

Decentralized Autonomous Organizations and Decentralized Finance, A Bibliometric- and Content Analysis

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Abstract

Decentralized Autonomous Organizations (DAOs) present a new technological advancement that may pose a challenge to traditional organizations in terms of governance and decision-making. DAOs offer a novel approach to organization and collaboration by implementing a decentralized, immutable, and trustless system. These organizations run on blockchain technology through the use of smart contracts, enabling autonomous and self-executing operations.

Despite their potential, DAOs still face uncertainties regarding their security, governance, and scalability, among other challenges. To determine research gaps and aid in the successful development of DAOs, this paper conducts a bibliometric and content analysis, which is currently missing from existing literature, to provide structural support for this process.

This paper identifies the most significant research streams and influential articles on DAOs, providing a comprehensive overview of the current state of this field. Moreover, it investigates the performance of major Decentralized Finance (DeFi) DAOs in light of these research streams, offering insights into their practical applications and effectiveness.

To facilitate future research in this domain, the paper proposes several research questions for each identified research stream. These questions aim to address gaps in the current understanding of DAOs, paving the way for novel research that can contribute to the development and enhancement of this innovative technology.

Keywords: Decentralized Autonomous Organizations, DAO, Blockchain, Bibliometric Analysis, Smart Contracts, Decentralized Finance

Sammendrag

Desentraliserte autonome organisasjoner (DAO) representerer et nytt teknologisk fremskritt som kan utfordre tradisjonelle organisasjoner når det gjelder styring og beslutningstaking. DAOer tilbyr en ny tilnærming til organisasjon og samarbeid ved å implementere et desentralisert, uforanderlig og tillitsløst system. Disse organisasjonene er basert på blokkjedeteknologi gjennom bruk av "smart-kontrakter", som muliggjør autonome og selvutførende operasjoner.

Til tross for deres potensiale, står DAOer fortsatt overfor utfordringer, blant annet angående deres sikkerhet, styring og skalerbarhet. For å avdekke forskningshull og legge et fundament for en vellykket utvikling av DAOer, blir det i denne artikkelen gjennomført en bibliometrisk- og innholdsanalyse, som per i dag mangler i eksisterende litteratur, for å gi strukturell støtte for denne prosessen.

Denne artikkelen identifiserer de viktigste forskningsstrømmene og mest innflytelsesrike artiklene om DAO, og gir en omfattende oversikt over den nåværende statusen for dette feltet. Desentralisert Finans- (DeFi) DAOer undersøkes i lys av disse forskningsstrømmene, i tillegg til at det blir gitt innsikt i deres praktiske anvendelser og effektivitet.

For å legge til rette for fremtidig forskning på dette området, foreslår artikkelen flere forskningsspørsmål for hver identifisert forskningsstrøm. Disse spørsmålene tar sikte på å vise til hull i den nåværende forståelsen av DAOer, og baner vei for ny forskning som kan bidra til utvikling og forbedring av denne innovative teknologien.

Nøkkelord: Desentraliserte Autonome Organisasjoner, DAO, Blokkjede, Bibliometrisk Analyse, Smart Kontrakt, Desentralisert Finans

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1. Introduction

Bitcoin, the first Blockchain technology as we know it today, was launched in 2009. This innovative technology has captured the attention of people worldwide, presenting a new approach to transactions and trust in the digital realm. With decentralized and secure transactions, Blockchain technology lays a foundation for the creation of new types of applications and innovations that are transparent and immutable.

As the potential of Blockchain technology became increasingly apparent, developers began exploring new use cases beyond just cryptocurrency. One of the most notable applications of Blockchain technology is the creation of Decentralized Autonomous Organizations (DAOs). DAOs are organizations that are run entirely on the Blockchain, without the need for a central authority or intermediaries. DAOs have emerged as a novel and promising innovation in the field of blockchain technology as digital organizations that operate through a set of rules encoded on a blockchain using smart contracts, with decisions made democratically by its members based on their voting power. DAOs have the potential to automate decision-making processes, reduce transaction costs, and provide transparency and disintermediation in organizations. Despite its benefits, there are challenges, including security issues, divisions in blockchain communities, lack of accountability due to unregulated organizations, and more.

This paper aims to provide a structured approach for the successful development of DAOs by conducting a bibliometric and content analysis of existing academic literature. The goal is to capture the different research streams and fill the current gap in perspectives on DAOs. In order to do this, this paper seeks to address the following research questions:

1. What are the most influential works in the field of DAOs, and what are the key topics and themes addressed in this work?
2. What is the current state of research on DAOs, and what are the main research themes and theories in the field?
3. How has the concept of DAOs been defined and evolved in the academic literature, and what are the key dimensions and characteristics of DAOs?

4. What are some major applications of DAOs, particularly in Financial industries, and how have they performed in the context of key topics that have been detected in the academic literature?
5. What are the main drivers and barriers to the adoption of DAOs, and how can they be addressed or mitigated?

Through the use of bibliographic coupling and citation count, this paper employs bibliometric analysis to investigate academic literature, and conducts a content analysis to further delve into this. Its objective is to identify different research streams, pinpoint the most impactful articles in the field, and explore trends and developments in DeFi DAOs. Ultimately, the paper aims to provide valuable insights into the current state of DAOs and lay the foundation for future research.

The rest of the article is structured as follows: (1) A literature review provides an overview of the key topics and theories in the field of DAOs. The paper reviews the literature on blockchain, smart contracts, agency theory, game theory, transaction cost theory, institutional theory, and other key topics. The review also covers the macro, meso, and micro perspectives of DAOs, including law and regulation, governance, applications, security, scalability, and decentralization. (2) The paper then covers the methodology, hereby presenting the data collection method and what methods are used to answer the aforementioned research questions. (3) Next, the methods are applied to find the most influential articles, research clusters, identify some of the most prominent applications of DAOs in financial industries, and examine how they have performed in the context of common themes in academic literature. (4) The paper's discussion section discusses the main drivers and barriers to adopting DAOs and gives suggestions for future research. (5) Finally, the paper concludes by summarizing the main contributions as well as addressing the limitations of this paper and what measures have been taken to limit these.

2. Literature Review

The first part of this literature review explores the core components of DAOs and then DAOs themselves. It begins by discussing blockchain technology, including the mechanisms and infrastructure that enable blockchain technology to function securely and transparently, such

as consensus mechanisms and cryptography. Second, smart contracts are explored, which are self-executing programs that are written on the Blockchain. This section examines smart contracts' potential benefits and limitations, including their potential to revolutionize various industries. Finally, a review of DAOs, organizations whose management and operational rules are written on the Blockchain in the form of smart contracts. Potential benefits of DAOs are highlighted, such as enabling more democratic and participatory forms of decision-making and exploring the challenges and limitations that need to be addressed for widespread adoption and success.

2.1.Blockchain

Blockchain Technology (BLT) is a decentralized ledger technology (DLT) that uses encrypted and chained blocks of data across a peer-to-peer network. Its key advantage lies in its properties such as immutability, security, and transparency. It thus creates a framework for decentralized autonomous ecosystems without the need for mutual trust and centralized control. For a blockchain to exhibit the desired properties, it requires certain mechanisms, such as consensus mechanisms that enable nodes to participate in a controlled manner and incentive mechanisms that reward participants for their contributions. Additionally, the technical infrastructure is essential for the proper functioning and security of the blockchain system (Morrison, Mazey, & Wingreen, 2020). Blockchain stores data in the aforementioned blocks, verify data with distributed consensus algorithms and guarantees security and privacy in data access and transmission with cryptography. Blockchain has many potential applications in various industries, including smart devices, a decentralized sharing economy, enterprise management, and more (Yuan & Wang, 2018).

Blockchain technology is commonly associated with cryptocurrencies, most famously Bitcoin, but it has far-reaching applications beyond cryptocurrencies and payments. (Hsieh, Vergne, Anderson, Lakhani, & Reitzig, 2018). However, the first implementation of blockchain technology was introduced by an unknown person or group called Satoshi Nakamoto in 2008 and then put into operation on January 3, 2009. It was introduced as a novel peer-to-peer electronic cash system, namely Bitcoin. Nakamoto's invention was a breakthrough that combined existing technologies such as cryptography, distributed systems, and game theory to create a new way to manage and verify transactions in a decentralized network.

All blockchain systems feature a similar data structure. Each “block” is an imagined block that contains several inputs. First, there is text, such as transactions and in some cases programmable code. Second, each block has a hash function, which is a code that has been made by converting a text of any size into a fixed-size string of characters. Hash functions have the properties of being unique and are shown to be irreversible unless you guess the hash, which is a method called brute force. Each block contains its own unique hash and the hash from the previous block in the chain. Thus, any changes made in a block will ultimately change the hash of the entire chain from the point where the change was made, and the validators will disregard this change due to consensus mechanisms that exist to ensure the integrity of the chain. Once a new block is deemed valid by the network, it is added in sequential order to the previously validated block. This process is repeated as new transactions occur. The Blockchain is maintained and replicated across a distributed set of nodes that abide by a set of rules, called consensus mechanisms, to process valid transactions and maintain the integrity of the database (Zachariadis, Hileman, & Scott, 2019).

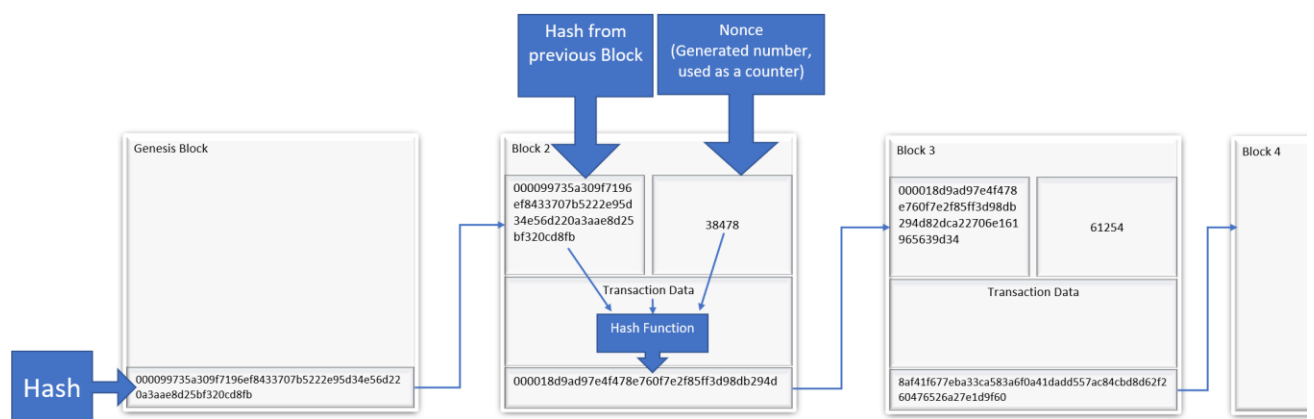


Figure 1: Blockchain

Consensus mechanisms are underlying processes that enable decentralized systems to validate transactions and achieve agreement among participants which is responsible for ensuring the integrity and security of the network. Some of the most commonly used consensus mechanisms are proof of work (PoW) and proof of stake (PoS). PoW (consensus mechanism used in Bitcoin) is decentralized and has proven to be secure. However, it is energy-intensive and requires significant computational power, which makes it costly and can create centralization in the hands of a few powerful miners. PoS (consensus mechanism used in Ethereum 2.0) is energy-efficient and can handle a high number of transactions per second.

However, it can lead to centralization if few stakeholders hold a large proportion of the investments. It can also suffer from the "nothing-at-stake" problem, where validators have no cost associated with validating multiple forks. Both consensus mechanisms have advantages and disadvantages, and the choice of which to use should depend on the blockchain network's specific use case and goals. There are several other consensus mechanisms as well, such as proof of authority (PoA) and proof of reputation (PoR), which aim to address some of the limitations of PoW and PoS (Hsieh et al., 2018). Incentive mechanisms exist for nodes to contribute resources to the network, such as rewards in the form of newly issued tokens (coins) and transaction fees. (Zachariadis et al., 2019).

Blockchains also employ various forms of cryptography, such as public/private key infrastructure and the aforementioned hash functions, to secure the database and its users from attacks and other malicious behavior, such as double-spending tokens. Each block in the Blockchain contains a unique hash that is generated based on the contents of that block. Any attempt to tamper with the data in that block will change the hash, which will be immediately noticeable since the hash in the next block in the chain will no longer match. Digital signatures, public keys, and Merkle trees ensure the integrity and security of the data. These techniques help to ensure that the Blockchain is a secure and transparent technology (Beck, Muller-Bloch, & King, 2018). In order for the network to stay operational, validators are essential to ensure that new transactions and other types of information contained in a block are valid and consistent with the existing blockchain records. In a Proof of Work consensus mechanism, such validators are called Miners and are responsible for maintaining the distributed ledger in the Blockchain by processing and chronologically recording transactions to form an immutable chain through protocols and network consensus without relying on centralized intermediaries. Thus, they are responsible for maintaining and ensuring the security of the blockchain record of all prior transactions. They are compensated for the use of their computing power with tokens, which is the incentive mechanism (Murray, Kuban, Josefy, & Anderson, 2021).

There are various use cases where blockchain technology shows its potential, such as digital currency/payments, identity management, supply chain traceability, healthcare, education, corporate registration, data management, and more. For example, in the healthcare industry, blockchain technology can be used to securely manage patient records and ensure that only authorized parties have access to sensitive data. Also, Blockchain can be useful in tracking

goods and ensuring transparency in the supply chain industry. These application scenarios demonstrate the potential for Blockchain to improve efficiency, transparency, and trust in various industries (Tan, Mahula, & Crompvoets, 2022).

Blockchain technology has been widely recognized for its potential to enhance effectiveness, efficiency, and security in the digital domain. However, the literature also highlights several limitations and weaknesses of blockchain technology that need to be addressed for successful implementation and success. These limitations include a lack of regulation and standardization, security and privacy concerns, high energy consumption (particularly in the case of PoW), and adoption challenges due to its immutable nature (Tan et al., 2022).

An important development resulting from Blockchains are smart-contracts, which are most widely written on the Ethereum Blockchain, although other Blockchains have the same properties. These Blockchains have some key differences from blockchain platforms such as Bitcoin. While Bitcoin was primarily designed for peer-to-peer digital cash transactions, Ethereum was designed to be more flexible and serve as a platform for building decentralized applications (dApps) beyond just digital currencies. This is done by storing code within each block in addition to financial transactions. This allows developers to write and deploy smart contracts, self-executing programs that automatically execute when certain conditions are met. (Sayeed, Marco-Gisbert, & Caira, 2020).

2.2. Smart Contracts

Smart contracts are computer programs that automatically facilitate, verify and enforce the negotiation and execution of digital contracts between two or more parties without the need for intermediaries or central authorities. The use of smart contracts can increase the speed, efficiency, and security of contract execution. Smart contracts have the potential to revolutionize many traditional industries by enabling the automatic execution of digital contracts without the need for a trusted intermediary (S. Wang, Ouyang, et al., 2019).

An example of a simple smart contract can involve if-functions that automatically execute when certain conditions are met. They are typically written on a blockchain that accepts this functionality, and thus inherit the properties of the Blockchain such as immutability, transparency, and security.

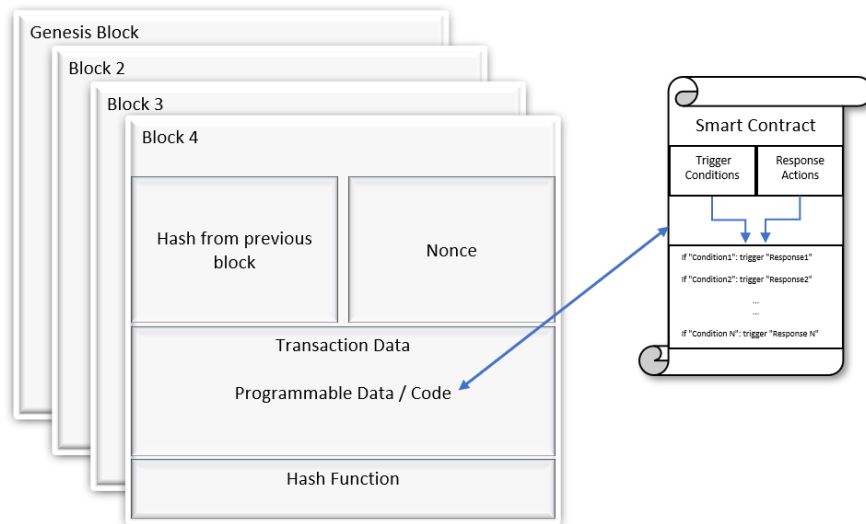


Figure 2: Smart Contract

As mentioned, Smart contracts have been recognized as a promising technology for enhancing automation and efficiency in various industries. For instance, the insurance industry can benefit from smart contracts by automating the claims process and payout based on predetermined conditions. Furthermore, in supply chain management, smart contracts can ensure compliance by executing pre-agreed terms and conditions between parties. In the real estate industry, smart contracts can streamline property transactions and reduce the need for intermediaries (Tan et al., 2022). Due to the potential improvements that smart contracts can contribute relative to traditional contracts, investigating the use of smart contracts in different industries is critical to realizing their full potential and ensuring their successful implementation. While blockchain-enabled smart contracts hold promise as an effective and efficient means to mitigate certain contracting- and agency costs, there are limitations to their applicability that need to be considered. The pseudo-anonymous nature of blockchain technology can make it difficult to verify the authenticity of data sources, which can impact the reliability of the information stored on the Blockchain. Additionally, the reliance on smart contracts may limit an organization's ability to adapt to changing circumstances due to the blockchain's Immutability, which may introduce new regulatory or compliance costs. (Murray et al., 2021).

2.3. Decentralized Autonomous Organizations

Decentralized Autonomous Organizations (DAOs) are organizations that utilize smart contracts to record their management and operational rules on the Blockchain. Some key characteristics of DAOs are decentralization, autonomous operations, and on-chain and off-chain collaboration. Incentive mechanisms based on tokens are the main motivators for DAOs. Tokens hold the attributes of equity, and currency, and they are used to map commodities and services to achieve low-cost or even zero-cost transactions. The design of the token model is crucial to promoting the incentive compatibility of participants and achieving a win-win situation (S. Wang, Ding, et al., 2019).

DAOs are organizations that are built by complicated designed smart contracts which contain the properties of an organization. The smart contracts automatically execute the rules of the organization, and the transactions are enforced autonomously, making it possible for DAOs to exist without any central authority or intermediaries, and it offers a new form of organizational design that can challenge established notions of governance. The governance of DAOs is defined by the rules in the smart contracts, thus, the decisions made by the organization are determined by the consensus of the network participants. These properties of DAOs could fundamentally change our understanding of governance, as they provide a new form of organizational design with decentralized decision-making and a high degree of transparency, security, and without the need for trust after the smart contract has been deployed (Beck et al., 2018).

The first references to Decentralized Autonomous Organizations (DAOs) emerged in the 1990s. It's worth noting that the modern meaning of DAOs can be traced back to the earlier concept of a Decentralized Autonomous Corporation (DAC), which emerged a few years after the introduction of Bitcoin. Early cryptocurrency enthusiasts coined the term DAC, with the terms "decentralized" and "distributed" autonomous corporations being used interchangeably. The term DAO has evolved over time, and the modern understanding of DAOs refers to organizations deployed as smart contracts on top of an existing blockchain network rather than to the blockchain network itself (Hassan & De Filippi, 2021).

DAOs have the potential to play an important role in shaping the future of economics, governance, and political theory. In terms of economics, DAOs can potentially enable new forms of decentralized and autonomous business models, allowing people to create new

forms of collaboration and value creation without relying on traditional centralized institutions. In terms of governance, DAOs can potentially enable more democratic and participatory forms of decision-making, giving people greater control over the organizations that affect their lives. In terms of political theory, DAOs can potentially enable new forms of decentralized and autonomous political organization, allowing people to participate more directly in the governance of their communities (Hassan & De Filippi, 2021).

With distributed consensus protocols, trust within a DAO is easier to achieve, and thus trust costs, communication costs, and transaction costs can be minimized. Consensus mechanisms are also used to ensure data consistency and agreement on proposals in a complex, open, and untrusted digital environment. (S. Wang, Ding, et al., 2019).

Decentralized Autonomous Organizations (DAOs) rely heavily on effective incentive mechanisms to drive participation and ensure long-term sustainability. Incentives within a DAO can take many forms, such as tokenization, reputation systems, and voting power. However, the specific design of these mechanisms should reflect the unique characteristics of each DAO, including its governance structure and decision-making processes. To create effective incentive mechanisms for DAOs, economic models, game theory, and mechanism design can be used. Tokenization is a particularly important concept within DAOs, as it can enable decentralized ownership and governance using governance tokens. However, tokenization also presents challenges such as regulatory compliance, legal issues, and the risk of fraud and hacking. In the context of DAOs, tokenization, and incentive mechanisms are often interrelated. Tokens can be used to incentivize certain behaviors or actions within the organization and can also be used for voting or as a form of currency. Incentive mechanisms can be designed to encourage members to hold onto tokens, participate in initiatives or projects, and align with the overall goals of the organization. By aligning incentives with the goals of the DAO, effective incentive mechanisms can promote greater participation, collaboration, and commitment from members, ultimately leading to a more sustainable and successful organization (S. Wang, Ding, et al., 2019).

Even though DAOs show great potential, it also includes significant challenges and limitations, including finding ways to balance decentralization and autonomy with effective decision-making and accountability, and addressing security and legal issues (Hassan & De Filippi, 2021).

2.4. Theories motivating the research of DAOs

The following section explores the most prominent theories in the literature that inform our understanding of DAOs. These theories include agency theory, game theory, institutional theory, and transaction cost theory. Each of these perspectives offers a unique lens for analyzing the challenges and opportunities associated with decentralized autonomous organizations. By examining these theories, we can better understand the implications of blockchain technology and by extent DAOs. These theories motivate the research themes in chapter 2.5, which are macro, meso and micro levels of analysis of DAOs as displayed in figure 3.

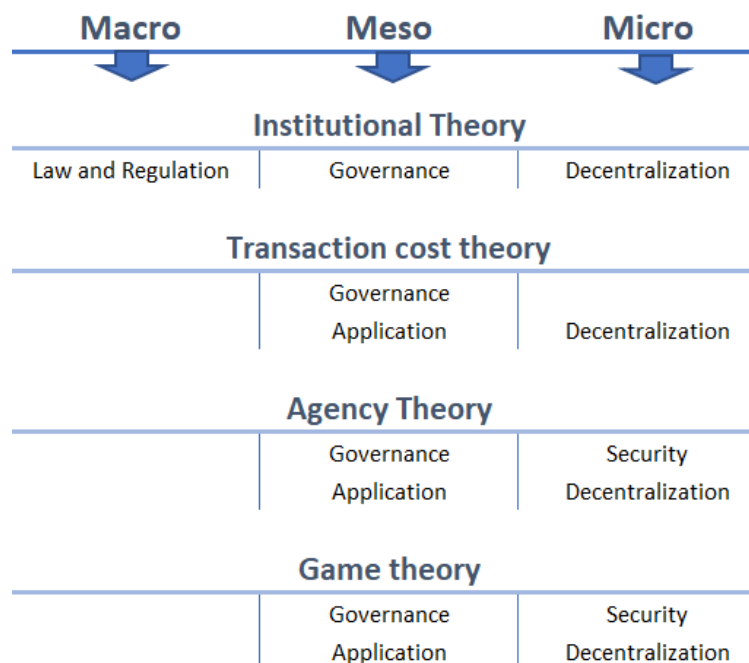


Figure 3: Theories and Research Themes

In the coming sections, the theories will be discussed, revealing their importance and how they have been studied in the academic literature. Following that, in chapter 2.5, the most prominent research themes in the literature will be presented, in the structure of Macro, Meso, and Micro levels of analysis.

Table 1 provides a summary of articles that discuss the integration of these theories within the context of Blockchain, Smart Contracts, and DAOs. Subsequently, the following sections offer a more comprehensive explanation of each theory and its connection to the field.

Theories

	Year	Citations
Agency Theory		
GOVERNANCE IN THE BLOCKCHAIN ECONOMY: A FRAMEWORK AND RESEARCH AGENDA	2018	151
CONTRACTING IN THE SMART ERA: THE IMPLICATIONS OF BLOCKCHAIN AND DECENTRALIZED AUTONOMOUS ORGANIZATIONS FOR CONTRACTING AND CORPORATE GOVERNANCE	2021	25
THE DAO CONTROVERSY: THE CASE FOR A NEW SPECIES OF CORPORATE GOVERNANCE?	2020	10
BLOCKCHAIN-ENABLED CORPORATE GOVERNANCE AND REGULATION	2020	6
DECENTRALIZED CORPORATE GOVERNANCE VIA BLOCKCHAIN TECHNOLOGY	2020	2
BLOCKCHAIN AND THE EMERGENCE OF DECENTRALIZED AUTONOMOUS ORGANIZATIONS (DAOS): AN INTEGRATIVE MODEL AND RESEARCH AGENDA	2022	0
FORMAL VERIFICATION OF BLOCKCHAIN SMART CONTRACTS VIA ATL MODEL CHECKING	2022	0
Game theory		
RESOURCE TRADING IN BLOCKCHAIN-BASED INDUSTRIAL INTERNET OF THINGS	2019	119
BORN GLOBAL ON BLOCKCHAIN	2018	31
BLOCKCHAIN GOVERNANCE IN THE PUBLIC SECTOR: A CONCEPTUAL FRAMEWORK FOR PUBLIC MANAGEMENT	2022	9
THE WOLF AND THE CARIBOU: COEXISTENCE OF DECENTRALIZED ECONOMIES AND COMPETITIVE MARKETS	2018	4
TOWARDS A BLOCKCHAIN-BASED MULTI-UAV SURVEILLANCE SYSTEM	2021	2
INCENTIVE MECHANISM DESIGN FOR DISTRIBUTED AUTONOMOUS ORGANIZATIONS BASED ON THE MUTUAL INSURANCE SCENARIO	2021	1
FORMAL VERIFICATION OF BLOCKCHAIN SMART CONTRACTS VIA ATL MODEL CHECKING	2022	0
Transaction cost theory		
GOVERNANCE AND CONTROL IN DISTRIBUTED LEDGERS: UNDERSTANDING THE CHALLENGES FACING BLOCKCHAIN TECHNOLOGY IN FINANCIAL SERVICES	2019	59
CONTRACTING IN THE SMART ERA: THE IMPLICATIONS OF BLOCKCHAIN AND DECENTRALIZED AUTONOMOUS ORGANIZATIONS FOR CONTRACTING AND CORPORATE GOVERNANCE	2021	25
THE DAO CONTROVERSY: THE CASE FOR A NEW SPECIES OF CORPORATE GOVERNANCE?	2020	10
BLOCKCHAIN GOVERNANCE IN THE PUBLIC SECTOR: A CONCEPTUAL FRAMEWORK FOR PUBLIC MANAGEMENT	2022	9
BLOCKCHAIN-ENABLED CORPORATE GOVERNANCE AND REGULATION	2020	6
BLOCKCHAIN AND THE EMERGENCE OF DECENTRALIZED AUTONOMOUS ORGANIZATIONS (DAOS): AN INTEGRATIVE MODEL AND RESEARCH AGENDA	2022	0

Table 1: Theories and articles in the academic literature of DAOs

2.4.1. Agency Theory

Agency theory is an economic theory that analyzes the relationship between principals and agents within an organization. It addresses the challenges that can occur when one party delegates work to another party, i.e., the principal and agent, respectively. A key challenge is that the agent's interests may not align with those of the principal, creating a potential conflict of interest. This misalignment of incentives can cause the agent to make suboptimal decisions from the principal's perspective (Jensen & Meckling, 1976). A traditional example can be managers who prioritize their own job security or job satisfaction over maximizing shareholder value. This can lead to agency costs, which are the costs that arise from the conflict of interest between the shareholders and the managers.

The implications of blockchain technology for governance in the emerging blockchain economy can give rise to a new type of governance, where transactions are autonomously enforced through smart contracts (Beck et al., 2018). Some types of agency costs include monitoring agent motivations to detect and prevent self-serving behavior, monitoring a firm's operations to reduce the informational advantage of agent managers, excessive expenses such

as managerial benefits, interest alignment of agent-managers to reduce divergence from owners' interests, and unrealized profits from suboptimal management decisions. Since DAOs operate in a decentralized and trustless manner, they present a unique solution to mitigate agency costs by using smart contracts to automate decision-making and thus ensure alignment with the agent and the principal, as the owners themselves take part as managers in this decentralized system. However, DAOs also face new challenges in ensuring accountability and effective decision-making, particularly during crises in the decentralized space (Murray et al., 2021).

2.4.2. Game Theory

Game theory is a theory within mathematics that focuses on the study of decision-making in strategic situations. As DAOs operate in a decentralized and autonomous manner, decision-making is carried out through the interaction of multiple agents, making the use of game theory relevant to understanding the strategic behavior of these agents.

In an article written by Yao et al. (2019), game theory is used to model the interaction between the cloud provider and miners in a Stackelberg game to optimize resource pricing between the two parties. Another example of the utilization of Game Theory in relation to DAOs is how a technique called Alternating-time Temporal Logic (ATL) model has been used. Using this technique, the interaction between the smart contract and any potential attacker is modeled as a two-player game. The players in this game are the contract itself and the attacker, and they play the game based on the rules specified in the smart contract. To manage the game, an environment agent is introduced to oversee the turns of the players, while properties to be verified are specified using an ATL formula. This approach represents a formal verification, which leverages mathematical logic to verify the correctness of software systems. By using game theory to model the interaction between the players in the game, and formal verification techniques to prove the correctness of the system, the proposed framework provides a robust means of identifying and addressing potential vulnerabilities in smart contract design (Nam & Kil, 2022).

Game Theory in the context of DAOs can provide insights into the strategic behavior of agents and help achieve their objectives in a decentralized and transparent way. However, challenges in its applicability may arise due to the decentralized and autonomous nature of

these organizations, making the identification of agents and their strategies potentially more complex.

2.4.3. Transaction cost theory

In "The Nature of the Firm" by Coase (1937) he explains that firms exist because the costs of using the market to organize production are high. One of the most significant costs of using the market is the need to constantly discover and create contracts with all the entrepreneur's supplying inputs to the production process. This involves being aware of all relevant prices, which are constantly changing and enforcing contracts over an indefinite period, regardless of how much the circumstances of production change. By contrast, firms can reduce these transaction costs by organizing production within the firm and using internal coordination mechanisms rather than relying on the market.

DAOs can help reduce transaction costs by allowing for more efficient coordination of economic activity in a trustless and decentralized manner, which can lead to more effective governance and value creation (Zachariadis et al., 2019). These benefits of DAOs are in line with the transaction cost theory, which emphasizes the importance of reducing transaction costs in order to achieve efficient economic outcomes (S. Wang, Ding, et al., 2019).

This idea is widely accepted in the literature, both internally in a DAO and also in the more general case of Blockchain-enabled smart contracts which may provide a new option for conducting complex and uncertain transactions via contracts outside the organizations. This has the potential to reduce certain transaction costs and increase market efficiencies (Murray et al., 2021).

In summary, agency theory provides a framework for understanding potential conflicts of interest in DAOs, while game theory can help to model the strategic behavior of agents in a decentralized and autonomous environment. Transaction cost theory emphasizes the importance of reducing transaction costs to achieve efficient economic outcomes and suggests that DAOs can help to reduce these costs by allowing for more efficient coordination of economic activity. Understanding these theories is crucial for the effective governance of DAOs and the successful implementation of blockchain technology in various industries.

The theories that have been discussed are the most prominent theories found in the articles that have been analyzed. However, there are several other theories discussed in the literature on DAOs, such as social-, economic, governance and network theory, and more. An important theory that has been discussed to some degree, but not as much as agency-, game- and transaction cost theory, is institutional theory.

2.4.4. Institutional Theory

Institutional theory is the study of formal and informal rules that govern human interaction and how these rules shape economic performance. It distinguishes between institutions and organizations, where institutions consist of formal rules, informal constraints, and enforcement characteristics, while organizations consist of groups of individuals engaged in goal-oriented activities. The institutional framework and the technology employed determine transaction costs, which affect economic performance. The theory highlights the importance of institutions in reducing uncertainty and structuring human interaction. However, the results are not always efficient, as actors are often incompletely informed, which impacts their choices. The transaction costs arise because distribution of information is costly and held asymmetrically by the parties to exchange, leading to market imperfections. Institutional innovations have lowered transaction costs and allowed more of the gains from trade to be captured but have not created the conditions necessary for efficient markets. Institutional theory revolves around the role of institutions and formal rules in governing human interaction, as well as the importance of informal constraints such as norms and personal standards of morality and honesty. These concepts are related to the distinction between rule-based and relations-based governance. Rule-based governance emphasizes formal rules, laws, and regulations to structure and govern human behavior, while relations-based governance focuses on informal networks, personal relationships, and trust to facilitate cooperation and coordination (North, 1992).

In the context of DAOs, the governance structure is written down in code and deployed on the Blockchain through smart contracts. This Code-based governance is similar to rule-based governance in that they both rely on explicit rules to control behavior within an organization, although there are some key differences between them.

Rule-based governance refers to a mode of governance in which laws and regulations are the primary means of controlling behavior. Rules are created and enforced by a central authority,

such as a government, and are designed to be transparent, fair, and universally enforced. In relation-based governance, the rules are typically written in natural language and may be subject to interpretation by those who enforce them (Shaomin Li, Park, & Li, 2003). Code-based governance, on the other hand, is a form of governance that relies on computer code, such as smart contracts and decentralized technology. The rules are encoded in the smart contracts and are executed automatically without the need for human intervention. In code-based governance, the rules are typically more specific and precise than in rule-based governance, as they are written in code and must be executed exactly as written. Another key difference between code-based and rule-based governance is the level of decentralization. Decision-making power is distributed among participants, and there is no central authority in Code-based governance. In rule-based governance, decision-making power is typically centralized in a governing body or authority.

The table below shows important distinctions between relation-based and rule-based governance, which was retrieved from an article by Shaomin Li (2009). In this table, Code-Based Governance has been included to highlight the distinctions in this mode of governance.

Relation-based Governance	Rule-based Governance	Code-based Governance
Laws tend to be opaque and unfair, enforcement particularistic	Laws tend to be transparent, fair, and enforcement universal	Laws tend to be transparent, immutable fair and enforcement universal
Relying on private and local information	Relying on public information	Relying on public and private information (On- and Off Chain)
Implicit and non-verifiable agreements	Explicit and third-party verifiable agreements	Explicit and verifiable agreements
Person-specific and non-transferable contracts	Country specific, public and transferable contracts	Global, public and transferable contracts
High entry and exit barriers	Low entry and exit barriers	Very low entry, and exit barriers
Requiring minimum social order	Requiring well-developed legal infrastructure	Requiring no infrastructure (Code is law)
Low fixed costs to set up the system	High fixed costs to set up the system	High fixed costs to set up the system, economies of scale
High and increasing marginal costs to maintain	Low and decreasing marginal costs to maintain	Low and decreasing marginal costs to maintain
Rely on particularized trust	Rely on generalized trust	Trustless governance

Table 2: *Institutional Theory, Relation Based-, Rule-Based- and Code Based Governance*

Source: (S. Li, 2009)

Code-based governance differs from rule-based and relation-based governance in several ways, although more similar to rule-based governance as it is explicit, transparent, and the rules contained in the contracts are fair and enforced on all participants in the Governance structure. Both rule-based and Code—based Governance has the possibility to make changes, and updates, although the immutable nature of the Blockchain, in which the code-based government is built, makes it more difficult. Another difference between rule-, and code-based governance is that rule-based governance has third-party verifiable agreements, while code-based governance is decentralized and transparent, i.e., open-source code, making it verifiable by anyone. Code-based governance differs from relation-based and rule-based governance in that it has the potential to significantly reduce entry and exit barriers for actors. Code-based governance relies on software and algorithms to regulate behavior, which can be designed to be transparent and easy to use. This means that actors can easily understand and comply with the rules and can enter or exit the network without facing significant costs or penalties. In contrast, relation-based governance relies on personal relationships, which can take time to develop and may be difficult to navigate. Rule-based governance relies on formal rules and regulations, which can be complex and costly to comply with. Code-based governance offers the potential for a more accessible and equitable system of governance that can be customized to meet the needs of a diverse range of actors.

Another key difference between code-based governance and relation-based and rule-based governance is that code-based governance relies on both private and public information, while the other two structures rely primarily on one or the other. Relation-based governance relies on private information, such as personal connections and trust, to govern the behavior of actors. Rule-based governance relies on public information, such as laws and regulations, to guide behavior. In contrast, code-based governance can operate on both on-chain and off-chain information, allowing for a more nuanced and comprehensive approach to governance. On-chain information is publicly available and encoded in the blockchain, while off-chain information is privately held outside of the Blockchain. By incorporating both public and private information, code-based governance has the potential to create a more transparent and adaptable system that can respond to the needs and interests of a diverse range of actors.

Both rule-based and code-based governance rely on transferable contracts, which means that the terms of the contract can be transferred from one party to another without the need for renegotiation. However, there is a key difference between the two structures. Rule-based

governance is limited by the jurisdiction of the country in which it operates. This means that the rules and regulations governing the behavior of actors are specific to that country and may not be applicable or enforceable in other jurisdictions. In contrast, code-based governance is global, meaning that the rules and protocols are not limited by geographic boundaries.

Code-based governance represents a new paradigm in governance that does not rely on traditional social or legal infrastructures. Unlike relation-based governance which requires a minimum level of social order, and rule-based governance which relies on a well-developed legal infrastructure, code-based governance operates solely through software and algorithms. This means that the rules and protocols governing the behavior of actors are encoded into the software and can be executed automatically without the need for intermediaries, social-, or legal systems, which is often referred to as "code is law".

Relation-based governance has low fixed costs to set up because it relies on personal relationships and trust, which can be developed over time without significant financial investment. However, as the number of actors in the network grows, the costs of managing and maintaining those relationships also increase, resulting in increasing marginal costs. Rule-based governance, on the other hand, has high fixed costs to set up because it relies on formal rules and regulations that must be developed and enforced by a legal system, which can be expensive and time-consuming. However, the costs of enforcing those rules can be spread over a larger number of actors, resulting in decreasing marginal costs. Code-based governance has high fixed costs, due to the development and implementation of software and algorithms, but can benefit from economies of scale, allowing for lower costs as the number of actors in the network grows.

Relation-based governance relies on particularized trust between individuals, while rule-based governance relies on generalized trust in formal rules and institutions. In contrast, code-based governance is often referred to as trustless governance, because it operates through transparent and enforceable rules that are executed automatically, without the need for trust in any particular actor or institution. This creates a more open and equitable system of governance that is not dependent on traditional social or legal infrastructure, but rather on the integrity of the software and algorithms that govern the system.

Overall, while relation-based and rule-based governance structures have their own advantages and limitations, code-based governance in DAOs offers a novel approach to governance that emphasizes immutability, transparency, decentralization, and automation.

2.5. Key Topics in the Literature of DAOs

The literature on Decentralized Autonomous Organizations highlights a range of challenges and opportunities for these emerging technologies. This section will focus on these challenges and opportunities in the context of Macro, Meso, and Micro perspectives. Macro refers to a perspective which includes factors and influences that lies outside the boundaries of the DAO, such as law and regulation. Meso is the organizational layer, including the governance structure of the DAOs and their applications. Finally, the Micro level consists of technical features and properties of the DAO, such as decentralization, scalability and security.

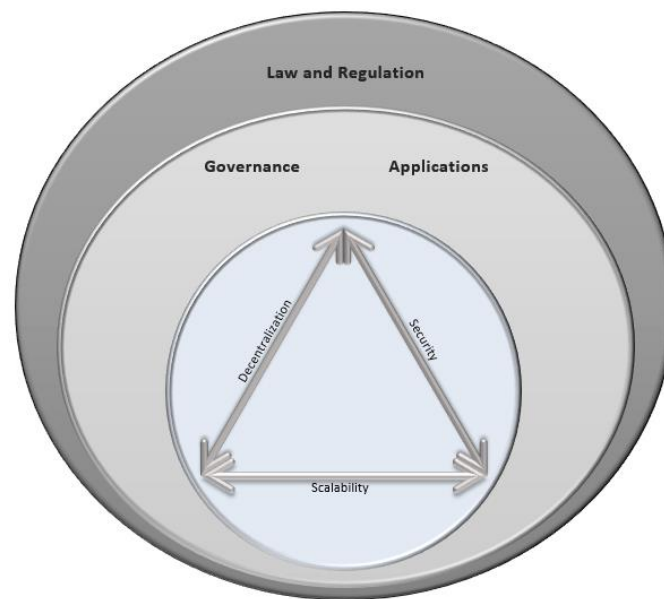


Figure 4: Macro, Meso, and Micro perspectives

Scholars have examined various aspects of governance practices in times of crises, legal and regulatory issues, the security challenges associated with smart contract technology and the effectiveness of existing security tools, scalability solutions and the feature of decentralization. Additionally, the literature has explored the potential applications of DAOs and Blockchains, including their impact on socioeconomic systems. The most frequent case

study found in the academic literature on DAOs is the case of TheDAO, which revealed both potentials and vulnerabilities in this technology in the context of the aforementioned topics.

TheDAO Attack

TheDAO, a Decentralized Autonomous Organization built on the Ethereum Blockchain, was established in 2016. Despite not being the first DAO, it is regarded as one of the most extensively researched case studies and has uncovered significant topics surrounding security and governance for DAOs. It was an investment organization that operated with a decentralized and “trustless” governance structure, which was entirely based on smart contracts. TheDAO had no central authority, and all decisions regarding the distribution and management of its \$150 million dollar fund were achieved through the consensus of the investors, i.e., participants in TheDAO. In June 2016, TheDAO experienced an attack that was caused by a vulnerability in the smart contract, which allowed a hacker to drain a significant amount of funds. The proposed solution was a hard fork (which will be explained in more detail later in this chapter). This event highlighted legal, ethical, and governance issues that strike at the foundations of the blockchain philosophy as a decentralized, immutable, trustless system. The hard fork broke the concept of immutability since the majority of the community (more than 51%) decided to change the block from which the attack occurred. A portion of the participants wanted to accept the “hack” because of a principle in the Blockchain community known as “code-is-law”. This caused a split in the community and springing from that block, Ethereum was divided into Ethereum Classic (ETC) and Ethereum (ETH) (Morrison et al., 2020).

This case revealed a potentially new type of organization built on and operated by blockchain technology. It seemed like a successful endeavor for a period, until it also revealed major risks associated with governance, security, and regulations of DAOs.

2.5.1. Macro Perspective

Decentralized autonomous organizations are both impacting and being influenced by external sources. The macro level of analysis focuses on these broader contexts, in particular legal and regulatory frameworks governing DAOs. Unlike traditional organizations, DAOs are not limited to a particular jurisdiction, which brings up the question of accountability related to the economic and social impact DAOs have on society. By examining DAOs through a

macro-level lens, researchers can gain a deeper understanding of the broader trends and forces shaping the development of DAOs and their impact on society.

Law and Regulation

Issues of law and regulation in DAOs involve the fact that traditional contract law has not provided an adequate legal foundation for this technology. The lack of consistent information exchange and a decentralized decision-making structure pose a challenge for business processes in DAOs. As an example, TheDAO, which failed due to flaws in the written smart-contract code and the lack of appropriate legal foundations, highlights the importance of developing a legally-binding smart-contract framework for DAOs (Dwivedi et al., 2021).

Current regulatory frameworks may not fully apply to Blockchain technologies, and there is a need for new regulations to address the unique aspects of Blockchain and cryptocurrencies, such as their decentralized nature and pseudo anonymity. Zamani and Giaglis (2018) suggests that there is a need for collaboration between regulators, industry stakeholders, and technology experts to develop effective regulatory frameworks that balance innovation and security. Addressing the issues related to Law and Regulation has been a major topic in the literature, and some potential solutions have been proposed. An example of this is the proposal by Dwivedi et al. (2021) with a development of a smart-legal-contract markup language (SLCML) which provides a machine-readable language for legally-relevant contracts in DAOs while also ensuring compliance with existing laws and regulations.

The challenge of law and regulation in DAOs is a major topic in the literature. Collaboration between industry stakeholders, technology experts, and regulatory bodies is essential to ensure effective and appropriate regulatory frameworks that balance innovation and security. While some solutions have been proposed, development is needed to explore and implement additional solutions to address the legal and regulatory challenges facing DAOs and blockchain technology.

2.5.2. Meso Perspective

Decentralized Autonomous Organizations are complex organizations that require a well-designed governance structure to function effectively. The Meso level of analysis focuses on the organizational level, including the governance structure, decision-making processes, and applicability of DAOs within specific industries or sectors. By examining DAOs through a

Meso-level lens, researchers can gain a deeper understanding of how these organizations can be designed and implemented to meet the unique needs and challenges of different industries and sectors.

Applications

The literature has extensively discussed the potential of DAOs, which have diverse applications ranging from community-driven projects, social impact initiatives, corporate governance, and decentralized finance (DeFi). Moreover, DAOs can be used in various sectors, including land registry offices, enterprise management, and the sharing economy. These new approaches to governance and decision-making could potentially reduce friction and eliminate intermediaries, enabling individuals, organizations, machines, and algorithms to transact and interact with each other freely.

In land-registry offices, for instance, DAOs can replace traditional record keepers, providing trusted peer-to-peer transaction ledger systems and applications that document property ownership, reduce fraud, and increase transparency. Similarly, DAOs can introduce new ways of governing corporations that are less hierarchical and more decentralized, where power is distributed across the network (Zamani & Giaglis, 2018). Additionally, DAOs could transform the regulation and maintenance of administrative control, with contracts embedded in digital code and stored in transparent, shared databases. This could eliminate the need for intermediaries like lawyers, brokers, and bankers and allow for more efficient transactions and interactions between individuals, organizations, and machines (Zachariadis et al., 2019). Yuan and Wang (2018) explore how Blockchain technology can be used to establish DAOs in the sharing economy, creating a completely decentralized and disintermediated model. They present Lazooz, a blockchain-based ride-sharing platform that operates as a self-managed DAO, with formal decisions made collectively by the community. Also, they explain how in enterprise management, blockchain-powered smart contracts can help automate rules and regulations predefined by enterprise managers and enable internal tokens or coins to be designed and issued as incentives to improve employee performance. Employees can also cooperate with each other on specific tasks, forming various DAOs.

Another field where DAOs can thrive is through decentralized finance (DeFi), supporting trustless financial activities. However, current technology and institutions have limitations that may limit their full potential in supporting financial intermediation and lending in a

decentralized and anonymous environment. Nonetheless, DAOs have shown tremendous potential in transforming administrative control and decision-making in various sectors, providing trusted and efficient peer-to-peer transaction systems and promoting transparency and decentralization (Harwick & Caton, 2022).

Applications of DAOs are diverse and expanding as the potential for blockchain technology, and decentralized decision-making continues to be explored. As DAOs become more common, they show the potential to transform industries, including finance, real estate, and social media. By promoting transparency, decentralization, and peer-to-peer transactions, DAOs offer a new paradigm for trust and accountability that could ultimately reshape the way we do business and make decisions.

Governance in Blockchain technology

Governance in Blockchain refers to the way in which decentralized autonomous organizations (DAOs) operate in a blockchain-based economic system. Although traditional governance structures also rely on decision rights, accountability, and incentives, DAO governance differs in that it operates based on decentralized decision-making through smart contracts and relies on distributed consensus mechanisms and token-based incentives to incentivize participation and maintain network integrity. Also, with its decentralized properties, it is a governance structure that does not depend on trust (Beck et al., 2018). The literature acknowledges the potential of blockchain technology to transform the way governance is conducted in fields such as financial transactions but highlights that the biggest challenge for the growth of Blockchain and by extent DAOs is governance. The lack of structure to achieve consensus, coordinate action, and resolve differences in current blockchain platforms and cryptocurrency communities is deemed to be chaotic and could jeopardize the widespread adoption of the technology and future blockchain applications. Existing blockchains have been challenged and experienced setbacks that put their governance models to the test which has revealed issues of trust, risk, and efficiency that lie at the heart of robust functioning financial systems (Zachariadis et al., 2019).

Another challenge that the literature highlights is the entanglement of application and infrastructure. This refers to the complex relationship between the software application (such as a smart contract or a DAO) and the underlying technological infrastructure (such as the blockchain network on which the application is deployed). This entanglement can make it

challenging to establish effective governance mechanisms for the DAO, as the governance of the application may depend on the governance of the infrastructure itself (Rikken, Janssen, & Kwee, 2019). The elimination of third-party regulators poses various key governance questions related to decision-making authorities and accountabilities in a decentralized network. This includes questions such as who is responsible for what, who decides on changes in the blockchain application and organization, who can be held accountable for which failures, and who takes risk mitigation measures when incidents happen. Effective governance mechanisms are necessary to define and formalize decision-making structures in DAOs, particularly during crisis situations (Rikken et al., 2019).

In DAOs, effective governance is essential to ensure the integrity of the network and incentivize participation. However, governance structures can face challenges, such as disagreement among stakeholders or changes in the organization's direction. As a solution to such challenges, DAOs can use a mechanism known as a fork, which allows stakeholders to create a new version of the network with different rules and incentives. Forks include both soft and hard forks. A soft fork occurs when an update is made to the rules of the DAO that is backward compatible, meaning that members who do not adopt the new rules can still participate in the organization. Soft forks are often used to make minor changes to the organization, such as fixing bugs or improving efficiency. On the other hand, a hard fork occurs when an update is made to the rules of the DAO that is not backward compatible, meaning that members who do not adopt the new rules cannot participate in the new organization. Hard forks are typically used to make significant changes to the organization, such as changing the governance structure or strategic direction (S. Wang, Ding, et al., 2019). While forks can provide a solution to some challenges in DAO governance, they can also lead to significant issues. One issue is that forks can create a division within the community, with some members supporting the new version of the network and others remaining on the original version. This can result in a loss of trust, as well as a potential dilution of resources and a reduction in network effects. Furthermore, the existence of multiple versions of the network can create confusion for users and developers, leading to fragmentation of the network, such as in the case of Ethereum after TheDAO attack (Morrison et al., 2020).

2.5.3. Micro Perspective

Decentralized Autonomous Organizations rely on complex technical systems and protocols to operate effectively. The micro level of analysis focuses on these technical features and

properties, including the decentralization, scalability, and security of DAOs. By taking a micro-level approach, researchers can help to ensure that DAOs are designed and implemented with the highest possible levels of technical sophistication and security, allowing them to achieve their full potential as decentralized organizations.

Security

Blockchain ensures security and privacy in data access and transmission through various techniques such as data encryption, time-stamping, distributed consensus algorithms, and economic incentive mechanisms. It makes the use of data with self-executed programs, i.e., smart contracts, which are designed to run automatically when certain conditions are met. Blockchain data is stored with encrypted chained blocks, which makes it difficult for attackers to tamper with the data. While blockchain technology provides a highly secure and tamper-resistant framework, it is not completely immune to attacks. One method that attackers can use to exploit a blockchain is by performing a 51% attack. This occurs when an attacker gains control of 51% or more of the voting power in a blockchain network. This would allow the attacker to control the network and potentially modify transactions, double-spend coins, and prevent new transactions from being added to the Blockchain. Another method that attackers can use is known as a Sybil attack, where they create a large number of fake identities or nodes in the network to manipulate the consensus mechanism. This can enable the attacker to control the network and carry out malicious activities. Attackers can also use social engineering techniques to gain access to users' private keys, which are used to sign transactions on the Blockchain. Once an attacker has access to a user's private key, they can use it to transfer funds out of the user's account (Yuan & Wang, 2018). These examples of attack methods display that while blockchain technology provides a highly secure framework, it is important to recognize that it is not completely immune to attacks. However, as a blockchain scales, some known attacks are difficult and costly to accomplish. On the other hand, Blockchain enabled Smart-contracts and by extent DAOs, has some vulnerabilities that can occur due to programming errors, incorrect implementation, or flaws in the design of the contract. The immutable nature of smart contracts, once deployed to the Blockchain, means that they cannot easily be modified or updated, leaving them vulnerable to potential exploitation. Several attack methods, such as reentrancy, transaction order dependence (TOD), and abuse of Tx origin, have been used in the past to exploit vulnerabilities in smart contracts, causing significant financial losses. The most well-known

attack is TheDAO attack, which exploited a vulnerability in the smart contract to steal approximately \$50 million worth of Ether in 2016. Other attacks include the Parity Wallet hack, where an attacker exploited a vulnerability in the Parity multi-sig wallet code to steal approximately \$30 million worth of Ether in 2017, and the King of the Ether Throne attack, which exploited a vulnerability to win the entire balance of a flawed contract in 2016. These attacks demonstrate the importance of identifying and addressing vulnerabilities in smart contract code to prevent potential exploitation (Sayeed et al., 2020). According to the literature, there exist some potential solutions to these issues. Such solutions include multi-signature schemes, formal verification of smart contracts, and the use of off-chain computation (Zamani & Giaglis, 2018). However, securing smart contracts remains a challenge, and even the most widely used security tools contain known vulnerabilities which can be exploited by attackers (Sayeed et al., 2020).

Scalability

Scalability is the ability of a system to handle increasing amounts of data and transactions without sacrificing performance or security (Buterin, 2014). Scalability solutions can be classified into first layer and second layer solutions. First layer solutions indicate modifications to the entire blockchain structure, such as changing the block size or the use of sharding. Second layer solutions are mechanisms that are implemented outside of the blockchain. Sharding is a promising first layer solution to the scalability issue which involves dividing the blockchain network into multiple committees, each processing a separate set of transactions (Hafid, Senhaji Hafid, & Samih, 2020).

A proposed Layer 1 solution was presented in an article by C. Li et al. (2018) with Conflux, a blockchain system that has been developed and aims to address the performance issues of current blockchain systems. Conflux attempts to solve the scalability trilemma by using a direct acyclic graph (DAG) based approach that processes transactions and blocks without discarding any as forks. However, the scalability of Conflux is limited by the processing capability of individual nodes and increasing the block size can slow down the confirmation process. Additionally, the incentive mechanism for encouraging honest behaviors was outside the scope of the article and proposed as future work.

Other Layer 1 solutions to scalability have been suggested. According to Benitez-Martinez, Romero-Frias, and Hurtado-Torres (2022), recent innovations in DLT types, such as Hedera

Hashgraph or Tangle from the IOTA Foundation, have resolved some scalability issues. This solution is suggested by using neural blockchain technology, which is a type of private permissioned network. The proposed approach is intended to combat corruption in the field of procurement, and it uses smart contracts to support secure, agile contracting. Although these potential solutions focus specifically on the use of blockchain technology in public procurement, the general idea of using scalable blockchain technology and smart contracts can potentially be applied to other DAOs in different contexts. However, it would depend on the specific requirements and characteristics of the DAO.

Some proposed layer two scaling solutions are state channels, sidechains and rollups. State channels allow for off-chain transactions, allowing parties to transact directly with each other without the need to broadcast every transaction to the main blockchain. This can greatly increase transaction speed and decrease fees. Sidechains are separated blockchain networks that can be interoperable with the main blockchain, allowing for faster transaction processing by moving some transactions off of the main blockchain and onto the sidechain. Rollups are a type of Layer 2 solution that uses smart contracts to batch many transactions together and submit them as a single transaction to the main blockchain, which can greatly increase the efficiency of the network and reduce fees. By utilizing these and other Layer 2 solutions, blockchain networks can greatly increase their transaction capacity and provide users with a more efficient and cost-effective experience (BlockSpaces, 2023).

Decentralization

Decentralization is a fundamental aspect of blockchain technology that sets it apart from traditional centralized systems. In a centralized system, there is a single entity or group of entities that control the system, and all transactions and decision-making are managed by that entity. This can lead to issues such as a lack of transparency, censorship, and a higher risk of fraud or corruption. In contrast, a decentralized blockchain network allows for a more democratic and transparent system, where every participant has an equal role in the validation and maintenance of the network. Decentralization is achieved through consensus mechanisms that incentivize users to validate and maintain the blockchain (Buterin, 2014).

Decentralization provides a number of benefits to blockchain networks. First, it increases security, as there is no single point of control that can be hacked or attacked. Instead, the network is distributed across a large number of nodes, making it much more difficult to

compromise the system (Yuan & Wang, 2018). Decentralization also ensures that there is no single point of failure, as the network can continue to operate even if some nodes go offline. Furthermore, decentralization provides transparency, as every participant can view the entire blockchain and all of its transactions. This transparency helps to prevent fraud and corruption, as any suspicious activity can be quickly identified and investigated. Finally, decentralization allows for a more democratic and equitable system, where every participant has a voice in the decision-making processes of the network. However, achieving true decentralization can be a challenge. It requires a large and diverse network of participants who are willing to work together to validate and maintain the network. Furthermore, ensuring that the network remains decentralized over time can be difficult, as some participants may seek to gain more control or influence over the network. Nonetheless, decentralization remains a key feature and goal of many blockchain networks and is seen as a critical component in building a more open, transparent, and democratic financial system (Chu & Wang, 2018).

Vitalik Buterin's Trilemma

Vitalik Buterin's Trilemma, sometimes referred to as “trilemma of Scalability”, is a well-known concept in the blockchain community, described by Vitalik Buterin, the co-founder of Ethereum. The trilemma states that trade-offs are inevitable between three important properties of blockchain technology: scalability, decentralization, and security. This means that achieving all three properties simultaneously is challenging, and most blockchain scalability solutions can only optimize two of these properties at the expense of the third (Hafid et al., 2020).

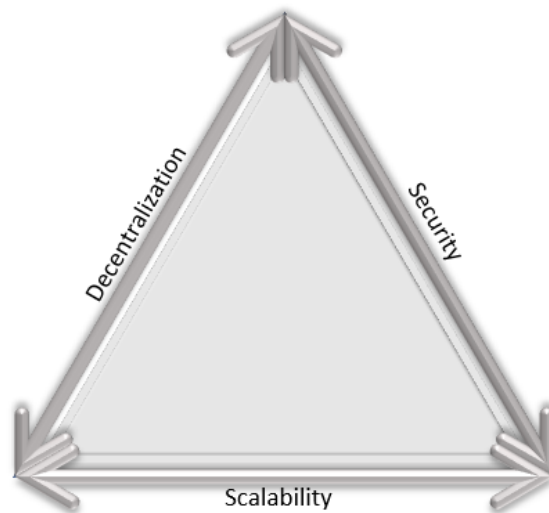


Figure 5: Vitalik Buterin's Trilemma

A hypothetical example of the trilemma can be described as follows: In order for a blockchain to become sufficiently secure against attacks such as a 51% attack, it would require a high quantity of nodes, such as miners- or validators, and participants to take part in the transactions. As the network grows, the number of transactions that need to be verified and processed increases, which can potentially slow down the system. By scaling the Blockchain, it could lead to higher transactions costs which could make a barrier for participants, and thus the power, i.e., decision-making, would fall into the hands of a selective group which would lead to centralization.

3. Methodology

In this study, a bibliometric and content analysis was conducted to determine significant topics in the field of Decentralized Autonomous Organizations. The data was gathered from Web of Science, and 73 relevant articles were selected using keyword-based searches. The analysis involved identifying important publications and clusters, as well as identifying theories and key topics in the field, including governance, applications, security, and legal challenges. This methodology provides a thorough analysis of DAOs, which can serve as a basis for future research and structured development in the field.

Web of Science as a Data Collection Source

Web of Science is a widely used bibliographic database that indexes high-quality, peer-reviewed scholarly literature from various fields. It provides comprehensive coverage of

academic journals and other research publications, and its reliability and validity have been demonstrated in numerous studies. The database is updated regularly, and new articles are added on a daily basis. One advantage of using Web of Science is that it provides standardized citation data that can be used to analyze the impact of individual articles, journals, and authors (K. Li, Rollins, & Yan, 2018). However, a limitation of using only Web of Science is that it may not include all relevant publications in the given field. Additionally, some articles may be behind paywalls or subject to other restrictions, which can limit access to the full text of the article. Therefore, while Web of Science is a valuable source for conducting bibliometric analysis, with a comprehensive coverage of academic journals, it may not capture the full scope of the publications in the field of Decentralized Autonomous Organizations.

3.1. Data Collection

As mentioned, the aim of this study is to conduct a bibliometric- and content analysis of Decentralized Autonomous Organizations to identify the most important topics within the field and lay the foundation for future work. Web of Science has been used as the source of data and articles were found using keyword-based searches of article titles, abstracts, author keywords, and keywords plus. Searches were limited to articles published in English and retrieved November 27th, 2022.

The initial keyword search resulted in 51 articles, which was not sufficient for the analysis. Therefore, the search terms were expanded. The final keyword search resulted in 88 articles. After reading all the articles, 15 articles were eliminated due to irrelevance and/or limited access resulting in 73 articles for the analysis.

Inclusion/exclusion criteria for selecting articles were based on their direct or indirect relevance to DAOs. Specifically, articles were included if they discussed DAOs indirectly through their relation to blockchain or smart contract with topics that were applicable in the context of DAOs. Articles that discussed DAOs directly were also included.

A limitation of the data collection is that it relies on a keyword-based search, which may miss some relevant articles that do not contain my specific search terms. However, I mitigated this limitation by setting clear inclusion/exclusion criteria for article selection. Also, I conducted a manual search of articles to identify additional relevant publications, which could be included in my final dataset.

The details of the keyword searches and the number of articles included in my analysis are summarized in Table 3. Overall, the data collection strategy is comprehensive, and will provide a good foundation for the bibliometric- and content analysis of DAOs.

Keyword Search	Articles
"Decentralized Autonomous organization*"	51
"Decentralized Autonomous Organization*" OR ("decentralized decision-making" AND ("blockchain*" OR "block-chain*") AND ("Smart Contract" OR "Smart-Contract*"))	56
"Decentralized Autonomous Organization*" OR ("DAO*" AND ("blockchain*" OR "block-chain*")) OR ("decentralized decision-making" AND ("blockchain*" OR "block-chain*") AND ("Smart Contract" OR "Smart-Contract*"))	73
"Decentralized Autonomous Governance*" OR "Distributed Autonomous Governance*" OR "Distributed Autonomous Organization*" OR "Decentralized Autonomous Organization*" OR (("DAO*" OR "DAG*" OR "DAS*") AND ("blockchain*" OR "block-chain*") AND ("Smart Contract" OR "Smart-Contract*")) OR (("decentralized decision-making" OR ("Business model" OR "Business-model")) AND "auto*" AND ("blockchain*" OR "block-chain*") AND ("Smart Contract" OR "Smart-Contract*"))	88
After Elimination due to irrelevance or limited access	73

Table 3: Keyword Search

3.2. Methods

Research Question #1:

What are the most influential works in the field of Decentralized Autonomous Organizations (DAOs), and what are the key topics and themes addressed in this work?

In response to this research question, the R Package "Biblioshiny" was utilized to generate a list that displays the most influential articles, ranking the articles based on citations per year. Following this, a content analysis was conducted to provide a review of the key topics and themes presented in these articles. This analysis aimed to identify the most influential articles, including their research themes.

Research Question #2:

What is the current state of the research on DAOs, and what are the main research themes and theories in the field?

The first step in answering this research question was by conducting a bibliographic coupling, using VosViewer. All 73 articles were included, and the network was constructed using the method of “Association Strength”. When the clusters were identified, this method was combined with a Content analysis to identify research streams within each cluster. This analysis aimed to identify the current state of the research in DAOs, and the research themes identified in the field. In order to capture the current state of the research, the research streams were plotted into a line graph, revealing the growth of the streams.

Research Question #3:

How has the concept of DAOs been defined and evolved in the academic literature, and what are the key dimensions and characteristics of DAOs that have been identified?

To answer this research question, a thorough content analysis and literature review has been conducted to identify the evolution of DAOs in the literature, and to identify the components of which it is built. Through the bibliographic coupling, key research streams were identified, including a research stream focusing specifically on features of Decentralized Autonomous Organizations. The purpose of this method was to identify key dimensions, and characteristics of DAOs, and how this term has evolved in the academic literature.

Research Question #4:

What are some major applications of DAOs, particularly in Financial industries, and how have they performed in the context of key topics that have been detected in the academic literature?

To answer this question, a set of DeFi DAOs were selected based on their Market Capitalization. The whitepapers of the DAOs were used to identify key information, and a content analysis was conducted to identify key topics in the academic literature. Finally, the selected DAOs were evaluated based on these research topics.

Research Question #5:

What are the main drivers and barriers to the adoption of DAOs, and how can they be addressed or mitigated?

In response to this research question, a literature review and content analysis was conducted to identify challenges to the successful implementation of DAOs, and potential solutions to

these issues based on findings in these articles. Furthermore, the research streams detected in the bibliographic coupling followed by a content analysis was done with a focus on detecting challenges to the successful adoption of DAOs, and how the literature has proposed solutions to this.

4. Bibliometric- and Content Analysis

This section of the paper will apply the methods discussed in the preceding chapter. First, the most influential articles will be presented, followed by an examination of DeFi DAOs. Then, the bibliographic coupling is presented, along with a content analysis to further investigate the research streams. Subsequently, the findings in this analysis will be discussed in more detail, linking them together to form a conclusion, aiding in a nuanced and structured continuation of the research in DAOs for future studies.

4.1. Most influential articles

Table 4 reveals the ten most influential articles from the data collection, based on Total Citations per Year.

Article Title	Author, Year, Journal	Total Citations	TC per Year
Blockchain-Enabled Smart Contracts: Architecture, Applications, And Future Trends	WANG S, 2019, IEEE T SYST MAN CY-S	327	65.40
Governance In The Blockchain Economy: A Framework And Research Agenda	BECK R, 2018, J ASSOC INF SYST	172	28.67
Blockchain And Cryptocurrencies: Mode Techniques, And Applications	YUAN Y, 2018, IEEE T SYST MAN CY-S	166	27.67
Resource Trading In Blockchain-Based Industrial Internet Of Things	YAO HP, 2019, IEEE T IND INFORM	128	25.60
\ Distributed Framework For Detecting Ddos Attacks In Smart Contract-Based Blockchain-Iot Systems By Leveraging Fog Computing	KUMAR P, 2021, T EMERG TELECOMMUN T	50	16.67
Now The Code Runs Itself: On-Chain And Off-Chain Governance Of Blockchain Technologies	REIJERS W, 2021, TOPOI-INT REV PHILOS	44	14.67
Governance And Control In Distributed Ledgers: Understanding The Challenges Facing Blockchain Technology In Financial Services	ZACHARIADIS M, 2019, INFORM ORGAN-UK	68	13.60
Decentralized Autonomous Organizations: Concept, Model, And Applications	WANG S, 2019, IEEE T COMPUT SOC SY	61	12.20
Smart Contract: Attacks And Protections	SAYEED S, 2020, IEEE ACCESS	47	11.75
With A Little Help From The Miners: Distributed Ledger Technology And Market Disintermediation	ZAMANI ED, 2018, IND MANAGE DATA SYST	46	7.67

Table 4: Most Influential Articles based on Citations per year

The most influential article in this data set is by Wang et. al., (2019), which provides a comprehensive overview of blockchain-enabled smart contracts, including their operating mechanism, an ideal framework, application scenarios, challenges, and future trends. The article aims to stimulate further research efforts and provide helpful guidance and reference for researchers and practitioners. The top ten most influential articles also contain similar comprehensive overviews of both Blockchain and Decentralized Autonomous Organizations. Also, key themes such as Governance, Security and Scalability are represented as key topics in these articles.

4.2. DeFi DAOs

Decentralized Finance (DeFi) has transformed the traditional financial landscape by enabling peer-to-peer transactions and providing financial services that are accessible to anyone. One of the most notable developments within the DeFi ecosystem is the emergence of DAOs, which are collectively owned and governed by their members through smart contracts. DeFi DAOs have gained significant traction over the past few years, providing a range of services such as lending, trading, insurance, and asset management. Table 5 displays the ten highest-ranked DeFi DAOs in terms of market capitalization as of March 14th, 2023. Following, in Table 6, a matrix presenting the top five DeFi DAOs, providing details of each in the context of research themes found in the academic literature.

DeFi DAOs	
1 Compound (COMP)	Market Cap: \$4.6 billion USD
2 Aave (AAVE)	Market Cap: \$3.7 billion USD
3 Uniswap (UNI)	Market Cap: \$3.2 billion USD
4 MakerDAO (MKR)	Market Cap: \$1.8 billion USD
5 SushiSwap (SUSHI)	Market Cap: \$1.6 billion USD
6 Curve DAO (CRV)	Market Cap: \$1.2 billion USD
7 Yearn.finance (YFI)	Market Cap: \$1.1 billion USD
8 Balancer (BAL)	Market Cap: \$757 million USD
9 Synthetix (SNX)	Market Cap: \$653 million USD
10 Bancor (BNT)	Market Cap: \$431 million USD

Table 5: Largest DeFi DAOs by market capitalization as of March 14th, 2023
(CoinMarketCap, 2023)

	Compound (COMP)	Aave (AAVE)	Uniswap (UNI)	MakerDAO (MKR)	SushiSwap (SUSHI)
Application	Decentralized lending and borrowing platform	Decentralized lending and borrowing platform	Decentralized exchange platform for blockchain-based tokens	Decentralized platform for issuing and governing stablecoins.	Decentralized exchange platform for blockchain-based tokens
Governance	Decentralized Governance, using governance-token (COMP) with proportional voting power.	Decentralized Governance, using governance-token (AAVE) with proportional voting power.	Decentralized Governance, using governance-token (UNI) with proportional voting power.	Decentralized Governance, using governance-token (MKR) with proportional voting power.	Decentralized Governance, using governance-token (SUSHI) with proportional voting power.
Decentralization/Centralization	Potential risk of centralization due to large token-holders. Measures taken: Timelocks	Potential risk of centralization due to large token-holders Measures taken: Cooldown Mechanisms	Potential risk of centralization due to large token-holders Measures taken: Timelocks	Potential risk of centralization due to large token-holders Measures taken: Debt-Ceiling	Potential risk of centralization due to large token-holders Measures taken: Timelocks
Security	Bug Bounty Program Formal Verification, security verifications Audited Smart contracts by third-party security firms	Bug Bounty Program Formal Verification, security verifications Audited Smart contracts by third-party security firms	Bug Bounty Program Formal Verification, security verifications Audited Smart contracts by third-party security firms	Bug Bounty Program Formal Verification, security verifications Audited Smart contracts by third-party security firms	Bug Bounty Program Formal Verification, security verifications Audited Smart contracts by third-party security firms
Scalability	Layer 1: Ethereum 2.0 Layer2: Polygon, zkSync	Layer1: Ethereum 2.0 Layer2: Polygon, Aave Arc (zkRollup)	Layer1: Ethereum 2.0 Layer2: Optimism, Arbitrum, zkSync	Layer1: Ethereum 2.0 Layer2: StarkNet, Optimism, Arbitrum	Layer1: Ethereum 2.0 Layer2: Polygon, zkSync
Regulation	potential regulatory uncertainty in some jurisdictions	Electronic Money Institution license from the UK Financial Conduct Authority	potential regulatory uncertainty in some jurisdictions	potential regulatory uncertainty in some jurisdictions	potential regulatory uncertainty in some jurisdictions

Table 6: Matrix of top 5 Largest DeFi DAOs by market capitalization as of March 14th, 2023

Compound and Aave are decentralized lending and borrowing platforms (Aave, 2020; C. Labs, 2018). Meanwhile, Uniswap and Sushiswap serve as a decentralized exchange platform for blockchain-based tokens (docs.sushi, 2022b; hackmd, n.d.), while MakerDAO (MKR) operates as a decentralized platform for issuing and governing stablecoins (MakerDAO, 2017). These DeFi platforms provide open, transparent, and accessible financial products and services online.

All of these DeFi platforms utilize decentralized governance through their respective governance-tokens, which grant proportional voting power to their token-holders (Aave, 2020; Adams, Zinsmeister, Salem, Keefer, & Robinson, 2021; CryptoLibrary, 2023; docs.sushi, 2022a; C. Labs, 2022b; MakerDAO, 2017). This decentralized governance model allows for greater transparency and community involvement in the decision-making process for these platforms, however there is a potential risk of centralization if the top investors hold a large portion of governance-tokens. To address this concern, each platform has implemented various measures. Aave has implemented cooldown mechanisms, which require token-holders to wait a certain amount of time before being able to vote or take other actions on the platform (Dodao, n.d.). This helps to prevent large token-holders from making hasty or unilateral decisions that could lead to centralization. Compound, Uniswap and SushiSwap

have implemented timelocks, which delay the execution of certain actions on the platform for a specified amount of time (C. Labs, 2022b; SolidityDevStudio, 2022; Uniswap, n.d.). This helps to ensure that decisions are made with careful consideration and in the best interest of the community, rather than by large token-holders seeking to increase their own power. MakerDAO has implemented a debt-ceiling mechanism, which limits the amount of stablecoins that can be minted based on the collateral held in the system (MakerDAO, 2017). This helps to prevent large token-holders from dominating the platform and ensures a more equitable distribution of power among users. By implementing these various measures, these DeFi platforms aim to mitigate the potential for centralization and ensure a fair and democratic governance process for all users.

Security as a fundamental aspect of their operations is a high priority for each of these DeFi platforms. To ensure the security and safety of their users and assets, each platform has implemented a range of security measures, including bug bounty programs, formal verification, and security verifications, with all smart contracts audited by third-party security firms. These measures help to identify and mitigate potential security vulnerabilities and ensure that the platforms are able to provide a secure and reliable environment for the users (Aave, 2023; GitHub, 2023; C. Labs, 2022a; security.makerdao, n.d.).

In order to tackle the challenges of scaling, these DeFi platforms have implemented various Layer 1 and Layer 2 scaling solutions, all of which are built on the Ethereum 2.0 blockchain. Ethereum 2.0 is an upgrade to the Ethereum blockchain that offers significant improvements in scalability, security, and energy efficiency. Layer 1 scaling solutions used in Ethereum 2.0 include sharding and Proof of Stake (PoS) consensus mechanism. Sharding is a technique that splits the Ethereum network into smaller partitions called shards, allowing for parallel processing of transactions and reducing congestion. The PoS consensus mechanism replaced the former Proof of Work (PoW) mechanism, which required high computational power and energy consumption, with a more efficient and environmentally-friendly approach (Crypto.com, 2020). In addition to Ethereum 2.0, each DeFi platform has integrated different Layer 2 scaling solutions to improve their performance and scalability. Compound, Sushiswap and Aave have integrated Polygon and zkSync as their Layer 2 scaling solutions. Polygon is a Layer 2 scaling solution that utilizes sidechains to enable faster and cheaper transactions, while zkSync is a Layer 2 scaling solution that bundles many transactions together into a single batch, which is then submitted to the main chain (Compound, 2022;

Cryptorubic, 2021; M. Labs, n.d.; OpenZeppelin, 2023; TheBlock, 2023). In addition to these, Aave have developed their own Layer 2 solution, called Aave Arc, which uses the same concept, bundling up transactions before submitting it to the Ethereum chain (DeFiSlate, 2023). Uniswap has integrated Optimism, Arbitrum, and zkSync as its Layer 2 scaling solutions (M. Labs, n.d.; support.token, 2022, 2023). Optimism is a Layer 2 scaling solution that enables high-speed and low-cost transactions by processing them off-chain and periodically committing them to the Ethereum blockchain. Arbitrum is a Layer 2 scaling solution that uses a similar approach but with some differences in implementation. MakerDAO has integrated StarkNet, Optimism, and Arbitrum as its Layer 2 scaling solutions (TheBlock, 2022). StarkNet is a Layer 2 scaling solution that uses zk-rollups to enable high scalability and throughput while maintaining Ethereum-level security. By integrating these Layer 2 scaling solutions, each DeFi platform is able to further increase its capacity and throughput, while reducing transaction fees and improving user experience.

Regulation is a significant challenge facing DeFi platforms, as they operate in an unregulated environment. Each platform faces potential regulatory uncertainty in some jurisdictions. However, Aave has taken steps to address this issue by obtaining an Electronic Money Institution (EMI) license from the UK Financial Conduct Authority. This license allows Aave to provide financial services to organizations in the UK and demonstrates a commitment to compliance and regulatory oversight (Paypers, 2023).

4.3. Bibliographic Coupling

Figure 6 shows a network of bibliographic coupling containing three clusters in the field of Decentralized Autonomous Organizations and Blockchain Technology. The colors reveal the different clusters and each node represents an article from the data collection.

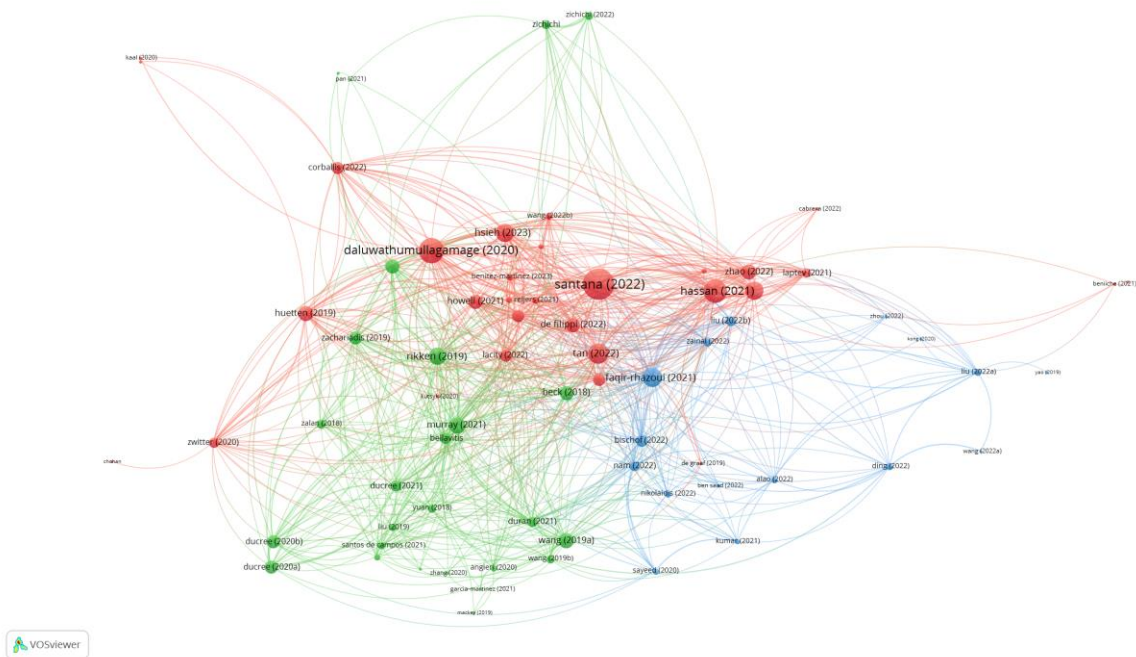


Figure 6: Bibliographic Coupling – VosView
Red: Cluster 1 – DAOs, Governance-, Legal-, and Socioeconomic Implications
Green: Cluster 2 – Fundamentals in Blockchain, Smart Contracts, and DAOs
Blue: Cluster 3 – Applications, Security and Technical Attributes of BLT

Based on the bibliographic coupling, and a content analysis of the articles within each respective cluster, eight research streams were identified. The Clusters, research streams and articles within each stream are displayed in Table 7.

Although eight streams were detected, two streams are related to applications in Blockchain technology, separated mainly by the time they were published. Another similarity between research streams that have been detected in the two clusters is the topic of governance. Although we can detect some differences in these streams, it is worth mentioning that there are overlaps, and several articles within these streams could fit into either.

The first Cluster is labeled “DAOs, Governance-, Legal-, and Socioeconomic Implications”. It contains three research streams, in which the first is a set of articles focusing on blockchain governance, as well as legal and regulative implications, such as accountability and contract law. The second stream involves the effect DAOs and Blockchain technologies have on society, and in particular the financial industry. The Third and final stream in Cluster 1

contains articles specifically on Decentralized Autonomous Organizations, how they are structured, and the features they hold.

The Second Cluster has been labeled “Fundamentals in Blockchain, Smart Contracts and DAOs”. This cluster contains mostly articles that have been written early relative to the other clusters and the content is widely focused on foundational ideas and descriptions of concepts. In this cluster, three research streams have been detected, with the first being “Governance and Control in Blockchain Technology”. Some articles in this cluster have a lot in common with articles in research stream 1.1, although most of the articles in this stream are more directed towards governance in the sense of management control and decision-rights rather than legal implications. The next research stream is labeled “Applications in Blockchain Technology” and contains different applications that have been created, such as decentralized voting systems, IP address management, data privacy etc. The third research stream in cluster 2 is named “Foundational features of Blockchain and Smart Contracts”. The articles in this stream involve technical foundations in the decentralized architecture of BLT, Smart Contracts and DAOs, as well as comprehensive overviews explaining how these technologies work.

The third Cluster is labeled “Applications, Security and Technical Attributes of BLT”. It contains two research streams with the first being applications in Blockchain technology. They have much of the same content as the second research stream in Cluster 2, although these articles are generally published more recently. The second research stream in the third cluster is focusing on the technical components of this emerging technology and security measures to inhibit attacks.

Cluster	Stream	Stream Title	Articles in each Stream
1	1.1	Blockchain Governance and Legal Implications	(Dwivedi et al., 2021), (Tan et al., 2022), (Daluwathumullagamage & Sims, 2020), (Zwitter & Hazenberg, 2020), (Laptev & Feyzrahmanova, 2021), (de Graaf, 2019), (Kutsyk, Redchenko, & Voronko, 2020), (Benitez-Martinez et al., 2022), (Reijers et al., 2021), (Muehleemann, 2018), (Z. W. Wang & Zhong, 2022), (Zhao, Ai, Lai, Luo, & Benitez, 2022), (De Filippi, Mannan, & Reijers, 2022), (Hutten, 2019), (Howell & Potgieter, 2021)
1	1.2	Social-, Socioeconomic-, and Financial Implications of Blockchain and DAOs	(Nabben & Rennie, 2022), (Lacity, 2022), (Hoffmann & Dahlinger, 2019), (Chohan, 2022), (Hsieh & Vergne, 2022), (Beniiche, Ebrahimzadeh, & Maier, 2021), (Corballis & Soar, 2022), (Harwick & Caton, 2022)
1	1.3	Features of Decentralized Autonomous Organizations	(Hsieh et al., 2018), (Santana & Albareda, 2022), (Hassan & De Filippi, 2021), (Kaal, 2020), (Cabrera, Nickson, Roland, Hall, & Ankel, 2022), (L. Liu, Zhou, Huang, & Zheng, 2021), (Saurabh, Rani, & Upadhyay, 2022)
2	2.1	Governance and Control in Blockchain Technology	(Zalan, 2018), (Murray et al., 2021), (Zachariadis et al., 2019), (Rikken et al., 2019), (Beck et al., 2018), (Morrison et al., 2020), (Bellavitis, Fisch, & Momtaz, 2022), (Zamani & Giaglis, 2018)
2	2.2	Applications in Blockchain Technology	(Angieri et al., 2020), (Mackey, Shah, Miyachi, Short, & Clauson, 2019), (Ducree, Etzrodt, et al., 2020), (S. F. Zhang, Wang, & Xiong, 2020), (Zichichi, Serena, Ferretti, & D'Angelo, 2022), (Zichichi, Ferretti, & Rodriguez-Doncel, 2022), (Garcia-Martinez, Angieri, Liu, Yang, & Bagnulo, 2021), (Bataineh, Mardini, Khamayseh, & Yassein, 2022), (Ducree, Gravitt, et al., 2020), (Freund & Stanko, 2018), (De Campos, Chanel, Chauffaut, & Lacan, 2021), (J. S. Zhang et al., 2021)
2	2.3	Foundational Features of Blockchain and Smart Contracts	(Yuan & Wang, 2018), (S. Wang, Ouyang, et al., 2019), (S. Wang, Ding, et al., 2019), (Pan & Deng, 2021), (C. C. Liu et al., 2019), (Duran & Griffin, 2021), (Ducree et al., 2021)
3	3.1	Applications in Blockchain Technology	(Faqir-Rhazoui, Arroyo, & Hassan, 2021), (Zainal et al., 2022), (Y. Liu & Shang, 2022), (Nikolaïdis & Refanidis, 2022), (Kong, Zhang, Wang, & Shu, 2020), (X. Wang, Yang, Han, Wang, & Wang, 2022), (G. Liu, Chen, Han, Zhou, & He, 2022), (Alao & Cuffe, 2022)
3	3.2	Technical Capabilities, and security attributes of Blockchain-Based Systems	(Kumar, Kumar, Gupta, & Tripathi, 2021), (Ben Saad, Ksentini, & Brik, 2022), (Zhou, Ma, Pan, & Zhu, 2022), (Ding et al., 2022), (Nam & Kil, 2022), (Bischof et al., 2022), (Sayeed et al., 2020), (Yao et al., 2019)

Table 7: Articles in each Research Stream for Each Cluster

4.3.1. Growth in Research Streams

In order to get a better comprehension of the research streams, all 73 articles have been included in Figure 7, showing the publications within each research stream over the past five years. We can observe that the second Cluster contains a lot of publications during the first years, with fewer towards 2022. These research themes involve foundational features of

Blockchain and smart contracts, applications in Blockchain Technology and Governance and Control in Blockchain Technology, laying the groundwork for future research. All the other research streams are showing an increasing curve, indicating topics of interest for future research. In cluster 1 we detect topics such as Blockchain Governance and Legal implications in addition to Social-, socioeconomic-, and financial implications of BLT and DAOs. Also, publications of comprehensive overviews, and features of DAOs are showing an increase in publications. From cluster 3, we find technical capabilities, and security attributes showing an increasing curve, alongside applications in Blockchain technology. It is worth repeating that the topics in the research streams: “Governance and Control in Blockchain Technology (2.1)” and “Applications in Blockchain technology (2.2)” overlaps with research streams 1.1 and 3.1, respectively.

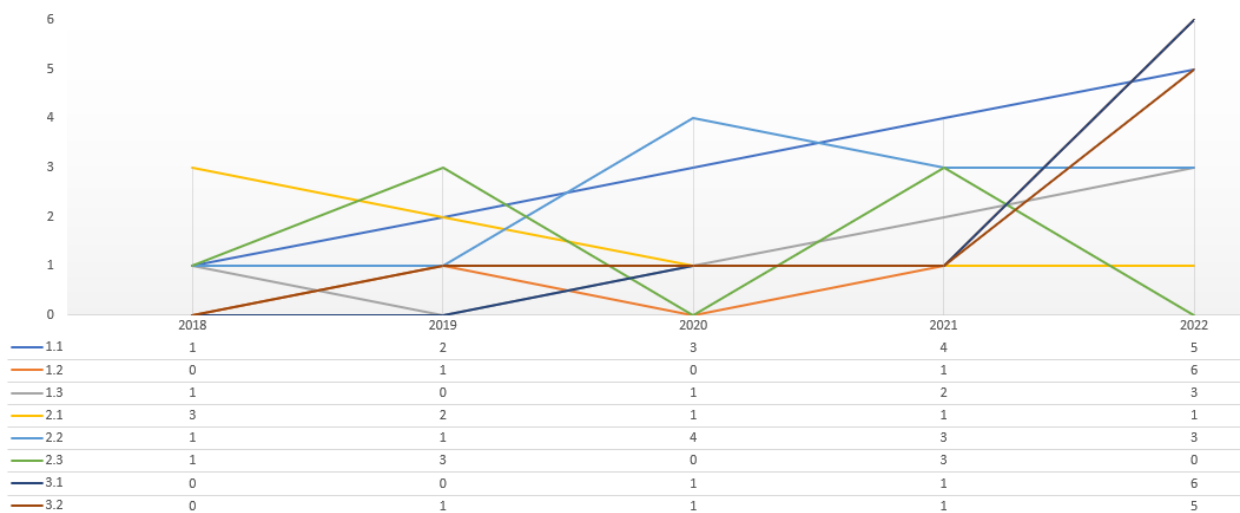


Figure 7: Growth in Research Streams

5. Discussion

By utilizing bibliographic coupling, three distinct clusters were discovered from the articles used in this analysis. Through a content analysis, eight research streams were identified within these clusters. Based on overlapping themes within some of the research streams across the clusters, separated by minor differences and time of publication, they have been combined as shown in Figure 8, resulting in five research streams to discuss.

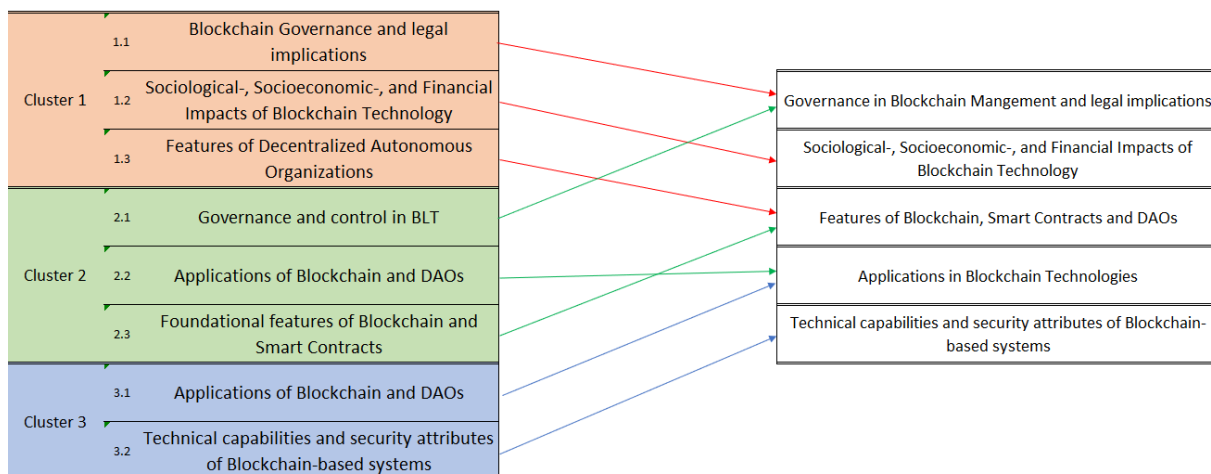


Figure 8: Research Streams

The following chapter will discuss each of the five research streams that have been identified and tie these topics to the information gathered in the literature review, the most influential articles and the major DeFi DAOs discovered in the analysis. Additionally, suggestions for research questions for future studies within each cluster are presented to aid future research and development in the field of Decentralized Autonomous Organizations.

5.1. Governance in Blockchain Technology and Legal Implications

Blockchain governance and legal implications are complex and evolving topics that are gaining increasing attention as decentralized autonomous organizations and other blockchain-based systems continue to grow. The number of publications in this research stream has seen an increase in publications, peaking in 2022, as shown in Figure 7. The research stream involves both macro- and Meso-level analysis, encompassing law and regulations as well as blockchain governance structures. Decision-making and accountability within a decentralized environment are found to be crucial but challenging topics. Several theoretical frameworks are necessary to fully understand these issues.

Agency theory, for instance, suggests that DAOs can mitigate agency costs, as the absence of managers allows investors to act as agents and make decisions for the organization (Murray et al., 2021). Game theory can also be a useful tool for understanding the interaction between multiple agents in DAOs. However, there are still issues in relation to decision-making,

particularly when a small group of investors holds a large proportion of investments, which can lead to centralization. In the context of blockchain governance, game theory faces challenges due to the complexity of the agents involved. These agents are often pseudonymous, and their strategies and goals may not be clear, which makes it difficult to design effective incentive structures and mechanisms.

Code-based governance, as shown in Table 2 (Institutional Theory), has global, public, and transferable contracts, which can raise questions of accountability as it does not need to be regulated by any country or union. This global feature of code-based governance creates issues of compliance and consumer protection. The DeFi DAOs chosen based on their market capitalization in Table 5 and 6 show that 4 out of 5 DeFi DAOs were not regulated, while one of them (AAVE) has willingly been regulated by the UK Financial Conduct Authority to include organizations as participants in their decentralized lending and borrowing platform (Paypers, 2023).

TheDAO case study, as discussed in the literature review, revealed major issues in blockchain governance and legal implications. TheDAO attack led to governmental issues in this crisis situation, which ended in a division in the community as the participants were unable to come to an agreement on how to handle the results from the attack. The issue of law and regulation was also central, as the attacker could not be prosecuted due to the absence of any judicial infrastructure to enforce any law against them. Moreover, due to the concept of “Code is Law,” many argue that the recursing method used by the attacker to obtain \$50 million USD was a feature of TheDAO, as the code in the smart contract allowed for it to happen (Morrison et al., 2020).

Developing effective governance models for blockchain-based systems is crucial for their success, as it requires interdisciplinary research and collaboration between experts in several fields. Four out of ten of the most influential articles are included in this research stream, underscoring the importance of this topic. The literature suggests that creating effective mechanisms for decision-making and dispute resolution is a central challenge (Hassan & De Filippi, 2021). One solution, which was used by all the aforementioned DeFi DAOs, is the use of government tokens as a decision-making mechanism to distribute and decentralize power. Cooldown mechanisms, timelocks, and debt ceilings are also used to prevent centralization of power when a small group of investors holds a large proportion of tokens.

While potential solutions have been proposed, addressing issues in crisis situations remains a significant challenge. The entanglement between applications and infrastructure is a major issue, DAOs and smart contracts being the applications and their underlying infrastructure being the blockchain. The DAO attack on the Ethereum blockchain highlighted the challenges posed by this entanglement, resulting in a hard fork and a division in the blockchain community.

Based on the bibliometric and content analysis conducted in this paper, the following research questions have been identified for future studies.

Research Questions for Future Research

What are the legal and regulatory challenges faced by decentralized autonomous organizations (DAOs) in various industries, and how do these challenges impact their operations and growth?

How can governance structures within DAOs be designed to effectively manage decision-making and dispute resolution, particularly in crisis situations?

What are the implications of code-based governance on accountability and regulation of DAOs, given their global features?

What are the potential benefits and drawbacks for DAOs of voluntarily seeking regulation, as demonstrated by AAVE's decision to be regulated by the UK Financial Conduct Authority?

How can DAOs balance the need for transparency and decentralization with the need for accountability and compliance with legal and regulatory requirements?

How can DAOs work with governments and regulatory bodies to establish frameworks that balance innovation and regulatory compliance?

What are the implications of blockchain for the governance of economic activities in different industries and contexts, and how can new approaches to governance in the blockchain economy be identified?

How can governance models be designed to ensure accountability in code-based governance?

How can the issue of entanglement between applications and infrastructure be addressed in DAOs and smart contracts?

How can interdisciplinary research and collaboration facilitate the development of effective governance models for blockchain-based systems?

Table 8: Research Questions for Future Research within Blockchain Governance and Legal Implications

5.2. Social-, Socioeconomic-, and Financial Institutions

The literature on the social, socioeconomic, and financial implications of blockchain and DAOs reveals a range of perspectives that has to be taken into consideration in the development of this emerging technology.

The articles in this cluster cover various perspectives on social, socioeconomic, and financial implications of blockchain and DAOs. They highlight the potential of blockchain in areas such as DeFi, and ad hoc networks, as well as the challenges and limitations that come with their adoption. They also discuss ethical standards for digital applications, the role of public value theory in incorporating citizen-driven digital innovations, and the potential of AI-enhanced mobile edge computing. The literature stresses the need for both technical and socio-political solutions to fully harness the potential of blockchain and DAOs for social, socioeconomic, and financial implications.

This research stream contains articles that have been published relatively recently, and due to its important aspect of the externality of DAOs, this is a research area that will be important in the future, alongside the technological development.

Other areas for exploration include the implications of decentralized platforms for the digital economy, the organizational and coordination mechanisms that support their growth, and the logic behind the creation of digital organizations and their impact on society. Also, exploring the role of oracles, smart contracts, and off-chain transactions in supporting decentralized finance and entrepreneurial solutions to the problem of blockchain finance.

Based on the bibliometric and content analysis conducted in this paper, the following research questions have been identified for future studies:

Research Questions for Future Research

What are the socio-economic consequences of DAOs in various industries?

How can DAOs balance the need for transparency with privacy and confidentiality concerns?

What are the social and socioeconomic implications of DAOs in the context of the digital economy?

What ethical considerations need to be considered when developing digital applications for blockchain and DAOs, and how can these standards be established?

What are the potential implications of DAOs for traditional organizational structures, and how might these changes affect society as a whole?

How can DAOs be designed and implemented to promote greater financial inclusion and equity in society?

What role can DAOs play in promoting social and environmental sustainability?

Table 9: Research Questions for Future Research within Social-, Socioeconomic-, and Financial Institutions

5.3. Foundational features of Blockchain, Smart-contracts and Decentralized Autonomous Organizations

The literature that focuses on features of Blockchain, Smart-Contract and Decentralized Autonomous Organizations has been essential for explaining how the systems work, both in the infrastructures and frameworks that set the stage for future research and development.

This research stream that was detected from the second cluster consists of articles that were published in the former years relative to the data collection in this paper. The concept of decentralized ledger technologies has been around since the 90s, and Blockchain was introduced by an anonymous individual or group called Nakamoto in 2008 (Hsieh et al., 2018). Still, these concepts have evolved over time and the academic literature has to be able to capture the evolution of these technologies. This is also the case for Decentralized Autonomous Organizations which have evolved from the early stages and were called Distributed Autonomous Corporations and then changed over time to what they are today, namely DAOs (Hassan & De Filippi, 2021). During this evolution, Bitcoin itself has been

called a DAO, due to the properties of decentralized and autonomous nature of this technology (Hsieh et al., 2018). However, in later research Blockchains are not DAOs themselves, but the term DAO describes organizations built on the Blockchain through Smart Contracts, and the property of organizational structure is a key component to differentiate these technologies.

Three of the top ten influential articles are in the set of articles in this research stream, which consist of only seven articles. This indicates the importance of this research stream for further study. DAOs are still in their infancy, and ongoing research in this area will be critical for the structured and systematic development of DAO technology as it continues to evolve.

Based on the bibliometric and content analysis conducted in this paper, the following research questions have been identified for future studies:

Research Questions for Future Research

How has the concept of DAOs evolved over time and what are the main milestones of this evolution?

How does the organizational structure of DAOs impact their functionality and effectiveness?

How can the development of DAO technology be further advanced and what are the key components of this technology?

What are the latest developments and trends in Blockchain technology, and how do they impact the functionality and efficiency of Blockchain systems?

How can Blockchain technology be integrated with other emerging technologies such as AI, IoT, and cloud computing?

How can Blockchain technology be made more accessible and user-friendly for non-technical users, and what new tools and interfaces are needed to achieve this goal?

What are the technical considerations when creating and implementing a DAO, and how can these be addressed?

Table 10: Research Questions for Future Research within Foundational Features of Blockchain, Smart-contracts and Decentralized Autonomous Organizations

5.4. Applications in Blockchain Technology

The research stream of applications in blockchain technology reveals several potentials for DAOs, both through case studies and applications that have been made as potential solutions to issues related to these technologies. Few articles were published in the first two years of the publishing period for the articles within the data collection but have increased throughout and peaking in 2022.

The emergence of decentralized autonomous organizations (DAOs) has generated significant interest in the academic literature due to their potential to transform administrative control and decision-making in various sectors. One area where DAOs have shown tremendous potential is decentralized finance (DeFi). DeFi DAOs have provided a range of services, including lending, trading, insurance, and asset management, among others. These platforms are collectively owned and governed by their members through smart contracts, allowing for greater transparency and community involvement in the decision-making process.

However, as shown in Table 6, one potential concern with DeFi DAOs is the risk of centralization, particularly with regard to governance tokens, when few investors hold a large proportion, and thus inherit a large amount of voting power. To address this issue, various measures have been implemented, such as cooldown mechanisms, timelocks, and debt-ceiling mechanisms, to ensure that decisions are made in the best interest of the community rather than by large token-holders seeking to increase their own power. Moreover, security is also a fundamental aspect of the operations of DeFi DAOs, and measures such as bug bounty programs, formal verification, and security audits have been implemented to ensure a secure and reliable environment for users. In addition to the challenges of centralization and security, scalability must be consistently improved as the DAOs grow, and various Layer 1 and Layer 2 scaling solutions have been implemented.

Regulation is also a significant challenge for DeFi platforms, as they operate in a largely unregulated environment. While regulatory uncertainty remains a concern, some platforms have taken steps to address this issue, such as Aave obtaining an Electronic Money Institution (EMI) license from the UK Financial Conduct Authority (Paypers, 2023).

Further investigation is necessary for DAOs to reach their potential. This can be accomplished through studies in the structure, such as technical development, research in governance, regulations, and more. However, DAOs are organizations that have real life

implications, and the development of applications is necessary for testing concepts and revealing potential applications that can be gathered from practical experience.

Suggestion for future research questions for the research stream of applications in Blockchain Technologies is shown in the following Table.

Research Questions for Future Research
How have DeFi DAOs transformed administrative control and decision-making in various sectors?
How have cool-down mechanisms, timelocks, and debt-ceiling mechanisms and other proposals in the prevention of centralization impacted decision-making in DAOs, and what other solutions exist-or could improve on these concepts?
What are the most empirically effective Layer 1 and Layer 2 scaling solutions for DeFi DAOs?
What are the most promising applications of DAOs in sectors beyond DeFi?
How can DAOs be designed to promote transparency, accountability, and good governance practices?
How can DAOs be used to promote innovation and entrepreneurship, particularly in emerging markets and developing countries?
How can DAOs be designed to meet the specific needs and requirements of different industries, such as healthcare, energy, and logistics?
How can DAOs be used to facilitate cross-industry collaborations and knowledge sharing, and what are the potential benefits of such collaborations?
How can DAOs be integrated with existing infrastructure and technologies in specific industries, such as supply chain management systems or electronic health records?

Table 11: Research Questions for Future Research within Applications in Blockchain Technology

5.5. Technical Capabilities and Security attributes of Blockchain-based systems

DAOs are attracting growing attention in the blockchain community because of their potential to transform conventional organizational structures. Nonetheless, like any new technology, DAOs present certain obstacles, particularly with regard to security and scalability. Although research in this area has been limited until 2022, this year saw a significant increase in publications. Three of the ten most influential articles in this data set are found in this cluster, highlighting the importance of this topic.

In the literature review, several attacks of the blockchain and smart contracts were presented. One of the main security risks faced by Blockchains, and DAOs, is the potential for 51% attacks. This occurs when a single entity or group of entities controls the majority of the decision-rights in a blockchain network, allowing them to manipulate transactions and potentially steal funds. Sybil attacks are also a concern, whereby an attacker creates multiple identities in a network to gain control. Additionally, social engineering techniques can be employed to gain access to users' private keys, which can lead to the loss of funds (Yuan & Wang, 2018).

Smart contracts also pose a significant security risk, with reentrancy being one of the most notable vulnerabilities. This occurs when a contract is called multiple times before completing the previous operation, leading to unintended consequences. Transaction order dependence and abuse of tx origin are other security risks associated with smart contracts (Sayeed et al., 2020).

Scalability is another major challenge facing DAOs, as they struggle to balance security, decentralization, and efficiency. Vitalik Buterin's trilemma highlights this challenge, as it states that it is impossible to have a blockchain system that is simultaneously decentralized, secure, and scalable. As a result, DAOs face the difficult task of finding a balance between these three factors (Hafid et al., 2020).

Despite these challenges, DeFi DAOs have made significant strides in addressing security and scalability issues. One notable measure taken by these DAOs is the implementation of bounty programs, whereby individuals are incentivized to identify and report security vulnerabilities. Formal verification of smart contracts using third-party security firms is also a common practice to ensure that contracts are free from vulnerabilities. In addition to these measures, DeFi DAOs have also implemented layer 2 solutions, such as Polygon, zkSync, Aave Arc, Optimism, Arbitrum, and Startnet, to improve scalability. These layer 2 solutions enable DAOs to process transactions off-chain, reducing the burden on the underlying blockchain network. This, in turn, improves the speed and efficiency of transactions, which is essential for DeFi DAOs that rely on fast and secure transactions.

Furthermore, the selected DeFi DAOs are built on top of the Ethereum blockchain, which offers layer 1 solutions for scalability, such as sharding and rollups. Sharding involves splitting the blockchain network into smaller parts, enabling parallel processing of

transactions. Rollups, on the other hand, enable off-chain transaction processing while ensuring the security of the underlying blockchain network (Crypto.com, 2020).

DAOs present a new paradigm in organizational structure, but they also face significant challenges in terms of security and scalability. As the technology continues to evolve, it is important for DAOs to remain vigilant and continue to implement robust security and scalability measures.

The following table is a suggestion of research questions for future researchers to address some of aforementioned issues.

Research Questions for Future Research
How can DAOs be designed to balance the competing interests of decentralization, security, and scalability?
What are the best practices for testing smart contracts and their interactions within DAOs, and how can these be integrated into the development process?
How can formal verification techniques be used to ensure the correctness of smart contracts in DAOs, and what are the benefits and limitations of this approach?
What are the most effective methods for testing the security of DAOs against common attack vectors, such as 51% attacks and sybil attacks?
How can stress testing be used to identify potential bottlenecks in DAOs and improve their scalability?
What are the trade-offs between automated and manual testing of DAOs, and what types of testing are best suited for each approach?

Table 12: Research Questions for Future Research within Technical Capabilities and Security attributes of Blockchain-based systems

6. Conclusion

In conclusion, the paper provides a comprehensive analysis of the research streams in the field of Decentralized Autonomous Organizations (DAOs) through a bibliometric and content analysis. The paper seeks to answer five research questions, which include identifying the most influential works in the field, exploring the current state of research on DAOs, defining and evolving the concept of DAOs, examining applications of DAOs in financial industries, and identifying the main drivers and barriers to the adoption of DAOs. The paper uses bibliographic coupling and citation count as methods for the bibliometric analysis and

conducts a content analysis to further investigate the content in the academic literature to discover the different research streams. After conducting the analysis, the paper has identified three distinct clusters. The first cluster consists of articles that focus on DAOs, governance, legal-, and socioeconomic implications. The second cluster includes articles that cover fundamental aspects of BLT, smart contracts, and DAOs. Lastly, the third cluster comprises articles that provide information regarding applications, security and technical attributes of BLT. Based on these clusters, the paper has identified and discussed five research streams in detail.

The paper provides insights into the developments and trends in DeFi DAOs and offers suggestions for future research. The paper contributes to the understanding of DAOs and their potential to revolutionize the way organizations operate, automate decision-making processes, and increase transparency and accountability. In addition, this paper provides research questions that need to be answered in order to resolve some issues that are still missing for the successful implementation of DAOs.

The bibliometric and content analysis conducted on Decentralized Autonomous Organizations may have some potential limitations that need to be acknowledged. However, despite these limitations, the study provides valuable insights into the current state of research on DAOs and sheds light on factors that contribute to their success or failure.

The reliance on Web of Science as the primary data source may have excluded some relevant studies not indexed in this database. Additionally, the use of a keyword search method may have missed articles that do not contain those specific keywords. Still, the use of Web of Science as the data source provides a high-quality and reliable dataset for analysis, and the keyword search method used is a common approach in bibliometric research and was conducted thoroughly as an iterative process to include the relevant articles.

Although a selection bias resulting from the choice of a specific sample of DAOs may limit the generalizability of the findings, it allows for an in-depth analysis of a specific group of DAOs, providing a more nuanced understanding of the factors contributing to their success or failure.

While there may be potential limitations, the bibliometric and content analysis provides a valuable contribution to the literature on DAOs and serves as a foundation for further research in this area.

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8. Appendix

8.1. Discussion Paper – International

“International” in the light of Decentralized Autonomous Organizations

Written by Haakon Støle Klemetsen

This discussion paper is written as a mandatory component of the master's program at the School of Business and Law at the University of Agder. Its objective is to contemplate the notion of "international" within the context of my master's thesis, examining the impact of international trends and forces on the topic of Decentralized Autonomous Organizations (DAOs).

My master's thesis focuses on conducting a bibliometric and content analysis of DAOs. DAOs are built on blockchains through smart contracts deployed on the network that incorporate the properties of an organization. As the DAOs are built on the blockchain, they also inherit the properties of the Blockchain itself, such as scalability solutions, the blockchain's security, and their governance structure. These smart contracts execute the organization's rules automatically, and the transactions are carried out autonomously. As a result, DAOs can exist without any central authority or intermediaries, offering a new and innovative form of organizational design that challenges established notions of governance. The governance of DAOs is defined by the rules encoded in the smart contracts, which means that the decisions made by the organization are based on the consensus of network participants (Wang et al., 2019).

The aim of this thesis is to identify the main research streams, influential articles, and evolution of DAOs, as well as to systematically uncover research gaps that could assist in a targeted continuation of the development of this technology. This is achieved by addressing the following research questions:

1. What are the most influential works in the field of DAOs, and what are the key topics and themes addressed in this work?
2. What is the current state of research on DAOs, and what are the main research themes and theories in the field?

3. How has the concept of DAOs been defined and evolved in the academic literature, and what are the key dimensions and characteristics of DAOs?
4. What are the most prominent applications of DAOs, particularly in Financial industries, and how have they performed in the context of challenges and benefits that have been detected in the academic literature?
5. What are the main drivers and barriers to the adoption of DAOs, and how can they be addressed or mitigated?

The thesis undergoes an extensive study of key themes in the field of DAOs, dividing them into macro, meso, and micro levels of analysis. The macro analysis explores the external impact that DAOs have, as they do not require regulation by any third party. This section is also important in understanding how DAOs can be affected by these external factors. The meso analysis focuses on larger concepts within DAOs themselves, such as their governance structure and potential applications. The micro-level analysis focuses on more prominent technical features in the literature, such as scalability, security, and decentralization. The thesis also examines important theories essential to understanding how DAOs can be best implemented and why their existence is beneficial. This includes how DAOs can provide solutions to the principal-agent problem, decrease transaction costs, and use game theory to analyze how multiple agents act in relation to each other. Institutional theory is also discussed to understand how this new type of governance, called "code-based governance," differs from traditional types such as relation-based and rule-based governance.

The analysis in the paper is a combination of bibliometric and content analysis. The bibliometric analysis was conducted to identify the most influential articles using a citation count and to detect different clusters using bibliographic coupling. The content analysis was conducted to identify research streams within the clusters and to see how major Decentralized Financial Applications (DeFi DAOs) have performed regarding the challenges and opportunities detected in the academic literature.

Although the thesis does not focus specifically on the international aspect of Decentralized Autonomous Organizations, the concept of "international" is highly relevant in light of this thesis, as DAOs are not constrained by geographical borders and operate as a global entity. This novel technology has been argued in the literature to have properties that can change organizational governance, particularly how decision-making is made. In addition to this,

DAOs could have major financial implications. This can be displayed in several ways. First, DAOs can raise funds through initial coin offerings (ICOs), a relatively new crowdfunding method. Investors deciding to put their money into DAOs will have the decision right for the company, without giving the power to CEOs or other titled agents managing the operations. DAOs, in the form of Decentralized trading- and lending platforms can facilitate transactions and loans which can be obtained without the need for third parties such as banks. Without being subjective to country-specific governance, DAOs can operate internationally in several industries and thus present new and innovative solutions across borders.

Law and Regulation - Accountability

DAOs operate on a decentralized network, which means that they are not subject to any particular jurisdiction. While this may offer many benefits, such as increased transparency and efficiency, it also poses significant challenges when it comes to accountability. In the absence of a centralized governing body or legal entity, it can be difficult to determine who is responsible for any issues that may arise (Beck, Muller-Bloch, & King, 2018).

The incident with TheDao in 2016 highlights the challenges of accountability in DAOs. In this case, the smart contract governing TheDao was exploited, resulting in losing \$50 million USD worth of funds. However, because the attackers were pseudonymous, it was impossible to identify and prosecute them. Additionally, the concept of "code-is-law" in DAOs means that vulnerabilities or exploits in the system are considered legal and binding, further complicating matters (Hutten, 2019).

These challenges are particularly pronounced in the case of DAOs due to their international nature. Because they are not subject to any single country's jurisdiction, it can be difficult to determine who has the authority to intervene or hold responsible parties accountable. This raises important questions about the role of legal entities in regulating DAOs and enforcing accountability standards.

In order to address these challenges, it may be necessary to develop new legal and regulatory frameworks specifically tailored to DAOs. These frameworks would need to balance the benefits of decentralized decision-making with the need for accountability and transparency. Additionally, it may be necessary to establish new mechanisms for resolving disputes and holding parties accountable in cases where issues arise. This could include the development of new technologies that allow for pseudonymous but still traceable identities, or the creation of decentralized courts or dispute resolution systems.

Financial Industries - DeFi DAOs

Another link between the concept of "international" and DAOs is the potential economic impact that DAOs may have, particularly in decentralized finance (DeFi). While Bitcoin and Ethereum have significantly impacted the global economy, DAOs can potentially disrupt traditional financial systems even further. Although not all DAOs are focused on finance, some operate as DeFi lending and trading platforms that are decentralized, autonomous, immutable, and disintermediated. These platforms remove the need for traditional intermediaries such as banks and brokers, creating a more direct relationship between investors and their assets (Lacity, 2022).

One potential benefit of DeFi DAOs is the relatively low transaction costs associated with trading currencies. Investors can move their money without being subjected to the fees and limitations imposed by traditional financial institutions. This could be particularly beneficial in countries with strict financial regulations or corrupt systems where people may have issues in terms of saving and lending. DeFi DAOs could provide an escape where investors can trade and have a higher sense of financial freedom, without being limited by the financial laws in their country.

However, there are also potential risks associated with the international use of DeFi DAOs. Because they operate on a decentralized and pseudonymous network, they may be subject to criminal activity such as fraud and money laundering. This could create challenges for law enforcement agencies and regulatory bodies in enforcing compliance and tracking down perpetrators (Harwick & Caton, 2022).

The international impact of DeFi DAOs on the economy is complex and multifaceted. While they have the potential to revolutionize traditional financial systems and increase financial freedom for individuals, they must also be carefully regulated and monitored to prevent criminal activity and ensure compliance with global financial regulations.

Country-specific influence, as an international Decentralized Organization

Regarding international trends, DAOs are highly influenced by technological innovations and the ability of participants to work, trade, and collaborate across borders. While DAOs are not necessarily regulated by any particular country, they can still impact them. DAOs are built on blockchain technology through smart contracts, and if major investors or economies create laws against these blockchains, it can impact the value of the networks.

A recent example is China's State Council's announcement in May 2021 reiterating the country's ban on cryptocurrency mining and trading. This announcement surprised many in the cryptocurrency community, as China had previously been one of the world's largest Bitcoin mining and trading markets. The ban was particularly significant as China had been home to a significant portion of the world's Bitcoin mining operations. This was due to China's access to cheap electricity and favorable regulations, which made it an attractive location for Bitcoin miners. However, the Chinese government became concerned about the environmental impact of Bitcoin mining and the potential financial risks associated with cryptocurrencies. As a result, many mining operations in China were forced to shut down or move to other countries. This significantly impacted the global Bitcoin mining industry, as many of the world's largest mining pools were based in China. The price of Bitcoin also dropped sharply in the days following the announcement, as investors became concerned about the future of Bitcoin mining and trading in China (Reuters, 2021). Despite the ban, many Chinese investors have continued to trade and hold cryptocurrencies through overseas exchanges. However, the ban has made it more difficult for Chinese investors to access cryptocurrencies, as many exchanges have implemented measures to prevent Chinese users from accessing their platforms.

Another example of international influences on Blockchain is standards set by the Financial Action Task Force (FATF) organization, aiming to combat money laundering, terrorist financing, and other financial crimes. FATF's guidance has significantly impacted the Blockchain industry by setting global standards for Anti Money Laundering (AML) and Counter-terrorism Financing (CFT). Some Blockchain developers have responded to this guidance by incorporating compliance measures into their systems, such as identity verification and transaction monitoring. Furthermore, some Blockchain-based systems have been designed to comply with AML and CFT regulations from the outset (CrystalMarketingTeam, 2021).

These examples demonstrate how international regulations and policies can impact the value and operation of DAOs. As DAOs continue to grow and evolve, it will be important to consider the potential impacts of global regulations and policies on their operation and value. This may require the development of new legal and regulatory frameworks tailored to the unique nature of DAOs and blockchain technology. It will also require ongoing collaboration

and communication between DAO participants, industry leaders, and regulatory bodies to ensure these decentralized networks' continued success and viability.

Summary

The master's thesis focuses on conducting a bibliometric and content analysis of DAOs, which operate on a decentralized network and are built on blockchain technology through smart contracts that execute rules automatically. The thesis aims to identify the main research streams, influential articles, and evolution of DAOs, as well as uncover research gaps that could assist in a targeted continuation of the development of this technology. The thesis has divided the analysis into macro, meso, and micro levels of analysis. It also examines important theories essential to understanding how DAOs can be best implemented and why their existence is beneficial.

The concept of "international" is highly relevant in light of this thesis, as DAOs are not constrained by geographical borders and operate as global entity. DeFi DAOs offer a new form of financial design, which creates a more direct relationship between investors and their assets, removing the need for traditional intermediaries such as banks and brokers. However, the international impact of DeFi DAOs on the economy is complex as they must also be carefully regulated and monitored to prevent criminal activity and ensure compliance with global financial regulations.

In terms of international trends, DAOs are highly influenced by technological innovations. If major investors or economies create laws against these blockchains, it can impact the value of the networks. China's State Council's announcement in May 2021 reiterating the country's ban on cryptocurrency mining and trading is an example of how international regulations and policies can impact the value and operation of DAOs. It demonstrates how DAOs' continued growth and evolution will require ongoing collaboration and communication between DAO participants, industry leaders, and regulatory bodies to ensure their continued success and viability.

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