanding what is written in the transactions and smart contracts, they would need to trust that the operations actually performed are those they intended to produce.

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

"The code is a fork of UniSwap V2 and we have added a UI layer over that which we've developed. […] SpookySwap is known for its excellent user experience and UI. So that is kind of where we differentiate ourselves by having not only a faster UI, but just more intuitive and that users really like to use." (SpookySwap)

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

"Several contributors host the front end" (Yearn)

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

A third important point to be observed is that the governance mechanisms employed by decentralized applications to distribute decision-making powers resort to voting systems to determine the acceptance or rejection of a given policy or change. Voting power depends on the number of governance tokens one individual holds or locks into a contract for a certain period of time. As a result, wealthier token holders can have a greater impact on decisions, and thus the community, which is usually entitled to a consistent share of the tokens, would play a substantial role. This is true when considering the voting process. However, the execution of decisions and the encoding of desired changes into executable "spells" are once again mainly done by the core team. Despite the fact that anyone could develop a contract, the token holders are often not capable of developing the features themselves and do not have the power to force the development team to do so either.

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

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

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

"The current status is that Dinngo, the company, still manages the main development resources, so we develop features for the protocol [...]" (Furucombo)

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

"Well, there is a company that develops the code. There are employees of that company and we typically discuss things together [...]" (Curve)

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

"There is a group of people that is more involved in the day-to-day operations of Yearn." (Yearn)

"We usually work with auditors as a centralized entity. When we develop code, we work with auditors to check the code we contribute. […] the company can deploy something and it's up to the DAO to accept the smart contract, whether it goes into the DAO ecosystem or not" (Curve)

"The code of the smart contracts is audited to ensure they are safe" (Spookyswap)

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

"When proposals are made, they are not encoded yet; some of the contributors write the code and deploy it on chain. […] A year and a half ago, someone sent a proposal "I want an S&X synthetics vault". The proposal passed, but I cannot put a gun to anyone's head to make a synthetics vault, that's not going to happen. And then there was no yield available. So, the proposal passed, but it was never implemented because it was not possible since there was no yield, and anyway, I cannot point a gun to a developer's head to build it. I think we ended up doing it like a year and a half later." (Yearn)

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

"The organization basically is now based on this framework called Core units […] and they all have their own mandate. Each Core Unit has a so-called facilitator and that's basically the person that is responsible for that team. […] And as a facilitator, I'm basically mandated to hire and fire people from my team as long as we do our work right. And every year we have to renew our budget […]" (MakerDAO)

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

"The yTeams have groups where they talk about stuff and they decide, sometimes on chain, sometimes off chain; it depends. If it needs on chain execution it's going to be on chain; if it is an off-chain decision, it is usually conducted as a poll in Telegram. Then for budget in particular, we have an Issue on GitHub so that it is transparent." (Yearn)

Voting power is exercised through the use of tokens, a mechanism that typically favors the wealthiest actors or those entitled to the largest allocations. Thus, voting power is only partially related to the role of a stakeholder in the ecosystem, to the extent that tokenomics initially defines the distribution and ownership of the governance token for each actor. Instead, the implementation of decisions and executive power are often concentrated in the hands of the core teams, who are also in charge of overseeing operational tasks.

De facto, the community has the ability to influence outcomes and have an impact on policy-making, but the involvement of the token holders in governance systems does not necessarily imply that they are able to execute decisions, or participate in maintaining the code base, defining and performing operating tasks and routines, as well as core business activities. The study also finds that in protocols with a higher degree of decentralization, token holders constituting a DAO delegate authority and responsibilities to core teams to run the operations and take autonomous action on behalf of the community, whereas in less decentralized protocols, the team retains direct control of the execution and do not necessarily need to confront token holders with their work.

Proposition 2: *the role of stakeholders influences governance as there is a disparity in the weights of different roles between decision-making and execution. Core teams are more influential than the rest of the community, even in more decentralized protocols*.

5.2.3. Incentives

According to mechanism design theory, a successful governance system should use individual incentives and local information to accomplish desirable results. In order to leverage individual incentives, the governance system of a digital platform should first ensure that platform owners and users can fulfill their particular goals and interests via the platform itself (Chen, Y., Richter, J. I., & Patel, P. C., 2021). When stakeholders can do so while also meeting the platform's overall goals, the governance system is defined as incentive-compatible. Thus, when incentive systems are properly designed and align the interests of different stakeholders, platform participants are more likely to legitimately commit to the pursuit of the common good, thereby alleviating concerns over power imbalances.

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

> *"The Foundation earns money through cooperation with the liquidity sources. […] We also aggregate PMMs, and those market makers are the ones who we monetize on currently as the Foundation. Also, there were two rounds of investments which raised 20 and 175 million USD. […] A big chunk of tokens would be distributed to the people who at some point in time are or were parts of the Foundation. The investors are also getting lots of it." (1Inch)*

> *"The Foundation has a contract with us (contractors) for us to provide them with certain services and for which we get certain money" (1Inch)*

> *"Contributors get economic incentives like monthly grants or one-time grants, depending on how they want to contribute. […] Some time ago we minted 6666 More YFI to pay contributors and more stuff." (Yearn)*

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

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

"We have done some over the counter sales to partners of ours" (Spookyswap)

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

"As for Furucombo protocol itself, currently we charge a transaction fee. We charge a percentage on the amount you transacted on Furucombo and that money will be stored in the Treasury" (Furucombo)

"We raised some money last year […]. Our developers are employees of the company, so we use the money we raised to pay them." (Furucombo)

Members of core teams frequently hold a considerable portion of the governance tokens and thus wield significant voting power. This may appear to induce them to pass proposals to pursue their own objectives, but the incentive systems just described are designed to ensure that teams are engaged in developing and growing the protocol in a way that meets the interests of the entire ecosystem. Indeed, the salaries guarantee that the core teams keep contributing code and maintaining the protocol, while token allocation ensures that they are interested in growing the value of the entire ecosystem as well as the demand and utility of the governance token which largely determine its price.

In DeFi applications, liquidity providers are also greatly incentivized, as the capital they provide is necessary for the proper functioning of the protocols; this is especially true in DEXs, where high volumes of liquidity are needed to achieve a successful and efficient exchange volume. Liquidity providers are rewarded with a portion of the fees charged to users, and additionally, they receive governance token emissions when they stake their LP tokens, which represent the capital paid into the pools. Governance tokens are distributed not only to attract more liquidity but also so that the protocol can keep fairly low fees as a means to also incentivize the application's adoption and usage. Indeed, the liquidity providers' incentives need to be balanced with those of the users, as the two parties often hold opposite interests. It is also true, however, that in DeFi applications, individuals tend to cover a variety of roles, both using and providing liquidity and holding governance tokens.

"The liquidity providers get about half of the fees which the pools make. In exchange for the other half of the fees which they 'give away', they get CRVs" (Curve)

"All the YFI was distributed as a fair launch; it was the first fair launch ever. There was no pre- mint, no presale to VCs or anything, only farming. The YFIs that that point in time at launch were only 30,000 tokens they were all farmed. (Yearn)

"Liquidity providers, for the capital they provide, will have in return a couple of things. For one, they will get a percentage of the fees when those tokens are traded. Then they will also get an APR from our BOO emission. Essentially, we have a governance token that emits a certain amount of BOO every second and each farm receives a certain amount of BOO depending on its set-up." (Spookyswap)

"After the launch we did several rounds of mining events to encourage users to use Furucombo. Last year we also had a staking program, so if you staked COMBO or LP tokens then you could earn COMBO tokens. There are also other kinds of marketing events to encourage some actions from the users where they can earn some rewards including COMBO tokens." (Furucombo)

To promote the usage of the application, especially in the early stages, protocols might also reward users with airdrops, i.e., free distribution of tokens.

“There was an original token allocation to early users.” (Curve)

“They launched the DEX and did very large airdrops to the community to distribute the tokens.” (Spookyswap)

“At first, when we launched the token, we did some airdrops to all users.” (Furucombo)

Instead, the community is often not particularly incentivized to contribute to governance and development; rather, it has incentives to just hold or stake the tokens.

“We are not planning any incentives to increase participation in governance because if you don’t have the information or the knowledge, you shouldn’t participate, to be honest.” (Yearn)

“The users who hold 1INCH token get their gas refunded. The amount they get depends on the number of tokens that they hold.” (1Inch)

“[...] Staking BOOs also grants you an APR which is roughly around 5%, but it can change, at a certain point it was even 100%. And then you can earn additional tokens and a boost on the yield by owning a magic cat, i.e., Spookyswap NFTs.” (SpookySwap)

As a result, token holders may keep tokens only as speculative investments and not because they are interested in participating in the governance of the protocol. Moreover, in addition to their financial value, appreciation, and eventual staking returns, native tokens can also be supplied in standard liquidity pools for other users to swap, allowing providers to earn trading fees. The absence of incentives destined for governance activities could be one of the reasons explaining the general lack of community participation and engagement in governance discussions and decision-making procedures.

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

> *"Only 3.1 thousand token holders have joined our Snapshot. […] Most of the proposals have been proposed by the team. (Spookyswap)*

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

> *"Participation depends on the topic. If the topic is controversial, like when we were going to mint some tokens, there is more participation in governance. When we proposed something concerned to changing the governance, there also was some participation. But if the change is small, we don't have that much participation. There is some voting apathy. […] the multisignature signers' rotation had close to 0 participation." (Yearn)*

> *"I think currently there are not many proposals made by the community on the forum. […] I haven't seen many of them really wanting to initiate*

something new. We haven't had formal proposals actually initiated from the community." (Furucombo)

Instead, some protocols, such as Curve, reward those individuals who lock their tokens to get voting power and also impose penalties for unlocking prior to the due date. In return, they tend to have a more active community, despite the fact that the incentive is not directly tied to the participation itself; possibly once the user has locked the token and cannot make another use out of it, it may as well engage more in the governance system. Finally, MakerDAO does not offer incentives to passive token holders, while it pays contributions for those members more involved in the governance, which encourages more ideas and dynamic discussions.

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

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

"If you are a delegate, you basically commit to spending more time on becoming knowledgeable and becoming an informed voter. […] Recognized delegates that have gone through a KYC process and have committed to the code of conduct, are eligible for receiving a DAI compensation based on how many MKRs are delegated to them." (MakerDAO)

"Proposal committees, usually they're part of the workforce, and if not, they get compensated for their work." (MakerDAO)

"When it comes to other participants, for example passive MKR holders, right now there is not really any incentive going on. There are not farming or other rewards." (MakerDAO)

To conclude, participation in governance often does not have any incentives other than the very possibility of taking part in the decision-making process. When it is incentivized, it may require token holders to lock their assets for different periods of time in order to obtain both the rewards and the voting power. Lack of incentives may lead to community opinion being expressed by a handful of powerful token holders, as those with little voting power may face higher opportunity costs to engage in governance. The possibility of delegation, eventually coupled with the presence of disincentives for those who do not participate in governance despite having the right to, would likely favor the increase of community voice and influence. The time-locking of tokens with penalties for pulling-out goes in a similar direction, as it pushes decision-makers to vote for the best of the ecosystem to see the value of the tokens increase in the long term.

Finally, DeFi applications' adoption is influenced by cross-side network externalities: the higher the volume of liquidity provided, the higher the number of users who have access to more efficient trades. At the same time, the more users, the more there should be LPs who would have higher chances of gaining from trading fees. The number of pools and tokens listed should also experience similar effects. Theoretically, such externalities increase the overall adoption of a dapp and its token value, which in turn creates incentives' compatibility and alignment. Once again, decision-makers are interested in finding resolutions that would benefit the whole community and ecosystem. Therefore, we could say that having proper incentives in place favors good governance, whether decentralized or not.

Proposition 3: *incentives schemes influence the participation in governance mechanisms and in contributing to the growth of the application. Distribution of decision-making powers needs to come with properly set, balanced and aligned incentives to ensure each participant in the dapp ecosystem has an interest in its success.*

5.2.4. Evolution and reasons for decentralization

Finally, it is important to recognize the reasons why governance decentralization is sought in the first place. Understanding what leads founding teams to distribute governance tokens to the wider community and, with them, some decision-making power, might help explain the governance systems adopted. Three main reasons are behind the phenomenon: (i) ideological reasons aligned with the ethos of blockchain technology and its founding motifs, (ii) to make the protocols more efficient and resilient to censorship and external regulations, (iii) to gather community feedback and more ideas on how to move forward.

> *"The idea actually comes from the beginning of the 20th century corporate America when it was introduced that the workers of certain factories or companies would be given shares of the same companies, so they become shareholders. And this idea we think makes the American Corporation work extremely successfully and efficiently." (1inch Network)*

> *"Initially, Andre, the founder, did it because he is lazy and did not want to maintain the protocol. Thus, he gave the tokens away so that some people would come and maintain it. For us, that we are the people that came and started maintaining the protocol, it's super important because you cannot think that you have the best ideas in the world. So, if you involve more people, you are going to have a collective intelligence. That's one side of the things. On the other side, there's the reality that decentralization is better to avoid censorship; the more decentralized you are, the more difficult it is to*

be censored. We want to be trustless, permissionless, and transparent. We want to be available for everyone, independent of the jurisdiction where one is from. We don't want to make the decision to like gatekeep our smart contracts to some people. These are the two sides of why we want to involve community and we want to decentralize. (Yearn)

"It's always interesting to have things decentralized, autonomous and existing without your wish, because then they are much more resilient. I think for resiliency against some regulations, it's probably important to have everything as decentralized as possible. And by decentralized, I mean that not even the creators could overrule the system. So, it should be really and fully autonomous. […] You could say that it's kind of an ideology and vision of what the future will be and trying to be in line with that future. Simply, I think that things which are not decentralized will not have less of a chance to survive." (Curve)

"Since the inception of Spookyswap there has been the idea of involving token holders in the decision-making process. The first proposal happened on May 2021, not long after the application was launched. […] The reasons are mainly ideological; we would like to make the protocol more decentralized and have users more involved in the decisions affecting it […] but it still needs to be discussed how the application can run on its own" (SpookySwap)

"I would say the main answer is resilience. The whole reason we want to build this Internet economy using crypto is because it's resilient. […] I think we are already at the phase where nation states, countries like the US and their governments, might see this crypto economy as a threat to their native economy, and they might want to control it and regulate it up to a

point where the core principles of Maker and the core principles of crypto get exceeded or limited. And once you're at that point, you want to make sure that a project can sustain itself even when a nation-state is hostile. So, you want to make sure that the contributors are somewhat independent of one nation-state or multiple nations and that also goes for the infrastructure that is used. I think that's the whole reason. It is the same reason why Bitcoin was invented and why it has a decentralized network or governance system. MakerDAO has an organizational structure with the same principles behind it, but for organizational design and governance design." (MakerDAO)

"I think one of the reasons is that it is something we should do as a Web3 team. Also, we already have so many COMBO holders, and I think they want to be one because they care about the project and believe in what we propose. I think it doesn't really matter who the people who build the stuff are. So as a result, I think token holders should be able to have a say in what we are going to do next and discuss how to allocate the resources we have. I think that's the main reason, but I also think that it's a little bit idealistic." (Furucombo)

All protocols share a vision of creating more decentralized organizations, increasing the level of community involvement, and distributing decision-making rights. Still, as the research has shown, the core teams keep a central role in the protocols' development, especially when it comes to programming and updating the code base, similar to what happens on the underlying blockchain networks. Regardless of how powers are distributed, protocols often require and rely on maintainers to build and maintain the smart contracts which constitute the essence of the protocols. This also derives from the fact that decisions typically need to be translated into executable code.

Moreover, decentralized applications start being fairly centralized, as a core team is necessary to oversee the original design and deployment, define the operational structure, and bootstrap the application in its early life. Indeed, it does not make a lot of sense and might not even be feasible to design products in an unstructured and individual contribution-based manner. Initially, the team needs to be driven by the necessity of finding product-market fit because, if the product does not work, there is no need for decentralization, as involvement of the community would not save the application.

"[…] otherwise in a decentralized manner you would not be able to build products, you need to have this organization type of structure and people working." (1inch network)

"In 2017 we felt blockchain had a lot of opportunities and we were thinking it could help us to solve some issues in fintech. That is the reason we did a little bit of pivoting and started to hire some blockchain engineers. At first, we were building a decentralized exchange. We worked on our project for around a year, but we felt like we didn't find a right angle to position ourselves to compete with other centralized exchanges because at that time the entry barrier was super high, so people were still using centralized exchanges. At that point we realized […] DeFi composability is amazing. So, we did a hackathon within our team and a group invented the Furucombo concept." (Furucombo)

As a result, dapps' builders are challenged to find ways to introduce community ownership at a later stage to guarantee the long-term health of the system while ensuring the security of the code base and that decision-making does not stagnate, leading to inefficiency and a lack of action. It is at this point that the core teams start to consider how to use tokens to incentivize continued contributions and participation from the community and institute DAOs. Their enactment aligns with blockchain ideology and the willingness of dapps' builders to gather community feedback and ideas with formal mechanisms. Still, as evidenced in the analysis within the cases, there is no unique and winning form of DAO structure. Usually, DAOs have a somewhat limited scope and control the tokenomics and treasuries of the protocols and possibly the governance contracts, which can be easily governed according to predefined rules with algorithmic administration of governance. Indeed, at this point in time, DAOs lack flexibility and do not seem to be mature enough or able to run protocols independently, autonomously, and efficiently, as it is difficult to guide the entire development of the protocol's code and make rapid decisions without proper teams of experts.

"But then of course you need to have some kind of structure in place, because if you have a fully decentralized and flat organization, then it's going to be very hard to do work because people are going to feel lonely, without guidance, and misunderstood and it's just going to be very difficult to make something happen. So, you need some kind of organizational structure, but it should respect the principle of decentralization." (MakerDAO)

"A DAO cannot control people; it can control things which happen on chain. But DAOs can control people indirectly by controlling streams of tokens." (Curve)

Moreover, algorithmic administration of governance is not suited to all decision types and phases since it does not address how upgrades and improvement are envisioned and ideated in the first place, it does not take into account human interaction and is not even applicable in all those contexts where decisions do not require execution on the blockchain layer.

This is the reason why even more decentralized protocols have specifically appointed development and operation teams alongside the DAO, whose powers are delegated and supervised by the token holders themselves. Still, to make the protocols more efficient and resilient to censorship and external regulations as envisioned, there is a need to reduce reliance on a single core team and increase participation in development roles, possibly establishing several independent groups contributing towards a common goal.

Proposition 4: *decentralized applications are still experimenting with the right form of organizational structures and community empowerment mechanisms by way of progressive decentralization. DAOs can help builders in achieving their vision of protocols running as designed without censorship from external regulations, but alone they are not suitable to ensure continuous development of the protocol.*

6 Discussion

This chapter of the research integrates the main findings stemming from the case studies and presents key considerations that can be drawn from the analyses. The research on the various decentralized applications allows for some critical insights into their governance models as well as, on a higher level, the governance variables, and interrelationships between them.

How governance variables and decision-making processes impact on governance

Starting from the higher level and the theoretical framework used for the analysis, the research has captured the role and impact that the variables ascertained by previous scholars have on the functioning of the governance systems of blockchain protocols. Decision making processes and mechanisms, and the different participants' roles have revealed to be decisive in determining the protocol's decentralization level as they define the extent to which different stakeholders have a say in the application's development and functioning and they dictate who has authority over certain processes and how such control is exercised. On the other hand, communication systems and incentives can be considered variables supporting the good governance of blockchain projects, and they determine whether decentralization is real and works effectively and efficiently. Indeed, the dispersion of decision-making rights among stakeholders is not sufficient for governance to be truly decentralized if it is not supported by well-designed structures that include and empower the community from the proposals' ideation to their implementation and execution.

To have meaningful and impactful contributions originating from different stakeholders, decentralized applications must have systems in place that distribute the proper information needed to support decision-making to all those actors who have a say in the decisions. Moreover, communication systems should be designed to ensure that identified issues, changes, and improvements are shared with all relevant stakeholders, beginning with the problem definition phase. Individuals will only be able to take part in the decision-making process in a significant way if they are given the opportunity to recognize and assess the various potential courses of action and expected outcomes. If information asymmetries are present or communication channels create disparities among different groups of stakeholders in their ability to organize action and reach agreements, then blockchain systems will mainly rely on the most knowledgeable actor to make decisions, which would then be presented to the rest of the community for approval. The resulting decentralization would then be fictitious. Even in the most extreme scenario of an application in which participation in all steps of the decision-making process, from the raising of proposals to the implementation of approved decisions, was conducted in a permissionless manner, individuals with no knowledge and no way to coordinate would probably not bring any change because their ideas would likely have no solid foundation, get no traction in the community, and not even have the code to be executed.

Well-designed incentive systems have a twofold function. First, they incite to action stakeholders that are needed for the proper functioning of the protocols themselves, like liquidity providers, they encourage user adoption, stimulate and reward community contribution, encourage token holders' involvement, and reward the work of core teams. Second, incentive schemes ensure that the parties that wield more power or simply a have stronger influence on the system—in the case of DApps, the core team—act in a way that benefits the entire environment rather than pursuing their personal interests, as is common in centralized platforms. Only with properly aligned incentives for all the various dapps' participants decentralized applications can have good governance, grow in value, and fulfill the needs of all the ecosystem participants. This is why the design of such variables is fundamental for the proper functioning of a truly decentralized governance model.

On chain and off chain governance use

Switching the focus to the governance of decentralized applications per se, the results shed light on who holds decision-making power, how it is dispersed among stakeholders, and what and how key decisions are made and enforced in Dapps. All applications analyzed show some recurring elements and similarities but still there is no prevailing governance system or structure in place. DeFi is a rapidly evolving space and thus protocols are still experimenting with the design of different governance models that can quickly react to the sudden changes and evolving market dynamics. To keep moving forward and evolve in a highly dynamic environment, decentralized applications rely on both off and on chain governance and still extensively use and need social governance and human involvement. It could be stated that in the context of decentralized applications algorithmic administration of governance, or governance by the blockchain enables the establishment of rigorous on-chain decision-making mechanisms and processes for autonomous rule enforcement. For example, through algorithmic administration of governance the rules and processes embodied in the smart contracts defining and enabling how proposals can be raised and presented for on-chain voting, how long does the voting period last, who can cast a vote, the conditions for proposals to be approved and when code is deployed on the underlying blockchain network are set and supported.

While transparent, predictable and fair in execution, as depicted in literature, algorithmic governance lacks flexibility to handle the unexpected and unforeseen and cannot take into account human factors which are essential to govern any community. Code itself can govern transactions, procedures, and protocol operations but it cannot govern human interactions and neither account for evolution and adaptation or the elaboration of rules and processes in the first place. Indeed, the identification of challenges and needs of making decisions, the gathering of information, the formulation of ideas, evaluation of alternatives and final choices as well as the upgrade and improvement of protocols remain within the domain of human effort.

The cases show that most decisions are first discussed on a social level on governance forums or private communication channels among the community and developers before being encoded and deployed on the blockchain, reaffirming the importance of off-chain governance in decentralized applications and probably in most non-infrastructure blockchain protocols. Blockchain allows for autonomous decisions and changes to the application protocol to be implemented. However, not all decisions can be automatically translated and implemented on-chain. Actually, few things are directly set with pure on-chain governance systems; an example is the instant governance of 1inch Network for tweaking products' parameters or the deployment of liquidity pools. The instances in which sole on-chain governance works efficiently are limited and bound to the scope and complexity of the decisions being taken. It might be good for quick, reversible decisions characterized by little uncertainty, but it does not work well in situations where uncertainty needs to be removed and thus information gathering plays a crucial role. Especially irreversible decisions that have meaningful consequences and require drastic changes need to be made carefully, methodically, and after consistent debate and discussion. For these kinds of decisions and all those where the needs and views of heterogeneous stakeholders need to be reconciled, off-chain governance is better suited, which explains its extensive use.

Design and distribution of decision-making systems and powers

Additionally, the analysis shows that decision-making processes are not copied and pasted across all types of decisions but are frequently tailored to the purpose. Indeed, the governance system is designed to fit the environment and the scope of the decisions with clear goals in mind. Governance design aspects are given careful thought when dealing with serious and far-reaching decisions and consequences. The people, whether being the founders or the entire community, responsible for establishing voting systems, for example, need to decide what kind of vote will be used, who will be allowed to vote, and what conditions must be met before a decision can be reached. It has already been said numerous times that for legitimate decentralization, the governance design must be backed up by structures that facilitate and support coordination and actions aimed at achieving remarkable common objectives. Information systems, for example, should supply relevant information pertinent to an impeding vote to those who require it. At times, however, it is more efficient to let more knowledgeable individuals take decisions in their field of expertise, also following what has been discussed above about reversible and irreversible decisions. This is why decision-making power is not just randomly and uniformly distributed among stakeholders. Typically, token holders are often given control over the mechanisms for token distribution itself, treasury fund spending, and the setting of product parameters. These are the features and topics that they care most about and that affect them closely. Instead, operational decisions, determination of expenditures of development resources, partnerships with external actors, modifications of processes, and substantial development work are carried out by core teams, which can either be delegated by token holders or directly retain their control from the beginning. Despite introducing some centralization, having experts writing the code and carrying out operational tasks ensures a high level of security and efficiency, which is fundamental for the thriving of the ecosystem. This is also somewhat necessary given that most community members do not possess the know-how, skills, and necessary information to encode proposals.

Semi-decentralization

Another consideration to be made is that centralization does not necessarily have to be considered negative and decentralization positive. Dapps try to find a balance between the two extremes, but none qualify as fully decentralized. In the observed cases, groups of individuals — the core teams — have more control while their power is restrained through partial distribution of powers and authority, and decision-making is driven by community feedback. These blended forms enable more effective processes and outcomes and are less likely to reach deadlocks. Having a formal leadership structure enables faster decision-making processes and rapid reactions to changing scenarios or adverse environments. Operational decisions need to keep up with the pace of the environment and development; it is not efficient to involve the community in voting on every matter, which might have a little impact on the protocol or might just be made to streamline it. Even if all decisions were transparently voted on-chain, as previously stated, many of them would be raised, discussed, and designed in private groups through self-managed initiative. Even voting power is less decentralized than token ownership; where delegation is instituted, many individuals entrust their power to community representatives to take decisions for them or unanimously vote as an informal group that centralizes "behind the scenes".

The research findings are in line with what is observed in the study by Chen, Richter, and Patel on the governance of digital structures, which comes to the conclusion that semi-decentralization appears to be a better performing governance structure. Both fully decentralized and fully centralized governance structures have their own drawbacks, which are mitigated with semi-decentralization. The authors state that in a completely centralized governance structure, authority over governance and decision-making powers are concentrated among platform owners, allowing them to determine processes and outcomes that may disadvantage and alienate platform participants. In such configurations, platform owners may prioritize their own interests over those of the larger community and ecosystem. Instead, in a fully decentralized governance system, platform members collectively have complete governance control, enabling them to express their views, pursue their goals, and exploit their local data via platform governance. However, the overdistribution of governance power can diminish the chances of collective action and slow down the decision-making process. According to the authors, a moderate degree of decentralization is more likely to achieve incentive compatibility, increase informational efficiency, and contribute to the achievement of desirable governance outcomes, as also evidenced by this study.

Traditional forms of governance with a new vest

As a result, the research finds that more than enabling drastically new forms of governance where power is held and exercised by the community, at this stage, blockchain seems to support or transform existing ones by increasing collaboration and participation among stakeholders in a project. The structures observed are not too dissimilar traditional organizational forms with the advantages of transparency, inclusiveness, privacy, auditable code, and bottom-up feedback systems.

Operations are almost exclusively carried out by core developer teams, which can be regarded as both the managers and workforce of dapps, even if there are usually no rigid hierarchical structures in such blockchain projects. While the accessibility to such development teams is more open than centralized counterparts, it is not permissionless, and thus protocols cannot be considered to be managed be the collectivity. Even more, the cases have shown that the practical and tangible contribution of individuals and platform participants in the protocol development is limited, unless arising from other independent group of builders. It could be thought as a new boosted paradigm of open innovation, where developer teams not only consider internal ideas and resources but make use of external ideas, tools and market routes to advance their technological competencies and drive innovation. The transparency of the underlying code base and composability of DeFi makes it even more efficient in reducing the risks of innovation and the R&D costs thanks to the use of already developed solutions and the possibility to build on top of other applications.

Token holders somehow represent shareholders of decentralized applications and can place a limit on the powers exercised by the platform builders and monitor their actions. This authority, however, is influenced by the protocol's level of decentralization and the extent to which the founding team has empowered token holders. Indeed, in protocols with higher decentralization levels, all protocol updates, changes, and releases are shared with the community and voted upon by token holders, who have the ultimate say on the code that is deployed and executed, whereas in less decentralized dapps, token holders merely express their support for or opposition to those issues that core teams confront them with. In contrast to traditional corporations, token holders are thus more engaged in the decision-making process. However, it often happens that the token holders are not involved in the execution and grounding of the proposals and plans of action for which they might have voted but rather express their opinions on already decided matters.

Similar to traditional organizational forms, token holders are exposed to capital gains or losses in the form of increased token valuations and may receive additional rewards in the form of financial profits derived from the protocol fees after having paid liquidity providers or additional token emissions, which can be seen as equivalent to stock dividends. In addition, token holders might enjoy the right to appoint members of an eventual multisignature responsible for the code execution or even ratify development teams, not unlike corporate shareholders nominating the board of directors' members. Furthermore, protocol founders tend to own a significant share of tokens and wield considerable power, similarly to what often happens in traditional companies that go public, with the difference that in dapps the remaining share of tokens are usually distributed as incentives through various initiatives rather than sold in financial markets. Though, often times, dapps' builders have sold a share of tokens to corporate investors to raise capital and fund development even prior achieving full functionality. While some elements and concepts introduced by blockchain governance are new to the space, many are just different iterations of existing traditional tools, and resulting organizations are not so distant from the long-established ones.

The myth of trustlessness and "hidden" vision

Finally, the findings of the research are somewhat at odds with the well-known and celebrated ethos of blockchain technology, which seeks to eliminate the need to trust a central entity. In decentralized applications, not all stakeholders are equal; there are still groups of individuals that continue to take the reins and make crucial choices on behalf of a wider ecosystem of participants, often without having real accountabilities assigned, similar to what has been observed by other studies on blockchain networks. Indeed, in the majority of cases, the applications do not assume liability for the operations they enable; legal risks and obligations are borne by the applications' participants.

The need to trust other humans has not yet been overcome, even in decentralized applications. Blockchain infrastructure enables "trustlessness" and "decentralization", but what is built upon it is the result of human decisions. The partial reliance on a team of developers also results from the fact that "trustless" DAOs are not capable of independently managing entire protocols by code, unless no changes were going to be made to the code base once deployed, which would likely lead to their obsolescence in a short time.

A final thought that could be further investigated is that decentralized applications are neither companies nor organizations but rather protocols and products; therefore, they do not have an inherent vision or strategy. Decision making in DApps does not appear to include vision setting and strategy formulation, despite the fact that these are the foundations of all platforms. More likely, the different parties that constitute the DApp ecosystem have their own perspectives. This is probably more applicable to the founding team and only partially to investors and the whole community. It is easier for the company to see the big picture and act in a cohesive manner than it is for the multitude of individuals with different needs and roles that interact with the protocol. Even more, the entity behind the original design and development must have had a vision and strategy in the first place when creating and bootstrapping the application, whereas the community has formed and gathered around the application at different times to make use of it. However, as the protocol develops and the community gets involved in the decision-making process, a shared vision is necessary to guarantee that all parties can contribute toward common goals and add value to the protocol. This is especially important as the protocol becomes more decentralized. Without guidance provided by a core team, the protocol faces the risk of stalling and becoming incapable of reacting to changes and anticipating future trends.

7 Conclusion

Since its inception, blockchain has evolved as a distributed computational tool enabling applications beyond currency exchange, emerging as a technological solution capable of redesigning patterns and paradigms of human interaction and coordination. By distributing power and value across peer-to-peer networks, blockchain promises to eliminate the need for trust in a central entity, thus creating more efficient, equitable, and collaborative systems and societies. The rise of decentralized applications is one of the most appealing representations in this sense, but whether they deliver on their premises remains unclear. This research thus investigates how Dapps' governance varies from that of traditional organizations, who, if anyone, has the power, how this is distributed and how community plays a role in the decision-making processes of such systems.

To explore such questions, the existent literature has been deeply studied first to gain a deep understanding of blockchain working mechanisms and peculiarities by describing the characteristics and functioning of the technology. Then the current state of blockchain technology, including its evolution and the notion of decentralized applications, has been investigated. Finally, literature on blockchain governance is examined, explaining the conceptual framework that support the empirical analysis by identifying the key variables that define this phenomenon. Due to the lack of specific tools to investigate governance of decentralized applications, an additional framework has been constructed to highlight who are the actors participating to the different phases of the decision-making process of dapps.

For a more accurate case selection and to understand how the overall decentralized applications ecosystem is evolving, a preliminary analysis covering the top 150 Dapps by user adoption in March 2022 was performed. This scrutiny highlights DeFi's prominent role in the space.

Six case studies of both emerging and established DeFi applications examine the research objectives, investigating which factors influence the effective distribution of powers in Dapps, and the implications for the governance of these systems.

7.1. Research contributions

The present study provides contributions to both academia, Web3 builders, participants and even regulators.

From a theoretical standpoint, this study advances the existing literature on blockchain and its effects on the governance of blockchain-based decentralized applications by presenting insights on a topic that is virtually unexplored in the academic literature. The research provides a construct to map, identify, and explain how decision-making unfolds in DeFi applications and how different stakeholders are involved in such processes. Moreover, it contributes to the understanding of the interrelationships among governance variables and how they affect and support both efficient and decentralized governance systems.

On the managerial side, the study provides Web3 builders with insights for designing the governance systems of the protocols they develop and on how to align the needs of various stakeholders to achieve common goals. Practitioners can refer to this research to plan and analyze Dapps' governance systems and to comprehend how to distribute decision-making powers to the community with the support of carefully designed information systems and incentive schemes so as to facilitate cooperation toward the common good while avoiding deadlocks.

Participants in decentralized applications also benefit from the research to grasp the role they can play in such systems, identify applications in line with their views and collaborate with developer teams to build better systems.

Finally, regulators also have the opportunity to understand how decentralized applications are governed and how power flows within them allowing them to design suitable legislation if deemed necessary.

7.2. Limitations and future research

As with all empirical studies, this research is not exempt from limitations, which may open opportunities for further research. All six cases analyzed belong to the DeFi category, which can place a limit on the generalizability of the results. Therefore, a further avenue of research could study Dapps operating in other sectors and offering different kinds of services. For example, it would be interesting to see how decentralized social media applications are governed, given the controversy over how traditional counterparts are controlled. Other applications that provide more complex services, such as gaming, require a core team for continuous development and will most likely produce results comparable to DeFi or show an even a greater extent of centralization.

Additionally, a study across sectors could help establish a common framework for decision-making by identifying similarities among the scope of decisions made in different contexts.

Moreover, the present research does not make distinctions among the stages of evolution of decentralized applications. Future studies may look at the governance practices used in conjunction with the stage of life of the applications or focus on a longitudinal view of the evolution of governance in decentralized applications.

Finally, it would be interesting to analyze the topic through the lens of open innovation, given the similarities noticed with certain practices used in open innovation.

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Acknowledgments

First, I would like to thank my family and beloved ones for the constant support provided throughout my studies and my life, giving me all the means to succeed. It is also thanks to you that I have achieved this important milestone today.

I would also like to express my gratitude towards my friends, who have been close to me for a long time and who I know I can count on even in difficult moments. This journey would have not been the same without you by my side.

I take this moment to thank Politecnico di Milano for giving me the opportunity to pursue an enriching academic journey, which has helped shaping the person I am today and the person I aspire to be in the future. I would also like to acknowledge Professor Luca Gastaldi and Giacomo Vella for the guidance provided in writing the master thesis.

Finally, I would like to thank myself for believing in my capabilities and putting in the maximum effort to reach this goal.

Niccolò