An Exploration of Governing via IT in Decentralized Autonomous Organizations

Completed Research Paper

Tobias Mini*[1]
University of Passau
Chair of Business Information Systems
tobias.mini@uni-passau.de

Eleunthia Wong Ellinger*
Universitat Ramon Llull
La Salle Barcelona Campus
Department of Management and Technology
eleunthia.ellinger@salle.url.edu

Robert W. Gregory
University of Miami
Miami Herbert Business School
rwgregory@miami.edu

Thomas Widjaja
University of Passau
Chair of Business Information Systems
thomas.widjaja@uni-passau.de

Abstract

A decentralized autonomous organization (DAO) is a distinct form of platform meta-organization that heavily relies on smart contracts running on blockchains to govern a distributed network of autonomous actors, thereby continuing the shift toward governance via IT. Motivated by the fact that this shift toward governance via IT in DAOs challenges established assumptions in the literature on IT governance, we explore how DAOs are governed via IT. For this purpose, we applied techniques of grounded theory to build inductive theory by analyzing five cases of DAOs (Aragon, Flare Networks, KyberDAO, MakerDAO, and MolochDAO) based on white papers, blog entries, and newspaper articles. Our findings implicate that DAOs governed via IT synthesize autonomy and alignment through the mechanism of "establishing algorithmic organization." At the same time, DAOs rely on a more pluralistic and decentralized form of algorithmic management through the mechanism of "taming algorithmic power."

Keywords: Governance via IT, Decentralized Autonomous Organization (DAO), Blockchain, Digital Platform, Meta-Organization, Algorithmic Management

Introduction

Decentralized autonomous organizations (DAOs) are globally distributed networks of actors who align around a common overall purpose governed with the help of blockchain infrastructures, the algorithms in the form of smart contracts that run on top of them, and a shared constitution or set of rules and processes for operating and changing the network (Beck et al. 2018; Chen et al. 2021; Lumineau et al. 2021; Murray et al. 2019; Risius and Spohrer 2017; Ziolkowski et al. 2020b). For example, MakerDAO is a DAO built on the Ethereum blockchain to automate lending and borrowing of cryptocurrencies without the need for traditional fund managers. It is made up of smart contracts that govern borrowing and lending, as well as two currencies, Dai and MKR, to regulate the value of loans. Shared rules and processes ensure that token holders can influence certain aspects of MakerDAO such as the stability fee, collateralization ratio, and emergency shutdowns. Indeed, DAOs are trending—an estimated 200,000 people are already participating

[1] *These authors contributed equally.

actively in DAOs, which due to tools offered by projects such as OpenLaw are becoming increasingly fast and easy to set up and are now also considered as a legal entity since July 2021 in the U.S. state of Wyoming extending the applicability of DAOs to for-profit purposes like tokenized art or music (Shin 2021). Proponents of DAOs highlight their transparency, fairness, inclusion, and incorruptibility due to the absence of bilateral agreements, the use of open-source software protocols, and a sophisticated incentive system based on the use of digital currencies in the form of tokens. Since DAOs are still a poorly understood phenomenon and multiple early instances of DAOs have failed (e.g., 'TheDAO') (Voshmgir 2020) it is important to understand the novel mechanisms that underly governance in DAOs (Beck et al. 2018).

Previous research highlights that DAOs enable distributed actors to interact and cooperate with each other based on shared rules encoded in software algorithms to facilitate automated steering and contract enforcement (Beck et al. 2018; Chen et al. 2021; De Filippi and Wright 2018; Lumineau et al. 2021). Governance in DAOs includes complex combinations of community-driven human and algorithmic mechanisms to ensure the alignment of autonomous actors with a shared purpose (Baird and Maruping 2021; Murray et al. 2020). While previous literature has started to shed light on these and other characteristics of DAOs, we still have little in-depth understanding of the functioning of governance in DAOs and the conditions under which DAOs provide a new form of decentralized platform meta-organizing (Gulati et al. 2012) and a viable alternative to classical command-and-control structures prevalent in most organizations that rely on bureaucratic governance mechanisms (Puranam et al. 2014). Thus, governance in DAOs is an important research topic, especially in the Information Systems discipline, because of the strong emphasis on governance *via* information technology (IT).

Examining governance *via* IT in DAOs is important because decentralization makes it necessary to institute alternative IT-enabled governance structures that do not rely on traditional human-centric and resource-intensive mechanisms since they are often not scalable and suitable for decentralized organizing contexts. To better understand the characteristics of governance *via* IT, previous IT governance research in the context of digital transformation has started to shed light on the shift from governance *of* IT toward governance *via* IT through platform-based and technology-enabled mechanisms for governance (Gregory et al. 2018). This shift toward governance *via* IT underlying the DAO phenomenon challenges established assumptions (Alvesson and Sandberg 2013) of traditional IT governance literature and instead assumes heavy reliance on governance *via* IT, decentralization of decision-making, and the transparent and automated enforcement of rules which motivates a fresh perspective on IT governance and a critical discussion of the unique mechanisms that underly governance in DAOs (Beck et al. 2018).

In this paper, we take the perspective of blockchain governance (e.g., Beck et al. 2018; Chen et al. 2021; Lumineau et al. 2021; Murray et al. 2019; Ziolkowski et al. 2020b) and draw on the lens of governance *via* IT offered by the literature on digital platforms (e.g., Gregory et al. 2018; Moehlmann et al. 2021; Tiwana et al. 2010) which allows us to address the following research question: *How are decentralized autonomous organizations governed via IT?* For this purpose, we analyze five representative cases of DAOs (Aragon, Flare Networks, KyberDAO, MakerDAO, and MolochDAO) using techniques of grounded theory (Birks et al. 2013; Charmaz 2006; Gioia et al. 2013; Glaser and Strauss 1967; Walsh et al. 2015). Our core finding is that governing DAOs *via* IT requires two mechanisms called "establishing algorithmic organization" and "taming algorithmic power." The first mechanism, "establishing algorithmic organization," refers to the reinforcement of the software protocol's central authority in the DAO through ongoing execution of routines. The second mechanism, "taming algorithmic power," describes how humans both systematically and spontaneously perform actions to bend automated processes in the DAO to comply with their organizational will. Our findings implicate that DAOs governed *via* IT synthesize autonomy and alignment through "establishing algorithmic organization." At the same time, governance *of* IT in DAOs involves a more pluralistic and decentralized form of algorithmic management through "taming algorithmic power."

Conceptual Background

Decentralized Autonomous Organizations

Decentralized autonomous organizations (DAOs) gained widespread attention through increased blockchain development activity around the globe. A blockchain refers to a distributed database that can record transactions between actors in a peer-to-peer (P2P) network drawing on consensus algorithms for verification (Beck et al. 2018; Lumineau et al. 2021; Murray et al. 2019; Nakamoto 2008). The first blockchain was outlined 2008 in a white paper by Satoshi Nakamoto, a pseudonymous person or group, and was called 'Bitcoin' describing the vision of a P2P payment system where online payments could be sent directly to each other without the need for a central financial institution that controls payment processing, i.e., in a fully decentralized way (Nakamoto 2008). Decentralization refers to the transfer of control and decision-making from a centralized entity, i.e., an organization, government, or company, to a distributed network (Chen et al. 2021). While not an entirely new phenomenon, decentralization has significantly gained new momentum in the context of blockchains (Cennamo et al. 2020). Decentralization in this blockchain space is driven to a large extent by the narrative that the current platform economy with its tendency toward surveillance, dominance, and centralized control over peoples' lives and perceived freedom lacks the degrees of fairness, protection of individual rights, transparency, and inclusion that digitally empowered citizens demand in the emerging token economy (Voshmgir 2020; Zuboff 2015). With Bitcoin's launch in early 2009 and subsequent growth toward becoming an accepted payment system, programmers began to explore the blockchain technology for uses outside of just digital currencies (Andersen and Bogusz 2019; De Filippi and Wright 2018; Lindman et al. 2017). Perhaps the most significant generalization over purely financial-oriented blockchains such as Bitcoin was envisioned 2014 in a white paper by Vitalik Buterin who introduced the Ethereum blockchain with the key idea of deploying so-called "smart contracts" on a blockchain (Buterin 2014b). Smart contracts refer to software programs that run on a blockchain and automatically execute preprogrammed rules and logic (Buterin 2014b; Szabo 1997).

In the same Ethereum white paper, Vitalik Buterin outlined the idea of using smart contracts to encode the bylaws of entire organizations, so-called 'Decentralized Autonomous Organizations' (DAOs) (Buterin 2014b). Vitalik Buterin characterized DAOs as having "automation at the center [and] humans at the edges" of the organization (Buterin 2014a). A DAO involves a distributed network of autonomous human or organizational actors who align around a common overall purpose with the help of blockchain infrastructures, the algorithms in the form of smart contracts that run on top of them, and a shared constitution or set of rules and processes for operating and changing the network (Beck et al. 2018; Buterin 2014a; De Filippi and Wright 2018; Murray et al. 2019; Voshmgir 2020).

The definition of DAOs above suggests that DAOs represent a distinct form of platform meta-organization (Gulati et al. 2012; Puranam et al. 2014) as members of a DAO are distributed and decentralized and make key decisions through voting on proposals such as how the rules and logic should be encoded in the smart contracts and finding agreement via majority consensus (Hsieh et al. 2018; Lumineau et al. 2021; Vergne 2020) which sets DAOs apart from most sharing economy platforms (e.g., Uber, Airbnb) where members are governed by powerful and centralized platform organizations (Kenney and Zysman 2016; Reischauer and Mair 2018). Members of a DAO are also (in part) their owners as they decide how the DAO should allocate its funds that represent the internal capital in the form of digital tokens that can represent anything from a store of economic value to a set of permissions in the physical or digital world and can be used to reward certain activities in a DAO (Buterin 2014a; Oliveira et al. 2018; Voshmgir 2020). Having internal capital sets DAOs apart from most decentralized online communities (e.g., Reddit, Wikipedia) or open-source projects (e.g., Debian) that often use reputation or status to reward contributions of its members (Aaltonen and Lanzara 2015; O'Mahony and Ferraro 2007). Potential contributors or investors in a DAO can exchange other digital cryptocurrencies or tokens for the DAOs native tokens to gain a stake in a DAOs internal capital (Buterin 2014a; De Filippi and Wright 2018). In accordance with the stake that the actors in the distributed network hold on a DAO, voting rights to participate in decision making are issued (Voshmgir 2020). DAOs heavily rely on smart contracts and the blockchain to automatically enforce the voting decisions by the members of a DAO and to transparently store transactions to align their interests and activities toward a shared purpose (Beck et al. 2018; Lumineau et al. 2021; Voshmgir 2020).

IT Governance in the Era of Blockchains and DAOs

The phenomenon of decentralized autonomous organizations summarized above provides the conceptual background for the shift toward blockchain-based governance *via* IT which is embedded in the historic evolution of IT governance. IT governance refers to the IT-related decision rights and accountability framework used to ensure the alignment of actors with the organization's overall purpose (Sambamurthy and Zmud 1999; Tiwana and Kim 2015; Wu et al. 2015). While the term IT governance became prominent in the late 1990s (Sambamurthy and Zmud 1999), earlier studies already focused on organizational IT-assets (e.g., mainframes) to which only individuals with specialized technical skills had rights to access and operate and who later formed the first IT functions (Niederman et al. 2016). In the 1970s to the early 1990s the focus of IT governance broadened significantly and included also more lightweight personal computers which increased the autonomy of end-users but also the coordination effort for IT professionals in the IT functions (Bygstad 2017; Niederman et al. 2016; Urbach et al. 2019). In the 1990s to the early 2000s enterprise resource planning systems and cross-organizational information systems (e.g., e-commerce applications) broadened the focus of IT governance again. Yet, the key responsibility of the IT function to provide user support for IT-related activities as well as the design, development, and maintenance of IT remained, which can be summarized as functional governance *of* IT (Drnevich and Croson 2013).

With the emergence of digital technology-enabled meta-organizations (Gulati et al. 2012) such as online communities (O'Mahony and Ferraro 2007) or digital platform ecosystems (Gregory et al. 2018; Huber et al. 2017; Tiwana et al. 2010; Tiwana et al. 2013; Wareham et al. 2014), IT governance began to span organizational boundaries. Building on digital infrastructures (Fuerstenau et al. 2019; Tilson et al. 2010) such as the Internet and guided by the 'code is law' principle from the open source movement (Lessig 2006), these online communities and digital platform ecosystems experimented with new mechanisms for IT governance using the code of their platforms to define rules that shape how people can act and interact online while also involving the community in governance (e.g., Aaltonen and Lanzara 2015; Gregory et al. 2018; Huber et al. 2017; O'Mahony and Ferraro 2007; Tiwana et al. 2010; Wareham et al. 2014). Governance in these technology-enabled meta-organizations is characterized by balancing alignment desired by the platform owner with autonomy of users or complementors in the surrounding ecosystem (Gulati et al. 2012). Centralized platform owners and their software engineers often develop and maintain standardized boundary resources or algorithms to govern their community in the ecosystem (Ghazawneh and Henfridsson 2013; Moehlmann et al. 2021; Tiwana et al. 2010). Using algorithms to govern the behavior of individual actors and to ensure their alignment to the meta-organization's purpose can be summarized as governance *via* IT (Drnevich and Croson 2013; Gregory et al. 2018; Moehlmann et al. 2021).

Blockchains and DAOs continue this shift toward governance *via* IT while allowing the whole community to actively shape the algorithms by which they are governed in a decentralized way. Governance of DAOs includes a collection of mechanisms to ensure the alignment of autonomous human actors toward the common overall purpose of a DAO (Beck et al. 2018; Chen et al. 2021; Lumineau et al. 2021; Murray et al. 2019). The governance structure that enables the community of human actors to interact and cooperate with each other is represented by rules that are encoded to empower network participants and administered by algorithms for automated steering and contract enforcement (Beck et al. 2018; Chen et al. 2021; De Filippi and Wright 2018; Lumineau et al. 2021). Especially three characteristics of blockchain-based governance challenge established assumptions (Alvesson and Sandberg 2013) of IT governance research.

First, DAOs heavily rely on governance *via* IT which includes mechanisms that rely on a set of sophisticated automated algorithms often encoded in smart contracts running on blockchains for governance of a distributed network of autonomous actors (De Filippi and Wright 2018; Lumineau et al. 2021; Murray et al. 2019). In the context of blockchains and DAOs, "IT solutions serve as a governance mechanism in their own right" (Lumineau et al. 2021, p. 507) where preprogrammed and automated smart contracts enforce decisions. This heavy reliance on governance *via* IT challenges the underlying assumption of the classical IT governance literature where decision-making, monitoring, and coordination are largely performed by human actors such as IT managers of an organization (e.g., Tiwana and Kim 2015; Wu et al. 2015).

Second, decentralization empowers actors in the distributed network of a DAO (e.g., developers or token holders) to modify the rules encoded in the automated smart contract code and to actively participate in governance decisions (e.g., via voting on proposals) (Beck et al. 2018; Chen et al. 2021; De Filippi and Wright 2018; Ziolkowski et al. 2020a; Ziolkowski et al. 2020b). By transferring previously centralized decision making to the community (Beck et al. 2018; Murray et al. 2019), decentralized governance in DAOs fundamentally challenges the assumption of the IT governance literature in which the design, development, and maintenance of IT systems is the primary responsibility of the IT function (e.g., Tiwana and Kim 2015; Wu et al. 2015) or of centralized platform owners and their software engineers (Tiwana et al. 2010).

Third, the enforcement of rules in DAOs is transparent, non-discriminatory, and automated by drawing on public smart contracts that are auditable and verifiable by almost anyone in the distributed network (Lumineau et al. 2021). This automated and public rule enforcement in blockchains and DAOs challenges the assumption held in the IT governance literature where rules are often described as being "latent" or invisible (de Vaujany et al. 2018) and architecture is often used as a form of non-overt control (Tiwana et al. 2013). These three refined assumptions invite an investigation of how DAOs are governed *via* IT.

Research Methodology

Theoretical Sampling and Data Collection

We adopted a theoretical sampling strategy (Charmaz 2006) to iteratively select cases for a multiple-case study (Yin 2009) of DAOs to explain how DAOs are governed *via* IT. As theoretical sampling assumes that grounded theoretical insights emerging from data can guide subsequent data collection and analysis (Glaser and Strauss 1967), we first collected an initial sample of 20 DAO cases that were mentioned in public blogs (e.g., on Medium.com and Twitter.com) and podcasts or videos on YouTube.com. This initial sample included MakerDAO, Flare Networks, Aragon, DigixDAO, TheDAO, Polkadot/PolkaDAO, MolochDAO, MetaCartel Ventures, OceanDAO, DarkDAO, The LAO, KyberDAO, SpiderDAO, Steem, SingularityDAO, Algorand, Colony, Tezos, Cardano/Project Catalyst, and CurveDAO. From there, we filtered these cases to maximize variation between DAO cases and allow for patterns to emerge more easily from constant comparisons across a manageable subset of DAOs (Glaser and Strauss 1967). To maximize variation within our dataset, we paid special attention to cases that fall on an extreme end of a spectrum of different DAOs (Gerring 2006). For example, we considered MolochDAO as an extreme case because its governance structure serves as a blueprint for other DAOs (e.g., MetaCartel or 'The LAO'). We also considered extremely unsuccessful and successful cases of DAOs (e.g., TheDAO and MakerDAO). Our final sample included the following five cases of DAOs: Aragon, Flare Networks, KyberDAO, MakerDAO, and MolochDAO. We chose these DAOs based on their relative maturity, complexity, and prominent status in the DAO community, reasoning that their inner workings would be well-formed and theoretically most interesting.

Our primary case material consisted of secondary data including white papers, blog entries, and newspaper articles since this material provides rich and holistic descriptions of real DAOs, often dives deeper into technological underpinnings of DAOs, and hears different people's voices (e.g., founders, developers of the technology, or token holders). For each DAO case in our sample we first collected one or more published white papers which are documents that detail technical, organizational, and economic specifications of a DAO and are often published for fundraising purposes before an initial coin offering (Voshmgir 2020). For each DAO case, we then also collected blog entries that inform about the current status of a DAO and are often written by the founders themselves and newspaper articles that provide additional information from the perspective of external observers. Overall, we collected and analyzed 257 pages of case material. To triangulate emerging findings, we concurrently also listened to podcasts, where influential people (e.g., founders) in the DAO space discussed recent developments and their motivation for participating in DAOs.

Data Analysis and Approach to Conceptualization

We used techniques of grounded theory (Birks et al. 2013; Charmaz 2006; Gioia et al. 2013; Glaser and Strauss 1967; Walsh et al. 2015) to iteratively build inductive theory. We performed open coding (Glaser and Strauss 1967) on each of the cases from the sample using the coding software MAXQDA, which led to an initial coding book consisting of first-order categories that remained close to our data (Gioia et al. 2013). Labels for these first-order categories were inspired by the structure of theoretical mechanisms (cf. Henfridsson and Bygstad 2013). Exemplary first-order categories were "fine-grained customization for who can perform an action" or "stakeholders vote on tokenomic parameters and listings." Following open coding, as the second step we identified relationships emerging between first-order categories to organize them into second-order themes (Gioia et al. 2013). For example, the two first-order categories mentioned above led to the second-order theme "granularizing empowerment." In the third step, all members of the author team regularly discussed the results and challenges of the coding, interrogating each other's interpretations, and proposing alternative explanations which resulted in refined first-order categories, second-order themes, and conceptualizations of the final mechanisms (Gioia et al. 2013). For instance, over time we assessed that the second-order themes of "granularizing empowerment," "triggering reactive interventions," and "negotiating limits of automation" were closely related to humans who perform actions to bend automated processes in a DAO yet distinct from each other and bundled them into the mechanism of "taming algorithmic power." The iterative coding and theoretical development stopped when we achieved a reliable and valid treatment of the mechanisms across the cases. This theoretical saturation (Charmaz 2006; Glaser and Strauss 1967; Saunders et al. 2018) was visible when the number of new first-order categories emerging from each additional case material decreased and no new second-order themes or mechanisms emerged from the data.

Findings

In this section, we delineate the key mechanisms that underly governance in DAOs, "establishing algorithmic organization" and "taming algorithmic power," inductively theorized from the data of our DAO sample, along with their definitions and key themes as illustrated in Table 1.

Mechanism	Definition	Themes
Establishing Algorithmic Organization	The mechanism by which the software protocol reinforces its central authority in the DAO through ongoing execution of routines.	• **Enforcing precise rules and steps:** DAO core code executes consistent, substantive processes independently. • **Encoding trust in the system:** Technology creates radical transparency that DAO users trust as accurate and up-to-date. • **Surveying the stakeholders and environment:** Algorithms constantly monitor all agents and conditions to protect the integrity of the organization.
Taming Algorithmic Power	The mechanism by which humans both systematically and spontaneously perform actions to bend automated processes in the DAO to comply with their organizational will.	• **Granularizing empowerment:** The organization provides opportunities for holders to express their power through deciding on fine-grained parameters. • **Triggering reactive interventions:** The technology serves up relevant information for humans to use to conduct course correction. • **Negotiating limits of automation:** Humans customize components to alter the default direction set by the technology.

Table 1. Two Key Mechanisms That Underly Governance in DAOs

Establishing Algorithmic Organization

The mechanism of "establishing algorithmic organization" describes how algorithms drive foundational activities of a DAO and imprint their automation into baseline processes of the organization. In this section, we name and elaborate three key themes of this mechanism (see Figure 1 for an overview of the key concepts and relationships) and provide illustrative examples from DAOs.

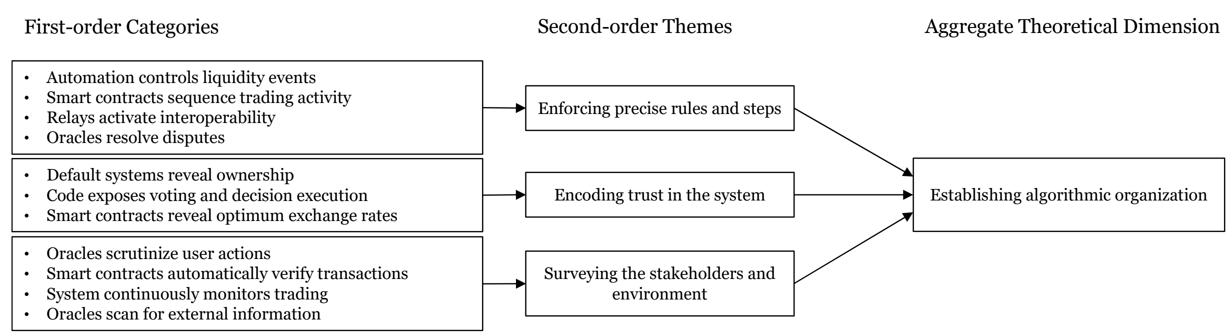

Figure 1. Mechanism of Establishing Algorithmic Organization

Enforcing precise rules and steps. First, exerting automated control over events regarding the internal capital is a core function in DAOs due to the functionality available in their core code. For instance, MakerDAO has created an automated protocol that without permission takes a series of steps to independently manage the liquidity of the internal capital for the DAO in multiple scenarios:

> *"To ensure there is always enough collateral in the Maker Protocol to cover the value of all outstanding debt (the amount of Dai[2] outstanding valued at the Target Price), any Maker Vault deemed too risky (according to parameters established by Maker Governance) is liquidated through automated Maker Protocol auctions. Once the Surplus Auction has ended, the Maker Protocol autonomously destroys the MKR[3] collected, thereby reducing the total MKR supply. During a Debt Auction, MKR is minted by the system (increasing the amount of MKR in circulation), and then sold to bidders for Dai"* (MakerDAO 2017, p. 8).

Second, smart contracts are often employed to sequence and bundle trading activity in DAOs. For example, KyberDAO provides an algorithm to handle trades:

> *"A taker is an entity that takes the liquidity provided by the registered reserves by calling the trade() function in the Protocol Smart Contracts to trade from one token to another token....Takers do not have to wait for their orders to be fulfilled, since trade matching and settlement occurs in a single blockchain transaction. This enables trades to be part of a series of actions happening in a single smart contract function"* (Kyber Network 2019, p. 7).

KyberDAO also enables *"trustless and atomic token trades"* that can be *"directly and easily integrated into other smart contracts, thereby enabling multiple trades to be performed in a smart contract function"* (Kyber Network 2019, p. 4). In addition, with Kyber Core smart contracts, actors are allowed to join and interact with the network. All these functions give control over significant trading activities to the codebase.

Third, DAOs set up relays that activate interoperability for the organization. KyberDAO achieves interoperability by implementing *"a bi-directional relay of block headers between two blockchains"* (Kyber Network 2019, p. 13). Relays at KyberDAO have been established to connect different blockchain systems:

> *"For smart contract-enabled chains, the most practical interoperability implementation is to have a light client as a smart contract which can be implemented on both blockchains and an efficient algorithm to verify the hash functions from both blockchains with minimal computation costs can be used. In our Waterloo project, we presented a proof of concept to prove the feasibility of a practical relay approach between Ethereum and EOS. We also demonstrated a similar approach in the PeaceRelay project to connect between Ethereum and Ethereum Classic"* (Kyber Network 2019, p. 13).

In this case, interoperability between blockchains increases the DAO network and is being operated within the codebase in a permissionless, unstoppable manner.

Fourth, non-human oracles which are data feeds that provide information about the outside world to the blockchain operate independently in some DAOs to resolve disputes between human agents. Aragon has established a *"decentralized oracle protocol,"* referred to as a Court, to settle disputes regarding proposals:

> *"The Aragon Court is a decentralized oracle protocol developed and maintained by the Aragon Network. The Aragon Court can be used by organizations, including the Aragon Network itself, to resolve subjective disputes with binary outcomes"* (Aragon 2020b).

The ability of software to intervene and decide the outcome of human disputes seems to be a novel feature of the Aragon DAO. Similar approaches exist in MolochDAO where members can 'ragequit' from the DAO and withdraw their funds which is enforced by restricting 'ragequitting' to only members who voted 'no' on a proposal (Soleimani et al. 2019), or the Flare DAO where different voting decisions need to conform to different requirements (e.g., simple majority, super majority, or super super majority) (Flare Networks 2020). In total, automation controls liquidity and trading activity (as in MakerDAO), interoperability (as in KyberDAO), and even human dispute resolution arising through contentious voting decisions (as in Aragon, MolochDAO, and Flare), all of which are administered by algorithms that enforce precise rules and steps.

Encoding trust in the system. A typical DAO provides significant transparency in its systems, which creates trust in the organization amongst its holders. First, by default, DAO systems reveal ownership, with extended descriptions of this ownership such as holdings or reward allocations. One example is Aragon:

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[2] Dai is the label for the cryptocurrency used in MakerDAO.

[3] MKR denotes the governance token in MakerDAO, i.e., the token that grants voting rights.

> *"Ownership in an Aragon Core organization is transparent and transferable. Each stakeholder's holdings are public, and a stakeholder has the right to transfer ownership to another party. There are four transparent functions of ownership built into Aragon Core.*
>
> *These are: - List all stakeholders (and their holdings) - Issue shares, arbitrarily or with parameters - Sell or transfer tokens - Issue new tokens"* (Cuende and Izquierdo 2017, p. 11).

As another example, KyberDAO's system records all its rewards due to its individual members on-chain, providing full transparency into distributions.

Second, typical DAO core code exposes voting and decision execution in the organization. Such transparency reveals intimate organizational details that make it possible for members to have data access to virtually everything about their organization. In one example:

> *"The KyberDAO and governance process was designed to empower our community with fair representation on topics that are meaningful to them, ensure maximum viable transparency on voting and post-vote execution, while ensuring the security and stability of Kyber Network"* (Kyber Network 2020).

With such minute yet critical details of organizational activity being exposed by the core code of DAOs, trust in the system of the DAO by its members should inherently increase.

Third, by nature of their configuration, smart contracts in DAOs can reveal optimum exchange rates. For instance, in KyberDAO, *"the protocol smart contracts offer a single interface for the best available token exchange rates to be taken from an aggregated liquidity pool across diverse sources"* (Kyber Network 2019, p. 4). When the best available rates are provided by protocol smart contracts, holders can trust that they can act on this information from a fair and completely automated source.

As the cases of Aragon and KyberDAO show, DAOs typically reveal fundamental details such as ownership, voting, and voting execution in their default configurations which is also featured in MolochDAO where membership proposals are hashed and stored for record-keeping (Soleimani et al. 2019). Through smart contracts, they provide undisputable and up-to-date information such as optimum exchange rates to all holders which is also salient in the Flare DAO where oracle data feeds provide accurate price information to incentivize shareholders to act honestly or in MakerDAO where keeper algorithms step in when the system is at risk to stabilize the DAO, which will reinforce the trust that members have in the DAO. In sum, through these software functions, DAOs encode trust in their systems. The trust that members place in the DAOs, based on algorithmic structure, reinforce participation and investment in organizational activities.

Surveying the stakeholders and environment. While DAOs are based on software systems in which its members place their trust, the software systems, in turn, are constantly monitoring its stakeholders and environment. First, oracles scrutinize stakeholder actions in exhaustive detail. According to the Flare DAO, *"the core feature of an oracle should be a decentralized data feed exploiting the distributed nature of the underlying system whilst incentivizing players to be honest"* (Flare Networks 2020, p. 9). The Flare Time Series Oracle provides data feeds to monitor two types of holders to a close degree, in relation to each other:

> *"The Flare Time Series Oracle...provides a periodic on-chain estimate of the current value of any number of off-chain time series. The contributors to a specific time series consists at a minimum of Spark token holders but will under certain circumstances include the token holders of an application that relies on that time series, called F-asset holders.*
>
> *The Flare Time Series Oracle (FTSO) has a reward function which generates new Spark tokens*[4]*. The new Spark tokens are used to reward Spark holding contributors.*
>
> *Each oracle estimate is determined by two groups with competing interests: holders of Spark, and holders of the F-asset tokens issued in relation to the relevant data estimate.*
>
> *The time series oracle provides the on-chain XRP*[5]*/Spark price, based on the estimates being submitted by both holders of Spark and FXRP. By virtue of holding either FXRP or Spark, both*

[4] Spark tokens refer to the native tokes of the Flare DAO.

[5] XRP refers to the cryptocurrency used by the Ripple blockchain settlement system.

these groups have an implicit stake in the system i.e. an incentive to act honestly, as accurate pricing maintains the systems integrity and utility" (Flare Networks 2020, pp. 7-10).

This automated monitoring scrutinizes user actions as a protective measure for DAO stability.

Second, smart contracts can also be used in DAOs to verify operations. For example, in KyberDAO, specific operations, such as token transfers, are automatically verified through smart contracts.

Third, algorithms in DAOs continuously monitor and execute trading. According to KyberDAO, public rate verification is a core functionality: *"Anyone can verify the rates that are being offered by reserves and have their trades instantly settled just by querying from the smart contracts"* (Kyber Network 2019, p. 4). Monitoring of trades is an additional way where the environment is regularly surveyed algorithmically.

Fourth, automated systems in DAOs monitor the environment, often through oracles. According to MakerDAO: *"The Protocol derives its internal collateral prices from a decentralized Oracle infrastructure that consists of a broad set of individual nodes called Oracle Feeds"* (MakerDAO 2017, p. 11). Through such software devices, oracles scan for external information without involvement or direction from humans.

DAOs can constantly monitor virtually any activity within or outside of the organization to protect organizational interests. Some oracles scrutinize stakeholder actions (as in the Flare DAO) while others scan for external information (as in MakerDAO). Smart contracts can verify operations and monitor trading (as in KyberDAO). This monitoring is created and maintained on the level of core software but could also be complemented by a partly automated bug bounty mechanism that raises human investigation if weird behavior or an unexpected state is detected as in the case of Aragon (Cuende and Izquierdo 2017) or to raise 'kick proposals' to jail malicious members as in the case of MolochDAO (MolochDAO 2020). In these ways, DAOs exert substantial abilities to survey their stakeholders and environments.

In the summary view of the mechanism, first, DAOs set up software systems to enforce precise rules and steps in the organization. The code of a DAO executes consistent, substantive processes independently. Second, through a series of default configurations, DAOs encode trust in their systems on the part of their members. Technology creates radical transparency that DAO users trust as accurate and up-to-date. Third, DAOs conduct ongoing surveying of their users and their environments through non-human oracles and smart contracts. Algorithms constantly monitor all agents and conditions to protect the integrity of the organization. Taken as a whole, such enforcement, encoding, and surveying establishes and institutes an algorithmic organization in a DAO. In the mechanism of "establishing algorithmic organization," software is the basis of the DAO and reinforces its central authority through its ongoing execution of routines.

Taming Algorithmic Power

While the first identified mechanism described above places software at the forefront of core DAO function, additional data analysis surfaced a second mechanism that counters this software dominance. The mechanism of "taming algorithmic power" describes ongoing human interventions within a DAO that harness and direct the power of the software systems and is based upon the processes by which human authority shapes outcomes of a DAO. This section describes the second-order themes of this mechanism (see Figure 2 for an overview of the key concepts and relationships) and includes supporting data.

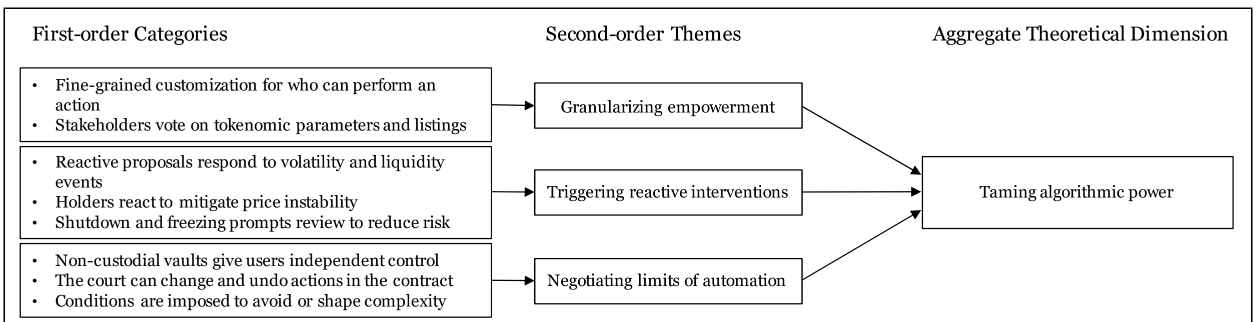

Figure 2. Mechanism of Taming Algorithmic Power

Granularizing empowerment. First, DAOs often provide fine-grained customization for who can perform a particular action in the organization. This customization facilitates human decision making on a wide variety of organizational activities by reducing decision complexity. As one example:

> *"Aragon organizations have customizable bylaws that allow for fine-grain customization into who can perform an action (ie, an executive can add an employee to the payroll) or what needs to happen (ie, a voting needs to be approved to issue tokens) before the action is allowed"* (Cuende and Izquierdo 2017, p. 10).

Second, stakeholders vote on automatable parameters and listings encoded in the smart contracts that substantially impact the way their DAO functions. KyberDAO delineates *"a host of tokenomic parameters, upgrade decisions, token listings, which KNC*[6] *stakeholders will in turn be able to vote and decide on"* (Kyber Network 2019, p. 17) for individual implementations on its blockchain.

As much as the DAO directs and monitors human action, it also provides code-based modular approaches enabling users to act autonomously (as in the cases of Aragon and KyberDAO) which is also salient in MakerDAO where the community is responsible for voting on encoded parameters to configure smart contracts to find an optimal balance between token supply and demand (MakerDAO 2017) and the Flare DAO where stakeholders vote on internal parameters but also on external oracles (Flare Networks 2020). In addition, existing members in MolochDAO can vote for the software code to admit new members or kick existing members (MolochDAO 2020; Soleimani et al. 2019). Granularizing human empowerment in the DAO enhances and extends the degree to which humans can shape their engagement in the organization, since increasing opportunities to make decisions on multiple levels typically leads to more impact.

Triggering reactive interventions. First, some DAOs have algorithms that alert holders to certain conditions (e.g., volatility or liquidity events) providing an opportunity for any holder to respond by making a proposal to the community. For instance, MakerDAO has defined a process called "*the reactive proposal*":

> *"Collateral types included in the system may have changed in terms of liquidity and thus may require an alteration to their specific debt ceiling. Volatility may have moved to a different regime for a collateral type or for crypto as a whole and the liquidity ratio may need to be changed. Basically, reactive proposals respond to changes in the system"* (MakerDAO 2018).

Second, oracles provide a way in DAOs to make holders aware of risky financial situations, and holders then have the option to react to mitigate price instability. For MakerDAO, the holders of the governance token MKR are granted voting rights to ensure stability of Dai:

> *"MKR holders can mitigate the price instability by voting to modify the DSR*[7] *accordingly:*
>
> - *If the market price of Dai is above 1 USD, MKR holders can choose to gradually decrease the DSR, which will reduce demand and should reduce the market price of Dai toward the 1 USD Target Price.*
> - *If the market price of Dai is below 1 USD, MKR holders can choose to gradually increase the DSR, which will stimulate demand and should increase the market price of Dai toward the 1 USD Target Price"* (MakerDAO 2017, p. 12).

The transparency encoded in the DAO software brings data automatically to the members, who can then opt to act based on this information.

Third, some DAOs institute human-based mechanisms to guard against risk. In the case of Aragon, shutting down and freezing operations is initiated by a member and prompts human deliberation:

> *"In extreme cases, there may be cause to freeze operations of the organization. For example, when all stakeholder funds are at risk. Any organization shareholder can raise an issue where the company's contracts are frozen and moved to a state of review"* (Aragon 2020a).

Though DAO algorithms may operate in a permissionless and unstoppable state, beyond the realm of human agency, there are several scenarios in which DAO code functions as helpmates to human members.

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[6] KNC denotes the native token of KyberDAO.

[7] DSR refers to the Dai Savings Rate and is the interest rate paid to deposits made by Dai holders.

The sophistication of its software allows DAOs to recognize emergency scenarios and to communicate it in a precise and timely manner to their community. This empowers the human actors to take control of the direction of a DAO by making reactive proposals and deciding on mitigations as in the case of MakerDAO or in extreme cases shutting down organizational operations entirely until a community review can be conducted as in the case of Aragon. Similarly, in KyberDAO certain events (e.g., token transfers to another blockchain) have to be approved by governance (Kyber Network 2019) while in the Flare DAO automated parameters have preset thresholds which trigger governance voting when reached (Flare Networks 2020) and in MolochDAO a dilution bound trigger prevents that more than 80% of members can 'ragequit' from the DAO (Soleimani et al. 2019). "Triggering reactive interventions" describes how non-human actors in a DAO support human actors in making proposals to the community to improve organizational function.

Negotiating limits of automation. First, DAOs often institute spaces in the organization that are largely autonomous. For instance, MakerDAO sets up non-custodial vaults that give users independent control:

> *"Vaults are inherently non-custodial: Users interact with Vaults and the Maker Protocol directly, and each user has complete and independent control over their deposited collateral as long the value of that collateral doesn't fall below the required minimum level"* (MakerDAO 2017, p. 7).

In the case of these non-custodial vaults, the default operation is independent, in other words, lack of intervention of the many algorithmic processes that usually run the DAO.

Second, DAOs often balance the automation of smart contracts with mediation based on human discernment. In Aragon, a court has been established that can change and undo actions in a smart contract:

> *"All organizations in the network agree to be bound to the ANJ[8] decentralized court. This protects individual organization stakeholders from the pure objectivity of smart contracts, that makes it very difficult and unproductive to encode certain things"* (Cuende and Izquierdo 2017, p. 36).

In this case, the DAO explicitly calls out the need at times to limit the function of smart contracts, because left to run alone, they may go in a direction that could be harmful to stakeholders. This tendency is balanced by a formally recognized court that interrupts the default action of the algorithm and resets its course.

Third, there is recognition in DAOs that basic blockchain technology, by itself, is not always beneficial to the organization. DAOs take various steps to mitigate the limits of technology such as imposing conditions to avoid or shape complexity. For instance, Flare explicitly restricts complexity in its organization:

> *"The EVM[9] defines a transaction's computational complexity in terms of units of Gas. To avoid extremely lengthy or interminable transactions, Flare imposes a complexity limit, defined in Gas units"* (Flare Networks 2020, p. 6).

In a related example, Aragon recognizes that in some cases, imposing a structure onto contracts can be beneficial to optimize operations in the DAO:

> *"Some contracts are intended to forward actions based on pre-defined criteria, for example, a voting app will forward action after a successful approval vote. By chaining multiple contracts together we can define complex criteria which constrain how actions can be performed within the organization"* (Aragon 2020b).

In these ways, whether it is by design or through specific intervention, human actors negotiate limits of automation. In the case of MakerDAO, components of a DAO, such as non-custodial vaults, are largely controlled by users. In others such as Aragon, a formal structure such as a court has been set up for human conflicts that exceed the abilities of smart contracts. Human actors also set policies to limit or shape the complexity by which smart contracts are executed as in the Flare DAO. Similarly, MolochDAO defines a dilution bound for the maximum dilution in value that the tokens of members can suffer while in KyberDAO members need to specify minimum or maximum values for transaction parameters when calling smart contract functions to trade tokens. Implicit in all of these processes is the acknowledgement that algorithms are limited in what they can accomplish, and sometimes there is no substitute for full human agency.

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[8] ANJ refers to the Aragon Network Jurisdiction token used in the Aragon Court.

[9] The EVM refers to the Ethereum Virtual Machine and runs smart contracts on the Ethereum blockchain.

Summing up this second mechanism, first, DAOs granularize empowerment through fine-grained customization and voting on automatable parameters, thus expanding the powers of human agents in the organization. A DAO provides opportunities for holders to express their power through deciding on parameters and configuration. Second, DAO automatic monitoring and informing of unstable conditions triggers reactive interventions by its members, reinforcing their authority to make proposals to the community. The technology serves up relevant information for humans to use to conduct course correction. Third, DAOs institute policies where members are either granted full autonomy outside of the realm of the software protocol, or where the protocol may be shaped or overridden based fully on human initiative to optimize the organization. Humans customize components to alter the default direction set by the technology. Thus, in the mechanism of "taming algorithmic power," humans both systematically and spontaneously perform actions to bend automated processes to comply with their organizational will.

Discussion

Implications for Research

The first significant implication of our study is for research on platform-based governance *via* IT in general (e.g., Ghazawneh and Henfridsson 2013; Gregory et al. 2018; Huber et al. 2017; Moehlmann et al. 2021; Tiwana et al. 2010; Wareham et al. 2014), and blockchain governance in particular (e.g., Beck et al. 2018; Chen et al. 2021; Lumineau et al. 2021; Murray et al. 2019; Risius and Spohrer 2017; Ziolkowski et al. 2020b). Our findings around the mechanism of "establishing algorithmic organization" extend and add more nuances to our emergent understanding of governance *via* IT in platform-based settings (e.g., Gregory et al. 2018). Platform-based governance not only relies on automated processes, which in centralized platform settings are oftentimes opaque to distributed users and can be bent by formal managers to re-align with their goals (de Vaujany et al. 2018; Tiwana et al. 2010). But, in DAOs we see such automation involving a process of "enforcing precise rules and steps" that helps resolve disputes and achieve co-functioning of dispersed parts of the network without having to rely on a centralized coordination mechanism such as the hierarchy (Beck et al. 2018; Lumineau et al. 2021). Even if prior literature has begun shifting the research focus from functional to platform-based governance mechanisms, including formal and informal control (Tiwana et al. 2010) or standardized rules (Ghazawneh and Henfridsson 2013; Wareham et al. 2014), the predominant focus on centralized platform settings has prevented scholars from explaining the shifting power dynamics and automated enforcement of rules accompanying the greater reliance on algorithmic processes in platform meta-organizations. In addition, our findings about "encoding trust in the system" shed new light on how transparent platform-based governance in DAOs acts as a microfoundation for facilitating peer-to-peer interactions and transactions, instead of relying on a single 'trust-worthy' platform owner that is in the middle of every transaction (Huber et al. 2017). As our findings highlight, revealing ownership of actors, exposing the use of their influence, and providing transparency more generally are all central components of "encoding trust in the system" which suggests a form of trust *in* algorithms (Ostern 2018; Risius and Spohrer 2017) complemented by a form of decentralized trust *through* algorithms. While autonomy and the voice of every individual actor are respected through this new form of governance *via* IT, our findings also suggest that "establishing algorithmic organization" involves the process of "surveying the stakeholders and environment," which is a commonality across different forms of platform-based governance *via* IT, but does not necessarily has to be associated with centralized control by a platform owner (Moehlmann et al. 2021) when paired with transparency and trust as achieved through "establishing algorithmic organization." These findings extend our understanding of a pattern that prior IT governance literature in platform-based settings has started to identify descriptively without offering a systematic explanation. In particular, as governance in decentralized platform settings such as DAOs relies on nonhierarchical mechanisms, a key challenge is synthesizing autonomy and alignment without relying on hierarchical control as in functional IT governance in traditional large organizations. While the process of "encoding trust in the system" increases autonomy of each member in a DAO, the process of "surveying the stakeholders and environment" complements that process by ensuring alignment and achieving dynamic equilibrium as the DAO continuously adapts to internal and external changes (e.g., changes in the composition of actors in the network or in economic data points). In sum, our findings about "establishing algorithmic organization" provide a systematic explanation of the patterns of DAO governance *via* IT.

The second significant implication for research is offered by the mechanism of "taming algorithmic power" identified in our study that extends the concept of algorithmic management itself (e.g., Faraj et al. 2018;

Kellogg et al. 2019; Moehlmann et al. 2021). Our findings about "taming algorithmic power" highlight that the more a DAO relies on algorithmic governance processes embedded into the design of the platform to achieve automation, efficiency, and scalability, the more the resulting mechanism underlying governance *via* IT must be complemented with a mechanism focused on governance *of* IT. When algorithms are relied on for coordination and governance in a DAO, the associated establishment of algorithmic organization as the new normal also requires several processes highlighted by our findings that contingently act as 'checks and balances' for algorithmic coordination and management. Extending previous research on algorithmic management (e.g., Moehlmann et al. 2021), we find that the process of "granularizing empowerment" ensures the ongoing influence of actors in the network to shape the functioning of algorithmic governance processes with their voice that they either use individually or collectively as part of their voting rights that come along with DAO token ownership. Thus, by "granularizing empowerment," a more pluralistic form of algorithmic management becomes possible, highlighting the contributions to collective organizing in complex environments that stem from the inclusion of a diversity of different perspectives and voices (e.g., Brès et al. 2018; Denis et al. 2001), that contrasts with the Taylorist principles of scientific management that previous research shows get reinforced through algorithmic coordination and governance in centralized platform settings (Kellogg et al. 2019; Moehlmann et al. 2021). Expanding further on our key findings, the process of "triggering reactive interventions" helps explain how through community-driven sensemaking and initiatives to change the system, oftentimes triggered by the algorithms themselves, a DAO develops an adaptive sensory system to mitigate the risk of organizational failure under stability-threatening turbulences and events (e.g., volatility events in the face of market turbulences or major socio-technical breakdowns in the functioning of the network overall). In addition, while research in centralized platform settings found that data is used by the platform owner to power machine learning algorithms that control and nudge the behavior of humans (Moehlmann et al. 2021), "triggering reactive interventions" instead suggests that data and information is used in DAOs by community members to adapt the code of the very algorithms. "Taming algorithmic power" and ensuring that governance *via* IT is complemented by governance *of* IT in DAOs to ensure they are conducive to human ideals, goals, and desires for change and improvement is also facilitated by the process of "negotiating limits of automation" which seems to free members of a DAO from the 'algorithmic iron cage' (Faraj et al. 2018; Kellogg et al. 2019) and instead empowers them to customize components to alter the default direction set by the technology. In sum, our findings about "taming algorithmic power" highlight governance *of* IT in DAOs as dynamic, emergent, multidirectional, and granular.

Third and overall, our findings imply that both mechanisms, "establishing algorithmic organization" and "taming algorithmic power," interact with each other, adding empirical depth and theoretical clarity to this conjoined agency between humans and algorithms that the literature has only recently started exploring (e.g., Baird and Maruping 2021; Cram and Wiener 2020; Murray et al. 2020; Raisch and Krakowski 2021; Rossi et al. 2019). Governance in DAOs involves combining governance *via* IT, through the mechanism of "establishing algorithmic organization," with governance *of* IT, through the mechanism of "taming algorithmic power," into a duality (Farjoun 2010). These findings point to a fundamental novel tension in blockchain governance that must be resolved for effective governance in DAOs, the tension between governance *via* IT and governance *of* IT. On the one hand, DAOs must rely on governance *via* IT to achieve maximum scalability for decentralized organizing and non-hierarchical control to maintain high autonomy and alignment of individual actors. On the other hand, governance *via* IT and the associated power of algorithms potentially also creates rigidities and limits the influence of actors to change and re-align the organization with new priorities and objectives to maintain its dynamic equilibrium. In a DAO, the one shared platform with its influential set of embedded algorithms that coordinate and govern interactions and transactions must coexist in a duality with the community of distributed actors in the network who ultimately need to support, change, and adapt the design of the decentralized platform to identify with the overall purpose of a DAO. In this regard, DAOs are similar to the way the individual and the collective group of individuals (i.e., the organization) have to coexist within a complementary duality for a humanistic and pluralistic organization to function. Without creating such a duality, DAOs cannot function, and they fall apart and fail as witnessed many times in the short history of DAOs. These findings relate to yet also extend previous research on the conjoined agency (Murray et al. 2020) between humans and agentic IS artifacts (Baird and Maruping 2021). While previous literature assumed that the algorithms themselves can be seen as actors and theorized the need for finding an appropriate delegation of tasks to and from humans and agentic IS artifacts as a centralized process of a designer (Baird and Maruping 2021), our findings highlight that in the context of DAOs this process involves complex negotiation between autonomous human and algorithmic actors. In particular, we find that in the conjoined agency between human and algorithmic actors, smart contracts not only "arrest" humans by intentionally constraining them in routine activities (Murray et al. 2020), but rather facilitate collective action by autonomous human actors.

Implications for Practice

Our findings have implications for practitioners who need to understand governance in DAOs. First, how to make technological and human actors accountable and liable in DAOs is still an open regulatory question (De Filippi and Wright 2018; Treiblmaier et al. 2021). Our two mechanisms, "establishing algorithmic organization" and "taming algorithmic power," along with their key themes can help to flesh out the legal requirements for both humans and technology in limited liability DAOs such as 'The LAO'—that ties binding legal agreements to smart contracts. Second, historic failure cases like 'TheDAO'—that heavily relied on governance *via* IT but famously failed due a programming error—question the sustainability of DAOs. Our findings regarding the mechanism of "taming algorithmic power" can help to increase the resilience of DAOs by quickly sensing and responding to endogenous or exogenous events (e.g., software hacks).

Limitations and Future Research

Opportunities for future research arise when considering the limitations of this study. First, while we systematically and carefully sampled the five DAO cases to ensure maximum variation and representativeness, these cases are still partly in development. Future research could study other DAO cases to further validate our two mechanisms. Second, while we advance the perspective of viewing governance *via* IT, through the mechanism of "establishing algorithmic organization," and governance *of* IT, through the mechanism of "taming algorithmic power," as a duality, we did not focus on the dynamic push and pulls between both poles of the tension over time. Future research may unveil the dynamic interplay and balancing act of governance *via* IT and governance *of* IT through the mechanisms of "establishing algorithmic organization" and "taming algorithmic power." Last, we answered the questions of 'how' DAOs are governed *via* IT and by 'what' mechanisms. We identified two key mechanisms, "establishing algorithmic organization" and "taming algorithmic power." However, we remained virtually silent about the underlying economic or social dynamics that justified 'why' DAOs rely on both "establishing algorithmic organization" and "taming algorithmic power" as mechanisms underlying governance (Whetten 1989).

Conclusion

DAOs continue the shift from governance *of* IT toward governance *via* IT by relying on algorithms to govern a distributed network of autonomous actors. Motivated by the fact that this shift challenges established assumptions in the literature on IT governance, we explored how DAOs are governed *via* IT. We found that DAOs governed *via* IT synthesize autonomy and alignment through the mechanism of "establishing algorithmic organization." At the same time, governance *of* IT in DAOs involves a more pluralistic and decentralized form of algorithmic management through the mechanism of "taming algorithmic power."

Acknowledgements

We thank the reviewers and the associate editor for their valuable suggestions.

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