Metaverse Governance: An Empirical Analysis of Voting Within Decentralized Autonomous Organizations

Mitchell Goldberg* Fabian Schär*

First Version: December 23, 2022
This Version: February 02, 2023

Citation info:
This is the working paper. Please cite the journal version – available here.

Abstract:
In this paper we explore the importance of platform governance. We discuss various problems of centralized architecture in the context of the metaverse or sharing economy applications which may lead to monopoly market structures. We argue that open standards and blockchain-based governance can potentially mitigate some of these issues. We then collect governance data from the first blockchain-based virtual world and conduct an empirical analysis to study voter behavior within Decentralized Autonomous Organizations (DAOs). We provide empirical evidence that open standards and blockchain-based governance are a necessary but not a sufficient condition for a decentralized and neutral platform. Centralization and concentrated voting power may lead to dependencies, rent extraction behavior and create hold-up problems. Consequently, producers, prosumers and service providers must evaluate the governance structure of the platform before establishing a presence.

Keywords: Attention Economy, Blockchain, DAO, Governance, Metaverse, Web3
JEL Classification: M37, M38

*Center for Innovative Finance, Faculty of Business and Economics, University of Basel, Switzerland. mitchell.goldberg@unibas.ch; f.schaer@unibas.ch

1 Introduction

The internet has changed the way we interact with each other and conduct business, and there is hardly an industry that has remained unaffected. Even the smallest companies are expected to have their own websites and social media profiles. Social networks have proven to be an effective tool for advertisement (Kumar et al. 2016, Li et al. 2022) and customer engagement, and the lack of an adequate online presence is a major competitive disadvantage that has the potential to diminish a company's success (Jones & Jayawarna 2010, Ye et al. 2022).

As such, the World Wide Web is a great example of an attention economy (Goldhaber 1997) – an information-rich environment where economic agents need to allocate their attention capacity among various sources (Simon et al. 1971), and a contest between information sources for the attention of recipients occurs (Falkinger 2007). Companies and brands compete for eyeballs and use search engine optimization (SEO), online advertisements (Berman & Katona 2013, Iyer & Katona 2016) and various other instruments to maximize traffic and conversion rates. Throughout the history of the World Wide Web, these parties adapted from the simple provision of static information to the era of user generated content, and the advent of vocal online communities. Many of these communities now move to the next virtual frontier: the *metaverse*.

Numerous companies and organizations have already established a virtual presence and use the metaverse to engage with new and existing customers. Atari has created a virtual arcade, JPMorgan has opened a virtual office and Samsung regularly hosts events in their virtual customer engagement space. Nike has acquired the virtual apparel creator RTFKT, Adidas has partnered with Bored Apes Yacht Club (BAYC) – a non-fungible token (NFT) based online community, and various well-known brands, including Coca Cola, Gucci, Tommy Hilfiger and American Apparel have sold clothing for avatars. Moreover, artists like Travis Scott, Ariana Grande, Deadmau5, Paris Hilton or Lil Nas X have held virtual concerts. Most prominently, Facebook has rebranded its company to "Meta", and has publicly announced that it is committed to the development of the metaverse.

The metaverse enables a more natural visualization of information, in a familiar, quasi-physical environment (Duan et al. 2021, Lee et al. 2021). Thus, it may create an opportunity for businesses to build more immersive and engaging points of contact. Users no longer browse alone through 2D text- or media-based websites and applications. Instead, they control an avatar, i.e., a virtual representation of themselves, in a 3D virtual space where they directly interact with others and the virtual environment. This allows companies to create online experiences that would otherwise not be possible (Giang Barrera & Shah 2023).

Similar to the World Wide Web, the metaverse is an attention economy. Due to its quasi-geographic context, where each piece of information has a specific location within a virtual world, the competition goes far beyond SEO and advertisements. There is strong empirical evidence that location matters, even in a virtual setting with negligible travel costs (Goldberg et al. 2021). Just like in the physical world, the distance to points of interest, main streets, plazas and popular districts are important criteria that affect visitor density. We refer to these as micro-level factors, i.e., the variables that determine the precise spot where a company should locate within a given virtual world.

However, before a company can make a decision regarding their precise location, they first have to assess the macro properties (Fernandez & Hui 2022) of the virtual world and explore whether it makes sense to establish a virtual presence. One of the key aspects for this assessment is the virtual world's governance structure and the implicit distribution of power (Egliston & Carter 2021). This can be compared to the choice of jurisdictions in the physical world. Clearly, governance and political systems do affect locational choices on a macro-level, and there are strong disincentives to locate a business in regions with political uncertainty, arbitrary decision making and a weak rule of law. Similarly, if metaverse governance is weak and the power not well distributed (Bloomfield & Coombs 1992), this may generate hold-up problems (Goldberg 1976, Klein et al. 1978, Williamson 1979) and monopolistic infrastructure. Businesses who ignore these aspects are at risk of becoming dependent on the operator, and may find themselves in a hold-up or lock-in situation.

In practice, this governance issue may also arise for other applications that are built on privately operated digital platforms, e.g., in the sharing economy. These sharing economy platforms facilitate trade between consumers and prosumers, but they usually rely on a trusted party which can unilaterally change the rules and affect the businesses of their stakeholders. Researchers have already looked at governance of these platforms, either through outside regulation (Hong & Lee 2018, Vith et al. 2019, Mont et al. 2020) or the democratization (Martin et al. 2017) of the platform itself.

Technology offers opportunities for novel governance structures. While blockchain technology has been listed as one of the most transformative factors for human resource management (Christ & Helliar 2021), operations (Filimonau & Naumova 2020), processes (Hew et al. 2020, Hughes et al. 2019, Tan et al. 2021, Tsolakis et al. 2021) and marketing (Kumar 2018, Eckhardt et al. 2019, Gligor et al. 2021, de Villiers et al. 2021, Cui et al. 2021), it could also serve as a governance tool (Pazaitis et al. 2017, Arruñada &

Garicano 2018) through disintermediation in the sharing economy (Kostakis & Bauwens 2014, Hawlitschek et al. 2018, Fiorentino & Bartolucci 2021, Mehrwald et al. 2019, Tan & Salo 2021). Furthermore, Talmon & Shapiro (2022) propose a grassroots democratic system through blockchains and Decentralized Autonomous Organizations (DAOs) which could potentially create an income-sharing alternative to social media, sharing economy platforms that are organized as cooperatives by the relevant stakeholders or a democratic metaverse. Others (e.g., De Filippi 2019, Bena & Zhang 2022) have pointed out that DAOs are not necessarily the right way to democratize these communities, especially due to the wealth component of token-based voting mechanisms.

In this paper, we study metaverse governance. We first discuss potential problems of virtual worlds which are under the exclusive control of a centralized operator and then explore blockchain-based virtual worlds as a potential remedy. We have collected data from the largest blockchain-based virtual world and use this data to analyze its governance process. We show that a blockchain-based tech stack can mitigate some of the governance issues, but should not be regarded as a guarantee for decentralized decision-making.

2 Preliminaries

2.1 Metaverse

Despite the recent media traction, there is much confusion around the *metaverse*. For instance, the term is often used synonymously for various Extended Reality (XR) technologies (e.g., Xi et al. 2022). This is problematic, as not all Virtual Reality (VR) and Augmented Reality (AR) applications take place in the metaverse. The problem becomes apparent when we use the analogy of the World Wide Web and a personal computer. While computers allow users to access the World Wide Web, they also enable them to use various offline applications. Similarly, AR and VR devices can be used to access the metaverse, but also for various unrelated tasks (e.g., Boud et al. 2000, Mujber et al. 2004, Zyda 2005, Ong et al. 2008, Ganiev et al. 2018).

The metaverse enables users and businesses to connect in a more natural way. It essentially resembles the World Wide Web, but it quite literally adds another dimension to the user experience and allows people to interact in a quasi-physical context.

The term itself has existed for decades and is often attributed to Neal Stephenson's 1992 science fiction novel "Snow Crash" where it describes an immersive virtual world that is populated by humans-as-avatars. The word itself is a portmanteau of "meta" (i.e., "transcending" or "beyond") and "verse" (i.e., "universe").

Academic literature on the metaverse is quite sparse. Yet, there are a few papers that analyze the subject from different angles.

Dionisio et al. (2013) summarize the history of the metaverse from a computer science perspective. In short, virtual worlds have existed since the late 1970's in a text-based format. They have since evolved to 3D graphical interfaces that visualize user-generated, and predominantly commercial, content. The authors clearly explain that the next step of the development of the metaverse is an immersive version of the World Wide Web.

The main drivers of these virtual worlds are social and economic interactions (Hendaoui et al. 2008). This has led to many cases where these platforms have grown to substantial virtual economies (Castronova 2002). Usually, these economies are driven by goods and services that are provided by third parties and not the operator itself – at least not exclusively. There are many examples in which the boundaries between consumers and producers start to blur, creating a prosumer economy, where everyone can create their own assets and provide various services.

Similar to other platform economies, virtual worlds may be prone to governance issues. In a recent paper, Nabben (2021) highlights that operators of a private metaverse may extract value and conduct arbitrary rule changes. In contrast, a public metaverse could be governed and owned by DAOs (Beck et al. 2018). Blockchains and DAOs offer new ways to organize collaborations (Lumineau et al. 2021, Allen & Berg 2020), and thus could also be employed for non-computational processes (Fernandez & Hui 2022), such as voting and content moderation, in the metaverse. For reference purposes, we have included a short Web3-specific glossary in Table 1 which describes the most frequently used acronyms in this paper.

But even DAOs do not solve all problems. In fact, their voting schemes may introduce new governance issues (Chohan 2017). Knowing that asset ownership usually follows a Pareto distribution (Newman 2005) this may lead to unequally distributed voting power.

In this paper, we empirically analyze potential problems of one DAO for a metaverse platform. For a more general empirical glimpse at the rise of DAOs, consider Bellavitis et al. (2022).

2.2 Governance

To get a better understanding of the potential governance issues in the metaverse, it may be useful to start with a simple framework. For this purpose, we briefly introduce a generic technical stack which allows us to analyse virtual

Acronym	Definition
DAO	A Decentralized Autonomous Organization. A collective which governs through blockchain technology without a centralized leader.
IPFS	The Interplanetary File System (see Benet 2014). A peer-to-peer distributed file system without a single point of failure which can be used to store and distribute files permanently through the internet.
MANA	A fungible ERC-20 compliant token that was designed to bootstrap Decentraland's economy.
NFT	A non-fungible token which represents ownership in a distinct asset.
SAB	The Security Advisory Board of Decentraland which has special privileges to upgrade the smart contracts which manage the ownership of land parcels.
VP	Voting power. An absolute measure of voting rights based on pre-defined rules, e.g., the number of owned land parcels, user names or MANA.

Table 1: Glossary of Web3-specific acronyms used in this paper.

worlds from various angles. The stack is divided into three layers, where each additional layer is built on top of the ones below. Similar to Ordano et al. (2017) we refer to them as the "ownership", "content" and "visualization" layers.

2.2.1 Ownership Layer

Users in virtual worlds can own various digital assets, e.g., monetary units, land parcels, avatar apparel, user names or even avatars themselves. These assets are virtual by nature and their ownership is usually stored on a database. The database must be managed by someone, e.g., the operator of a centralized ledger or the community in the case of a public blockchain system (Nakamoto 2008, Buterin et al. 2014).

A centralized database essentially requires trust in the operator. Assuming the operator is benevolent, this approach is unproblematic. Nevertheless, as suggested in various cases regarding social media and other platforms, operators sometimes face controversial decisions. Even worse, they may act maliciously (e.g., expropriation) or incompetently (e.g., getting hacked). Moreover, they may not always have an incentive to keep providing access to the database which could lead them to shut down the service, either temporarily or indefinitely (Schär 2021).

Decentralized solutions enable users to manage digital assets themselves, often in the form of (non-)fungible tokens on a public blockchain (see e.g., Belk et al. 2022). This provides a more robust infrastructure and trustless exchange environment (Tan & Saraniemi 2022), but comes with a tradeoff: the self-custody of these digital assets also requires self-responsibility with respect to the secure storage of the private key.

2.2.2 Content Layer

3D models, textures and applications must be stored in a way that makes them accessible to the end user. Content servers can be hosted by a single operator which can erase, modify or censor content.

Similar to public blockchains, one can employ a network of distributed content servers. However, this, requires a lot of storage space, and is often not feasible for the general public. Thus, some protocols, e.g., IPFS (Benet 2014), rely on a system where not all nodes store the entirety of the content.

A non-trivial task is the moderation of user-generated content. For example, who decides whether a particular user name is offensive or in line with the virtual world's guidelines? Who executes these decisions and how are these parties held accountable? In some cases, this may lead to controversial decisions due to the thin line between moderation and censorship (Myers West 2018, Gillespie 2018, Gillespie et al. 2020). DAOs could provide a solution in this regard (Wang et al. 2019, Hassan & De Filippi 2021), as they enable the community to vote on these specific cases.

2.2.3 Visualization Layer

Information from the ownership and content layers can be combined and visualized in a 3D environment which creates an immersive experience for the end user (Ordano et al. 2017).

Depending on the platform, the virtual world can be visualized by a wide range of devices, e.g., computers, gaming consoles, VR headsets, smartphones or tablets. Alternatively, the operator could require a specific device to be used by the end users. It is clear that businesses that operate in such a metaverse are highly dependent on the creator of this hardware device (Burgelman 2002, Farrell & Klemperer 2007).

The same applies to the software side. Some virtual worlds can only be accessed through a single, closed-source client. Once this client is no longer supported, the information can no longer be visualized and the centralized virtual world will also cease to exist. In contrast, an open architecture may enable client and device diversity, similar to browsers, computers and smartphones in the World Wide Web.

2.3 Separation of Layers

From a technical perspective, there is nothing that prevents a single provider from exclusively hosting all three layers of the tech stack. However, proprietary standards would make it hard for other platforms to be compatible (West 2003). Even if the centralized world has open interfaces and standards to allow for some interoperability, governance of these standards, particularly the process by which these rules are developed and changed, will still be a big issue (Simcoe 2012). The lack of interoperability comes at the costs of third party businesses. First, proprietary standards lead to a higher risk of dependencies and rent extraction. Second, businesses have a strong interest to attract the attention of as many potential customers as possible. Open standards may help in this regard. The separation of these layers could create a situation where most governance-related aspects exclusively revolve around the content layer. The ownership layer can be completely neutral without any governance intervention whatsoever (Schär 2021), but content on shared platforms should be moderated (Gillespie 2018). The visualization itself can be open, and thus enable multiple parties to offer clients and devices.

3 Field Data: Decentraland

In this section, we provide an overview of Decentraland (Ordano et al. 2017) its governance process and the governance data. Decentraland is the first large-scale virtual world that uses blockchain technology and a DAO with the goal of distributing power among its users. Its architecture aims to provide an infrastructure for businesses and developers to build and monetize applications on top of a shared, virtual world without having to fear a potential hold-up.

Decentraland employs NFTs on the Ethereum blockchain to track the ownership of land parcels, wearables and user names. Furthermore, it makes use of its own fungible token called "MANA" which was specifically designed to bootstrap the virtual world's economy. While the MANA smart contract is immutable and cannot be changed by anyone, the LAND smart contract, which manages the ownership of all land parcels, employs a proxy pattern which enables the DAO to make certain changes. The implementation of these changes is subject to a veto right by the members of the DAO's Security

Advisory Board (SAB), a group of five Solidity[1] developers. Originally, the SAB members were appointed by Decentraland's core team. Members can now be voted in/out by the DAO. The SAB's purpose is to intervene if a severe bug is detected in the smart contracts.

The virtual world creates an environment for various content creators. Land owners can combine arbitrary resources (e.g., 3D models, textures and applications) to create interesting scenes which can be deployed on the respective land parcels. Similarly, wearable designers make use of resources to create apparel for avatars. This process could theoretically be expanded to other types of assets, e.g., vehicles.

In order to minimize the dependency on a centralized operator, these resources, as well as user profiles, are stored on so-called "catalyst" servers. Decentraland's open-source approach allows anyone to run their own, local instance of such a server where they can deploy new resources, and thus, modify their own, local version of Decentraland. The DAO manages a list of trusted catalysts which are run in accordance with the community's rules and governance decisions. Thereby, this network of servers creates a consensus about the true state of the shared, virtual world, including all deployments.

This kind of architecture not only allows anyone to run the virtual world on their own hardware, it also serves as leverage for the various stakeholders over the catalyst server operators. Should the operators act maliciously, e.g., through unilateral rule changes, the stakeholders can easily fork the virtual world and run it on their own hardware with their own set of rules. Furthermore, if the ownership layer is indeed completely neutral, i.e., tokenized assets powered by immutable smart contracts on a public blockchain, any user who forked the virtual world can integrate these assets without having to fear an intervention by the malicious operator. We discuss (this threat of) forking later in Section 5.

Users access the virtual world via a desktop client or through their browser. When logging in, they cryptographically sign a message with the private key of their Ethereum address, allowing them to prove ownership of their Web3 identity. The use of Web3 credentials ensures that no single party controls the login process and identities. Once the user is logged in, all data in relation to their avatar and scenes in their close proximity are presented in a virtual 3D setting. The user can then explore the virtual world by themselves or with others.

Decentraland's architecture aims to distribute power among its users through the management of assets on a public blockchain and through a

[1]Solidity is an object-oriented high-level programming language for smart contracts on Ethereum Virtual Machine compatible blockchains.

server network which is managed by the DAO. The DAO also holds the power to make changes to the virtual world's rules, i.e., the governance of the virtual world.

Since anyone can create large numbers of pseudonyms (addresses) at effectively no costs, decentralized governance systems cannot rely on "one person, one vote" schemes. The approach would be prone to sybil attacks (Douceur 2002, Tran et al. 2009). This issue is often referred to as the "weak identities problem" and the reason why most DAOs, including Decentraland's DAO, rely on token-based voting.

All entities that own a land parcel, MANA or user name are considered to be members of the DAO. They have the right to propose governance changes and to vote on governance issues. Votes have different weights, or voting power (VP), depending on the voters' token holdings. The VP of each DAO member is determined by their Decentraland-related assets, i.e., their MANA balance, as well as the number of land parcels and user names they own. Members receive 1 VP for each MANA token they hold, 100 VP for each name, and 2,000 VP for each land parcel. VP can also be delegated to other parties. This enables users to cede their VP to a trusted party who can vote on their behalf, while keeping their assets.

Whenever a proposal is submitted, its metadata is stored on IPFS (Benet 2014) and a snapshot of the outstanding VP at the time of creation is taken. To cast a vote, users simply sign a message with the private key of their Ethereum address, which ensures the authenticity and integrity of their choice.

VP which stems from MANA, land and user names is essentially fixed at the time of creation of a proposal and cannot be transferred, even if the underlying asset is moved to another account. However, delegated VP can be revoked during the voting period. This ensures that delegators can vote on a topic themselves if their delegate does not vote in accordance with their own preferences.

All submitted proposals and cast votes are public and anyone can always track the current results of (on-going) votes or observe how each address has voted. Once the pre-specified voting time has passed, the VP submitted for each choice is summed up and the results are final. Any changes resulting from an accepted proposal are executed by the DAO Committee, a group of three DAO-elected community members. The DAO Committee is overseen by the SAB which has the ability to pause, resume or cancel any action taken by the Committee. Depending on the proposal type (see Table 2 for an overview of proposal types), a minimum threshold of VP must be reached for a proposal to be accepted.

Decentraland's DAO provides governance data[2] from various public sources (e.g., the Ethereum blockchain and snapshot.org). These data include information about all submitted proposals, the participating members and their cast votes. We use these data as a starting point for our analysis.

The data set consists of 1,414 proposals that were submitted by 789 Ethereum addresses between May 24, 2021 and Dec 08, 2022, as well as the 45,333 cast votes that were submitted by 4,345 addresses.

There are eight different proposal types, five of which are highly standardized and directly result in binding changes:

Ban Name Users can propose to vote on banning a specific user name to prevent harassment.

Catalyst Users can propose to add new servers to the DAO-approved list of catalyst servers. These servers are run in accordance with the DAO's rules, and thus, create a consensus about the current state of all deployments in the shared virtual world.

Grant The DAO controls a treasury of various cryptoassets and users can file applications and request funding for their community projects.

POI Users can propose to add or remove points of interests (POIs) within the virtual world. These POIs are displayed on the standard client's map and help others to identify interesting locations.

Wearables Users can request to be added to the linked wearables registry. Parties that are part of this registry can create and launch 3D representations of NFTs that originate from outside of Decentraland, e.g., NFT-based sneakers or shirts. A special Wearables Committee has the final say on the inclusion of new wearables.

Other, more complex issues that do not fit one of the standardized proposal types, follow a three-step process with increasing VP threshold values:

Poll Polls raise potential governance issues and act as a temperature check of the community sentiment. Their goal is to determine if there is enough support to move forward with a more specific proposal.

Draft Drafts present a potential policy to combat a raised governance issue and formalize the discussion about potential impacts and implementation issues.

[2]Daily updated data can be found at: https://github.com/Decentraland-DAO/transparency

Governance Governance proposals formalize the draft proposal into a binding outcome for the DAO to vote on. Note that all previously mentioned proposal types can also be considered governance decisions. We refer to this last category as "governance proposal" to be in line with the terminology used by the DAO.

We summarize the VP and number of votes for each proposal type in Table 2.

Type	Obs.	Min.	Mean	Median	Max.
Ban Name	64	21,372.26 (4)	1,195,084.89 (26.88)	671,788.71 (22)	13,913,407.10 (122)
Catalyst	2	247,539.60 (9)	1,149,658.98 (11)	1,149,658.98 (11)	2,051,778.36 (13)
Grant	388	9,424.48 (3)	2,644,817.14 (52.69)	1,707,725.34 (40)	17,516,017.18 (237)
POI	362	1,124.80 (1)	835,106.44 (32.85)	596,051.57 (19)	5,262,216.95 (205)
Wearables	50	5,807.00 (10)	2,201,559.29 (48.12)	1,444,523.65 (42.50)	8,961,879.08 (123)
Poll	508	361.15 (3)	1,269,732.41 (34.01)	595,619.37 (23)	14,645,927.66 (184)
Draft	25	8,410.14 (17)	3,502,918.55 (55.88)	2,656,538.98 (46)	11,014,717.99 (155)
Governance	15	1,303,498.13 (29)	6,862,381.95 (73.33)	6,940,498.80 (72)	12,684,829.68 (191)

Table 2: Summary statistics for VP and number of votes (in brackets) for each proposal type.

4 Data Analysis

While decentralized governance schemes enable different stakeholders, e.g., users, developers and businesses, to actively take part in crucial decisions, the question arises if this new type of institution evokes new forms of abuse and misuses. In particular, if VP is a function of wealth, there may be a risk of a plutocracy (Leech 2013). Moreover, sequential voting and the transparent nature of cast votes may lead to a vote timing issue with a high incentive to vote very late in the voting period (Battaglini et al. 2007). In the following subsections, we will use various approaches to explore these potential issues empirically.

4.1 Whale Analysis

There are vast differences in VP. Some addresses control large amounts of governance tokens, others extensive LAND estates, or large collections of names. VP may also be a result of delegation by other entities. In any case, these high VP voters have a significant say in the outcome of a proposal.

While the weak identities problem makes it hard to map VP to individuals and to compute metrics like VP Gini-coefficients (Nadler & Schär 2022), we can compute the relative VP of the dominant voter. Note that this is a lower bound value that could be higher if (a) the dominant voter uses multiple pseudonyms or (b) another voter uses multiple pseudonyms and has a higher cumulative VP than the dominant voter. As such, our whale analysis is a conservative approach that will likely underestimate the true influence of whales on proposal outcomes.

Figure 1 shows the distribution of the dominant voter's VP share. The ratio is computed for each proposal and categorized by proposal type. For *Ban Name*, *Grants*, *POI*, *Poll* and *Wearables*, the median value is between 0.45 and 0.7. Note that a median VP ratio of >0.5 would allow the top voter to unilaterally change the outcome of most proposals. "Catalyst" proposals are much more lopsided and effectively decided by a single person. However, the results must be interpreted with great care, as there are only 2 observations for the catalyst category. While the "Draft" category is mostly irrelevant, there is evidence in the data that pure "governance" decisions are slightly less centralized.

4.2 Marginal Voter Analysis

Similarly to lower bounds for dominant voter's relative VP share, we can also compute upper bound marginal voter thresholds. An upper bound marginal voter threshold essentially describes how many voters would need to abstain to flip the outcome of the voting process. The value constitutes an upper bound, as several addresses may be controlled by the same entity, effectively reducing the minimum number of entities required.

We have grouped the proposals by categories to see if there are significant differences. Table 3 shows how many of the proposals of each category could have been flipped, given a certain number of marginal voters who would be willing to abstain. Note that the numbers would be even worse if we considered scenarios where voters would be allowed to change their vote to another option.

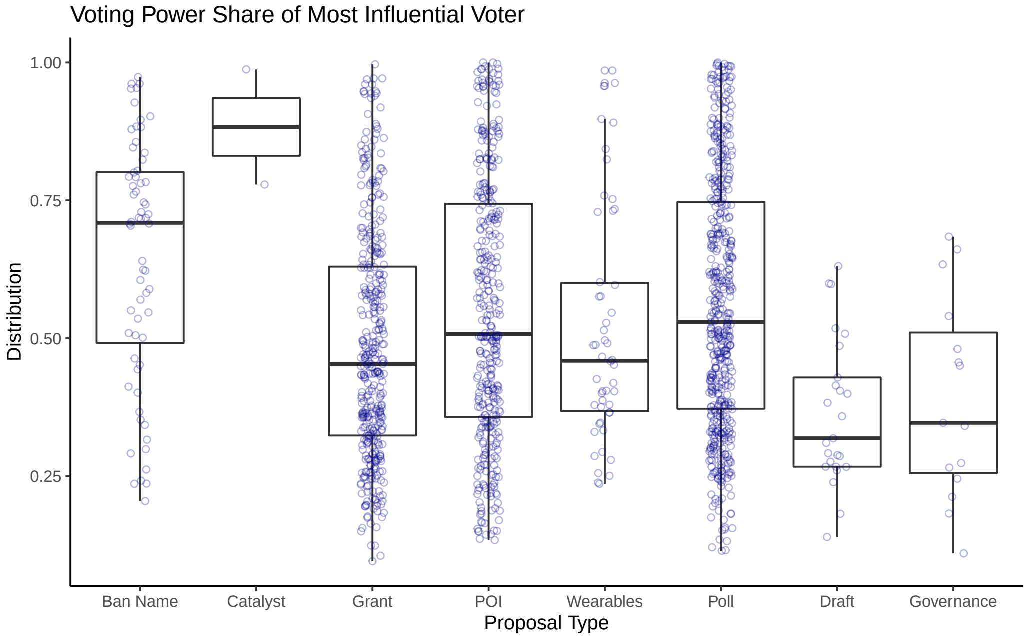

Figure 1: Relative VP of voter with highest VP share per proposal. Boxplot grouped by proposal categories.

		Number of Abstaining Voters					
Type	Obs.	1	2	3	5	10	25
Ban Name	64	0.1094	0.1562	0.1719	0.2500	0.5625	0.9531
Catalyst	2	0.5000	0.5000	0.5000	0.5000	0.5000	1.0000
Grant	388	0.1057	0.1830	0.2629	0.3737	0.5799	0.8660
POI	362	0.1796	0.2790	0.3481	0.4475	0.6381	0.8370
Wearables	50	0.1400	0.2000	0.2800	0.4200	0.5600	0.8000
Poll	508	0.2657	0.3740	0.4646	0.5630	0.7165	0.9350
Draft	25	0.0400	0.1600	0.2400	0.3600	0.4800	0.6400
Governance	15	0.1333	0.1333	0.1333	0.3333	0.4000	0.6000

Table 3: Marginal voter analysis: Ratio of proposal outcomes that could have been changed for a given number of abstaining voters.

Our analysis suggests that, depending on the proposal type, the absence of a single high VP voter would have been sufficient in 10% - 27% of the cases. Note that "Catalyst", "Draft" and "Governance" have only 2, 25 and 15 observations, respectively. These three categories are listed for completeness but must be interpreted with care.

4.3 Vote Timing

One could argue that the timing of the votes may have an effect on the outcome of the voting process. Early voters disclose their choices and allow others to respond accordingly. As such, an early voter could either discourage others from casting a seemingly ineffective vote for an alternative option or provoke large numbers of voters that oppose the choice, and allow them to rally behind a common cause. Clearly, there are various reasons why the timing of a vote could have an effect on the outcome and as such, it is important to conduct further analysis on when votes were cast.

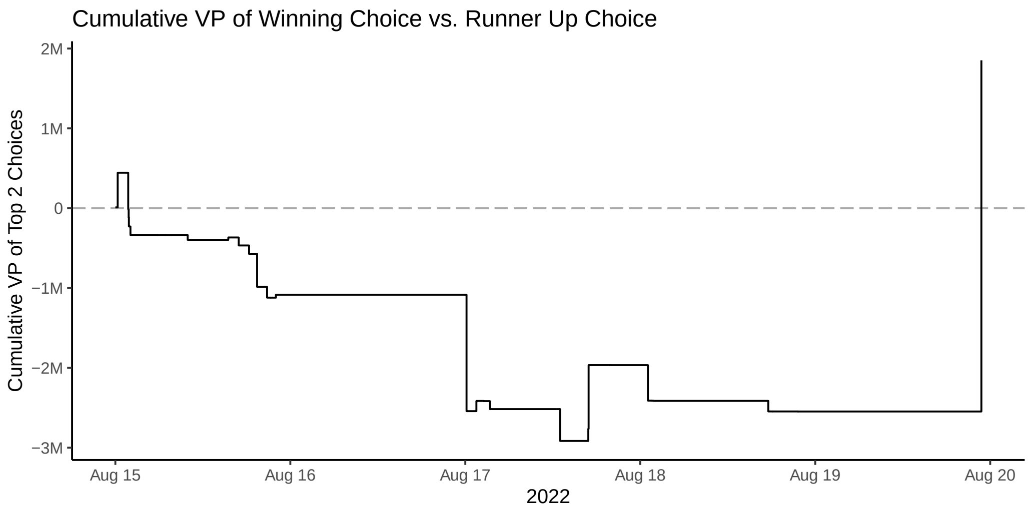

Figure 2: Time series of VP weighted votes for (positive) and against (negative) proposal. The proposal was a non-binding vote on an important governance issue, i.e., whether an open API should be closed and potentially restricted.

Initially, we found anecdotal evidence for proposal outcomes that were changed close to the conclusion of the proposals' voting periods. Sometimes the outcome was changed by a single "last minute" voter with a very high

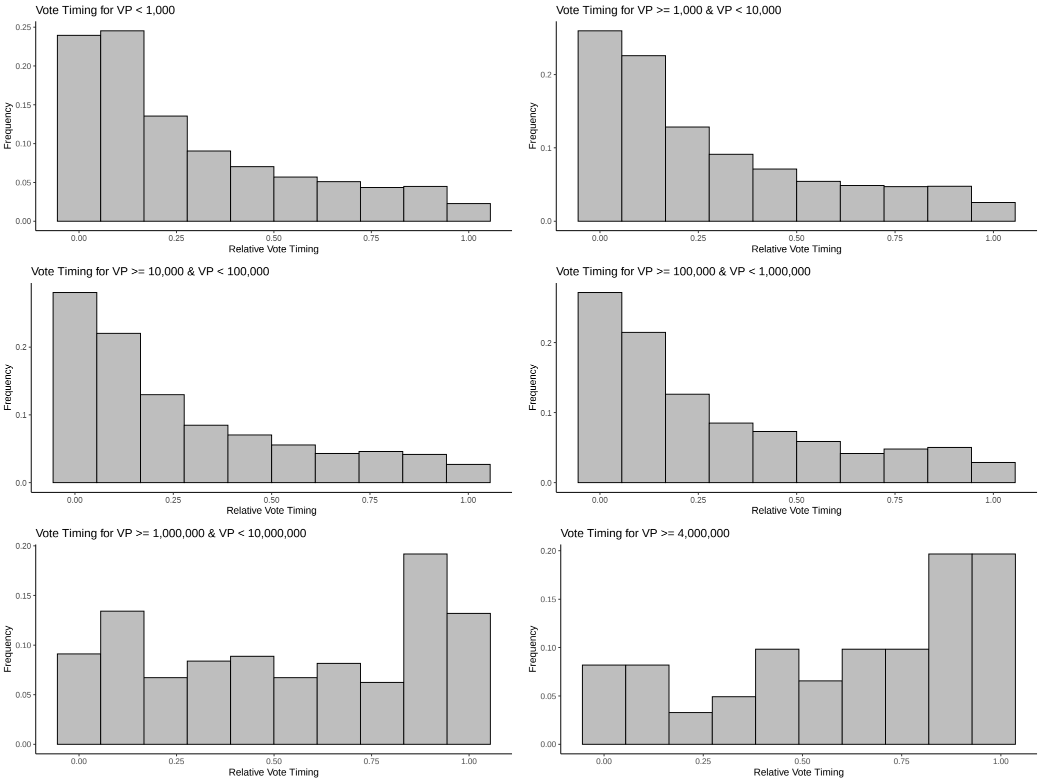

Figure 3: Relative time of vote for different categories of VP.

VP. One of these examples[3] is shown in Figure 2. The figure shows the cumulative VP-weighted time series of votes, where VP-values for votes in line with the final outcome were added as positive values and VP-values for votes in line with the runner-up as negative values. Note that the "No" choice had a comfortable lead of approx. 2M VP until right before the conclusion of the voting process, when a single vote with 4.4M VP was cast and subsequently flipped the result. It is important to understand that this observation was manually chosen. We do not claim in any way that this observation is representative of the entire data set but rather show this case as a motivation for the extended and more generalized analysis that follows in this and the next subsection.

To conduct a generalized analysis of when votes are cast, we first have to introduce a normalized time frame. Let us define V_S and V_E as the start and end time of the voting period. Let us further define V_i as the point in time at which vote i was cast. We can easily compute the relative vote timing

[3]The proposal ID for the example is `bafkreifk3pcxjthrmh5c2otxwgaqfmbgvxhgikqvb7nns7ebdt5j6droqu`.

$RVT_i = \frac{V_i - V_S}{V_E - V_S} \in [0, 1]$, i.e., the time a vote was cast relative to the duration of the voting period.

Figure 3a-f show the RTV distribution. We have grouped voters by their VP, from very small voters with VP < 1000, up to whales with VP $\geq 4,000,000$. Data suggest that small voters predominantly have a low RVT, while there is a significant shift towards higher RVT for voters with VP $\geq 1,000,000$.

While our analysis provides clear evidence for time preferences and strategic behavior among large VP voters, we do not yet know how large and late voters have affected proposal outcomes. This will be explored in the next subsection.

4.4 Outcome Robustness

To analyze outcome robustness we compute the dominant choices for the following 5 scenarios: `VP.ALL`, `VP.1`, `VP.2UP`, `VP.LATE` and `VP.EQUAL`. The computation is described below.

`VP.ALL` represents the final outcome, considering all votes weighted by VP. As such, it serves as a reference and can be regarded as the true outcome of the voting process.

`VP.1` reflects the choice of the voter with the highest VP. It ignores any votes by other voters. If a proposal was only voted on by one person, we get `VP.1` = `VP.ALL`.

`VP.2UP` represents the outcome, considering all votes, with the exception of the vote by the highest VP voter. The remaining votes are weighted by VP. It reflects the outcome if the highest VP voter would not have voted.

`VP.LATE` represents the outcome if we only consider votes with an $RVT \geq 0.9$. Recall that these are the votes that are cast in the last 10% of the proposal's voting period.

`VP.EQUAL` represents the outcome with equal weights. It completely ignores VP and instead simply counts the votes cast by distinct addresses. Note that this metric is not sybil attack resistant and must be interpreted with care.

Table 4 shows a simplified confusion matrix. Each cell represents the ratio of outcomes for which the column and row indicators yield the same result. For readability purposes we have plotted the values in both the lower and upper triangular matrix.

The values in the braces are the absolute number of observations for each pair. Observations vary, because there are some NA values for some of the computations. `VP.2UP` will yield an NA if there is only one vote on the proposal and `VP.LATE` will yield an NA if no votes were cast with $RVT \geq 0.9$.

	`VP.1`	`VP.2UP`	`VP.LATE`	`VP.EQUAL`	`VP.ALL`
`VP.1`	1.0000 (1,414)	0.7897 (1,412)	0.8360 (762)	0.7999 (1,414)	0.9484 (1,414)
`VP.2UP`	0.7897 (1,412)	1.0000 (1,412)	0.8045 (762)	0.8661 (1,412)	0.8414 (1,412)
`VP.LATE`	0.8360 (762)	0.8045 (762)	1.0000 (762)	0.8268 (762)	0.8583 (762)
`VP.EQUAL`	0.7999 (1,414)	0.8661 (1,412)	0.8268 (762)	1.0000 (1,414)	0.8388 (1,414)
`VP.ALL`	0.9484 (1,414)	0.8414 (1,412)	0.8583 (762)	0.8388 (1,414)	1.0000 (1,414)

Table 4: Simplified confusion matrix. Shows ratio of same outcomes and number of observations (in brackets).

In almost 95% of the observations, `VP.1` led to the same outcome as `VP.ALL`. This is particularly striking if we consider the fact that `VP.2UP` has a 21% disagreement rate with `VP.1`. Similarly, there is a significant difference between `VP.1` and `VP.EQUAL`. In roughly 14% of the cases, late voters would have picked a different option than all voters. Moreover, equally-weighted votes would have led to different results in 16% of the cases. `VP.EQUAL` provides further evidence for a potential imbalance in power. However, this result may be driven by the weak identities problem.

5 Discussion

When businesses choose to set up a virtual branch or otherwise engage in platform economies, they must consider the underlying governance process. Various stakeholders, including firms, developers and prosumers, are all subject to rule changes that may affect the core of their business and potentially render their investments worthless. If they ignore how rules are set and changed, they are at a severe risk of becoming dependent and subject to rent extraction (Goldberg 1976, Klein et al. 1978, Williamson 1979). It is important to be aware of this risk in the digital age as it exists in various platform economies, including traditional sharing economy platforms and the metaverse.

There are countless examples of how ecosystems with a monopoly market structure with respect to the platform provider can undermine competition and create hold-ups and rent extraction. In 2020, the United States' "Subcommittee on Antitrust, Commercial and Administrative Law of the Committee on the Judiciary" published an investigation report where it outlines the various risks associated with monopoly structures in digital markets. In the same report, the Subcommittee provides evidence that platform providers act as gatekeepers and use their proprietary platform data to mimic the behavior of successful competitors or take M&A actions to further entrench and expand their dominant market positions.[4]

The same logic applies to the metaverse. If the metaverse should indeed become an important business platform, these questions will be of even greater importance. In this case, the metaverse must be seen as fundamental infrastructure and a platform that hosts third party businesses. If a single service provider were in control of this infrastructure, they could unilaterally change the rules as they see fit, exclusively use proprietary data on other businesses, users and the world itself, and engage in unfair competition by acting as a gatekeeper. Most importantly, there would be a single point of failure and the platform provider could shut down the entire virtual world, even if third party businesses may still be profitable.

A permissionless and community-owned metaverse with open standards, blockchain-based ownership layers and governance processes can potentially mitigate some of these risks, at least in theory. In practice, these are necessary but not sufficient conditions for decentralization.

DAO-based governance can be set up in a way that involves all stakeholders of the virtual world. We have described that Decentraland uses different sources of VP, i.e., governance tokens, land parcels and user names. However, entities can still hold large asset pools and accumulate significant amounts of VP. One can argue that the system aligns incentives in a way that the entities with the largest exposure to the world will ultimately decide on its development. However, there will likely be situations that resemble principle agent theory, where what is best for a dominant individual is not necessarily a good choice for the virtual world as a whole as well as the majority of

[4]Link to full report: https://judiciary.house.gov/uploadedfiles/competition_in_digital_markets.pdf?utm_campaign=4493-519

its stakeholders. Essentially, the DAO-based governance model resembles an aristocratic system, which is a potential upgrade to monarchic, centralized virtual worlds where one single party rules.

We provide strong empirical evidence that many governance proposals are effectively decided by very few individuals. Table 3 shows that e.g., almost 27% of all polls were essentially decided by the most influential voter. Table 4 further suggests that dominant voters' choices almost always reflect the final outcome but are not necessarily in line with consensus among the other voters. In almost 16% of the cases, `VP.2UP` was flipped by a single high-VP individual. Figure 1 provides similar evidence. The median value of the dominant voter's VP share is close to or above 50% for almost all proposal types, meaning that the outcome of the median vote could have been decided unilaterally. For visualization purposes we also provide anectodal evidence of a specific case that combines these issues (see Figure 2) and shows how a single dominant voter flipped the outcome near the end of the voting period.

The weak identities problem has two effects: *First*, it is impossible to enforce entity-specific VP restrictions. Each entity may effectively create any number of pseudonyms and thereby render any constraints, limitations or measures to create a diminishing marginal VP useless. Traditional regulation, such as shareholder and dilution protection as well as reporting requirements, will be difficult to enforce. *Second*, we have to assume that some users split their VP across multiple entities. Consequently, our empirical analysis systematically underestimates the centralization problem. As such, our analysis must be regarded as a conservative lower bound, useful to point out a centralization problem, but potentially underestimating its extent.

Most of the risks that are seemingly introduced by DAO-based governance are mere variations of problems that also exist in traditional governance systems, but the transparency of DAOs allows for verifiable data to be collected and evaluated. This data may otherwise not be available (Yermack 2017).

However, there are certain risks that are amplified due to a decentralized governance system. As an example, consider rent extraction through grants. This may be much easier in a pseudonymous setup with weak identities, as individuals could potentially vote on their own grant proposals. This is an issue, especially with high VP voters. Figure 1 shows that approx. 45% of grants have effectively been approved by a single entity that may or may not be the person who proposed the grant. While lobbying and trying to extract rent through grants and tenders is a concept well-known in traditional governance systems, a pseudonymous setup could worsen this problem.

Moreover, virtual worlds may raise fundamental questions and have the potential for unclear competencies (Castronova 2002). In fact, pseudonymous actors will likely fall in the domain of multiple jurisdictions and find themselves in unclear situations with potentially conflicting policies.

In Section 2 we discussed the metaverse technology stack and introduced various layers of control. Based on our analysis, it is clear that the stack and the governance system are interrelated.

On the one hand, architecturial decisions will affect the governance system and may potentially allow for implicit and unconventional governance, like “forks.” A fork is a defense mechanism by the community by threatening a dominant governance actor to vote with their feet. It may occur on the blockchain- (Schär 2020) or software-level (Jiang et al. 2017). While abandoning a virtual world and moving to a new one is also possible in a centralized setup, a decentralized architecture allows the community to effectively clone and deploy another instance of the world, with an alternative governance system in place. This threat may help keep dominant governance actors in check and provide some balance to an otherwise lopsided governance. Public ownership layers, software client diversity, open hardware interfaces and more generally *open standards* will contribute towards a more balanced governance system.

On the other hand, governance decisions may directly affect the underlying architecture, e.g., “catalyst” proposals. Consequently, any business considering establishing a presence in the metaverse must pay close attention to the virtual world’s governance and the technical architecture.

6 Conclusion

6.1 Theoretical Implications

The metaverse has recently gained a lot of traction and countless examples show that it is on its way to becoming an important business ecosystem. As with various sharing economy platforms, producers, prosumers and service providers face the important decision as to whether and on which platforms they want to establish their virtual presence. They may face severe hold-up problems on traditional centralized platforms.

Blockchain-based virtual worlds have the potential to distribute the governance rights and create a neutral and mutually beneficial infrastructure. A well-defined and broadly supported governance system, as well as a blockchain and NFT-based ownership layer could mitigate the aforementioned problems – at least in theory.

In this paper we analyzed the governance system of the first and largest blockchain-based virtual world. We collected data from 1,414 governance proposals, with 45,333 cast votes. We provide data on whales, marginal voters and the potential for collusion, show how large voters strategically choose the time at which they cast their votes and analyze how their VP and strategic behavior may have influenced the outcome of the governance proposals. The data and our analysis suggest that decentralized governance may in fact be more centralized than expected.

We conclude that blockchain- and DAO-based governance must not be regarded as a guarantee for a decentralized governance process. They provide various advantages and the open standards and infrastructure allow people to vote with their feet and fork the entire project if necessary. As such, a blockchain-based governance system and ownership layer constitute a necessary but not a sufficient condition for neutral metaverse infrastructure.

6.2 Managerial Implications

Similarly to how political and judicial considerations influence a company's location choice in the physical world, the virtual world's governance system is a decisive factor when deciding where to set up a virtual branch. If a platform is managed by a single infrastructure provider who controls a proprietary tech stack and who may arbitrarily change the rules, increase fees or even shut down the entire infrastructure, businesses are at a severe risk. They are dependent on a single entity who may misuse its dominant position and extract monopoly rent. Well aware of this problem, businesses face a hold-up and may be reluctant to set up virtual branches in the first place, thereby preventing potentially beneficial business opportunities from realization. Thus, businesses should consider the architecture and governance structures of virtual worlds they engage in.

6.3 Limitations and Future Research

This paper is the first to analyze a DAO-based governance process of a metaverse platform. The findings and the data analysis are tied to a single virtual world, but the governance process is the de-facto standard for many DAOs. Most of the raised issues are a consequence of the exclusive use of pseudonymous token-based voting.

Future research may look at two extensions of this model. *First*, DAOs may use a bicameral system which combines pseudonymous token-based voting and community-appointed representatives with known identities. This may mitigate the weak identities problem, and yet give the community an opportunity to participate in the governance system. In a way, this is already done with the Wearables committee, DAO Committee and the SAB, but their influence in the governance process are quite unpronounced. *Second*, the current research primarily focuses on pseudonymous voters without distinguishing between delegated VP or obvious sybils, e.g., where a single entity votes with two or more addresses. Future research may use voting behavior and on-chain data to cluster addresses in order to estimate how pronounced the centralization of voting rights is in practice.

Acknowledgments

The authors would like to thank Emma Littlejohn for proof-reading the manuscript.

References

Allen, D. W. & Berg, C. (2020), 'Blockchain governance: what we can learn from the economics of corporate governance', *Allen, DWE and Berg, C (Forthcoming)'Blockchain Governance: What can we Learn from the Economics of Corporate Governance* .

Arruñada, B. & Garicano, L. (2018), 'Blockchain: The birth of decentralized governance', *Pompeu Fabra University, Economics and Business Working Paper Series* **1608**.

Battaglini, M., Morton, R. & Palfrey, T. (2007), 'Efficiency, equity, and timing of voting mechanisms', *American political science Review* **101**(3), 409–424.

Beck, R., Müller-Bloch, C. & King, J. L. (2018), 'Governance in the blockchain economy: A framework and research agenda', *J. Assoc. Inf. Syst.* **19**, 1.

Belk, R., Humayun, M. & Brouard, M. (2022), 'Money, possessions, and ownership in the metaverse: Nfts, cryptocurrencies, web3 and wild markets', *Journal of Business Research* **153**, 198–205.

Bellavitis, C., Fisch, C. & Momtaz, P. P. (2022), 'The rise of decentralized autonomous organizations (daos): a first empirical glimpse', *Available at SSRN* .

Bena, J. & Zhang, S. (2022), 'Token-based decentralized governance', *Available at SSRN 4248492* .

Benet, J. (2014), ‘Ipfs-content addressed, versioned, p2p file system’, *arXiv preprint arXiv:1407.3561* .

Berman, R. & Katona, Z. (2013), ‘The role of search engine optimization in search marketing’, *Marketing Science* **32**(4), 644–651.

Bloomfield, B. P. & Coombs, R. (1992), ‘Information technology, control and power: The centralization and decentralization debate revisited’, *Journal of management studies* **29**(4), 459–459.

Boud, A. C., Baber, C. & Steiner, S. J. (2000), ‘Virtual reality: A tool for assembly?’, *Presence* **9**(5), 486–496.

Burgelman, R. A. (2002), ‘Strategy as vector and the inertia of coevolutionary lock-in’, *Administrative science quarterly* **47**(2), 325–357.

Buterin, V. et al. (2014), ‘A next-generation smart contract and decentralized application platform’, *white paper* **3**(37), 2–1.

Castronova, E. (2002), ‘On virtual economies’, *Available at SSRN 338500* .

Chohan, U. W. (2017), ‘The decentralized autonomous organization and governance issues’, *Available at SSRN 3082055* .

Christ, K. L. & Helliar, C. V. (2021), ‘Blockchain technology and modern slavery: Reducing deceptive recruitment in migrant worker populations’, *Journal of Business Research* **131**, 112–120.

Cui, T. H., Ghose, A., Halaburda, H., Iyengar, R., Pauwels, K., Sriram, S., Tucker, C. & Venkataraman, S. (2021), ‘Informational challenges in omnichannel marketing: remedies and future research’, *Journal of Marketing* **85**(1), 103–120.

De Filippi, P. (2019), ‘Blockchain technology and decentralized governance: the pitfalls of a trustless dream’, *De Filippi, P.(2019). Blockchain Technology and Decentralized Governance: The Pitfalls of a Trustless Dream. Decentralized Thriving: Governance and Community on the Web* **3**.

de Villiers, C., Kuruppu, S. & Dissanayake, D. (2021), ‘A (new) role for business–promoting the united nations’ sustainable development goals through the internet-of-things and blockchain technology’, *Journal of business research* **131**, 598–609.

Dionisio, J. D. N., III, W. G. B. & Gilbert, R. (2013), '3d virtual worlds and the metaverse: Current status and future possibilities', *ACM Computing Surveys (CSUR)* **45**(3), 1–38.

Douceur, J. R. (2002), The sybil attack, *in* 'International workshop on peer-to-peer systems', Springer, pp. 251–260.

Duan, H., Li, J., Fan, S., Lin, Z., Wu, X. & Cai, W. (2021), Metaverse for social good: A university campus prototype, *in* 'Proceedings of the 29th ACM International Conference on Multimedia', pp. 153–161.

Eckhardt, G. M., Houston, M. B., Jiang, B., Lamberton, C., Rindfleisch, A. & Zervas, G. (2019), 'Marketing in the sharing economy', *Journal of Marketing* **83**(5), 5–27.

Egliston, B. & Carter, M. (2021), 'Critical questions for facebook's virtual reality: data, power and the metaverse', *Internet Policy Review* **10**(4). **URL:** *https://eprints.qut.edu.au/230384/*

Falkinger, J. (2007), 'Attention economies', *Journal of Economic Theory* **133**(1), 266–294.

Farrell, J. & Klemperer, P. (2007), 'Coordination and lock-in: Competition with switching costs and network effects', *Handbook of industrial organization* **3**, 1967–2072.

Fernandez, C. B. & Hui, P. (2022), 'Life, the metaverse and everything: An overview of privacy, ethics, and governance in metaverse', *arXiv preprint arXiv:2204.01480* .

Filimonau, V. & Naumova, E. (2020), 'The blockchain technology and the scope of its application in hospitality operations', *International Journal of Hospitality Management* **87**, 102383.

Fiorentino, S. & Bartolucci, S. (2021), 'Blockchain-based smart contracts as new governance tools for the sharing economy', *Cities* **117**, 103325.

Ganiev, A., Shin, H.-S. & Lee, K.-H. (2018), 'Implementation of online and offline building information system based on virtual reality and augmented reality', *International Journal of Engineering and Technology (UAE)* **7**(3.33), 37–40.

Giang Barrera, K. & Shah, D. (2023), 'Marketing in the metaverse: Conceptual understanding, framework, and research agenda', *Journal of Business*

Research **155**, 113420.
URL: *https://www.sciencedirect.com/science/article/pii/S0148296322008852*

Gillespie, T. (2018), *Custodians of the Internet: Platforms, content moderation, and the hidden decisions that shape social media*, Yale University Press.

Gillespie, T., Aufderheide, P., Carmi, E., Gerrard, Y., Gorwa, R., Matamoros-Fernández, A., Roberts, S. T., Sinnreich, A. & West, S. M. (2020), 'Expanding the debate about content moderation: Scholarly research agendas for the coming policy debates', *Internet Policy Review* **9**(4), Article–number.

Gligor, D. M., Pillai, K. G. & Golgeci, I. (2021), 'Theorizing the dark side of business-to-business relationships in the era of ai, big data, and blockchain', *Journal of Business Research* **133**, 79–88.

Goldberg, M., Kugler, P. & Schär, F. (2021), 'Land valuation in the metaverse: Location matters', *Available at SSRN 3932189* .

Goldberg, V. P. (1976), 'Regulation and administered contracts', *the Bell journal of economics* pp. 426–448.

Goldhaber, M. H. (1997), 'The attention economy and the net', *First Monday* .

Hassan, S. & De Filippi, P. (2021), 'Decentralized autonomous organization', *Internet Policy Review* **10**(2), 1–10.

Hawlitschek, F., Notheisen, B. & Teubner, T. (2018), 'The limits of trust-free systems: A literature review on blockchain technology and trust in the sharing economy', *Electronic Commerce Research and Applications* **29**, 50–63.
URL: *https://www.sciencedirect.com/science/article/pii/S1567422318300292*

Hendaoui, A., Limayem, M. & Thompson, C. W. (2008), '3d social virtual worlds: research issues and challenges', *IEEE internet computing* **12**(1), 88–92.

Hew, J.-J., Wong, L.-W., Tan, G. W.-H., Ooi, K.-B. & Lin, B. (2020), 'The blockchain-based halal traceability systems: a hype or reality?', *Supply Chain Management: An International Journal* **25**(6), 863–879.

Hong, S. & Lee, S. (2018), 'Adaptive governance and decentralization: Evidence from regulation of the sharing economy in multi-level governance', *Government Information Quarterly* **35**(2), 299–305.

Hughes, L., Dwivedi, Y. K., Misra, S. K., Rana, N. P., Raghavan, V. & Akella, V. (2019), 'Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda', *International Journal of Information Management* **49**, 114–129.

Iyer, G. & Katona, Z. (2016), 'Competing for attention in social communication markets', *Management Science* **62**(8), 2304–2320.

Jiang, J., Lo, D., He, J., Xia, X., Kochhar, P. S. & Zhang, L. (2017), 'Why and how developers fork what from whom in github', *Empirical Software Engineering* **22**(1), 547–578.

Jones, O. & Jayawarna, D. (2010), 'Resourcing new businesses: social networks, bootstrapping and firm performance', *Venture Capital* **12**(2), 127–152.
URL: *https://doi.org/10.1080/13691061003658886*

Klein, B., Crawford, R. G. & Alchian, A. A. (1978), 'Vertical integration, appropriable rents, and the competitive contracting process', *The journal of Law and Economics* **21**(2), 297–326.

Kostakis, V. & Bauwens, M. (2014), *Network society and future scenarios for a collaborative economy*, Springer.

Kumar, A., Bezawada, R., Rishika, R., Janakiraman, R. & Kannan, P. (2016), 'From social to sale: The effects of firm-generated content in social media on customer behavior', *Journal of marketing* **80**(1), 7–25.

Kumar, V. (2018), 'Transformative marketing: The next 20 years'.

Lee, L.-H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Kumar, A., Bermejo, C. & Hui, P. (2021), 'All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda', *arXiv preprint arXiv:2110.05352* .

Leech, D. (2013), Shareholder voting power and ownership control of companies, *in* 'Power, Voting, and Voting Power: 30 Years After', Springer, pp. 475–498.

Li, Y., Chang, Y. & Liang, Z. (2022), 'Attracting more meaningful interactions: The impact of question and product types on comments on social media advertisings', *Journal of Business Research* **150**, 89–101.
URL: *https://www.sciencedirect.com/science/article/pii/S0148296322005306*

Lumineau, F., Wang, W. & Schilke, O. (2021), 'Blockchain governance—a new way of organizing collaborations?', *Organization Science* **32**(2), 500–521.

Martin, C. J., Upham, P. & Klapper, R. (2017), 'Democratising platform governance in the sharing economy: An analytical framework and initial empirical insights', *Journal of Cleaner Production* **166**, 1395–1406.

Mehrwald, P., Treffers, T., Titze, M. & Welpe, I. (2019), 'Blockchain technology application in the sharing economy: a proposed model of effects on trust and intermediation'.

Mont, O., Palgan, Y. V., Bradley, K. & Zvolska, L. (2020), 'A decade of the sharing economy: Concepts, users, business and governance perspectives', *Journal of Cleaner Production* **269**, 122215.

Mujber, T., Szecsi, T. & Hashmi, M. (2004), 'Virtual reality applications in manufacturing process simulation', *Journal of Materials Processing Technology* **155-156**, 1834–1838. Proceedings of the International Conference on Advances in Materials and Processing Technologies: Part 2.
URL: *https://www.sciencedirect.com/science/article/pii/S0924013604005618*

Myers West, S. (2018), 'Censored, suspended, shadowbanned: User interpretations of content moderation on social media platforms', *New Media & Society* **20**(11), 4366–4383.

Nabben, K. (2021), 'Building the metaverse:'crypto states' and corporates compete, down to the hardware', *Available at SSRN* .

Nadler, M. & Schär, F. (2022), 'Decentralized finance, centralized ownership? an iterative mapping process to measure protocol token distribution', *Journal of Blockchain Research* **1**(1), 29–36.

Nakamoto, S. (2008), 'Bitcoin: A peer-to-peer electronic cash system', *Decentralized Business Review* p. 21260.

Newman, M. E. (2005), 'Power laws, pareto distributions and zipf's law', *Contemporary physics* **46**(5), 323–351.

Ong, S. K., Yuan, M. & Nee, A. Y. (2008), 'Augmented reality applications in manufacturing: a survey', *International journal of production research* **46**(10), 2707–2742.

Ordano, E., Meilich, A., Jardi, Y. & Araoz, M. (2017), 'Decentraland: A blockchain-based virtual world'.

Pazaitis, A., De Filippi, P. & Kostakis, V. (2017), 'Blockchain and value systems in the sharing economy: The illustrative case of backfeed', *Technological Forecasting and Social Change* **125**, 105–115.

Schär, F. (2020), 'Blockchain forks: A formal classification framework and persistency analysis', *The Singapore Economic Review* pp. 1–11.

Schär, F. (2021), 'Decentralized finance: On blockchain-and smart contract-based financial markets', *FRB of St. Louis Review* .

Simcoe, T. (2012), 'Standard setting committees: Consensus governance for shared technology platforms', *American Economic Review* **102**(1), 305–36.

Simon, H. A. et al. (1971), 'Designing organizations for an information-rich world', *Computers, communications, and the public interest* **72**, 37.

Talmon, N. & Shapiro, E. (2022), 'Foundations for grassroots democratic metaverse', *arXiv preprint arXiv:2203.04090* .

Tan, T. M. & Salo, J. (2021), 'Ethical marketing in the blockchain-based sharing economy: Theoretical integration and guiding insights', *Journal of Business Ethics* .
URL: *https://doi.org/10.1007/s10551-021-05015-8*

Tan, T. M., Salo, J., Ahokangas, P., Seppänen, V. & Sandner, P. (2021), Revealing the disintermediation concept of blockchain technology: How intermediaries gain from blockchain adoption in a new business model, *in* 'Impact of globalization and advanced technologies on online business models', IGI Global, pp. 88–102.

Tan, T. M. & Saraniemi, S. (2022), 'Trust in blockchain-enabled exchanges: Future directions in blockchain marketing', *Journal of the Academy of Marketing Science* pp. 1–26.

Tran, D. N., Min, B., Li, J. & Subramanian, L. (2009), Sybil-resilient online content voting., *in* 'NSDI', Vol. 9, pp. 15–28.

Tsolakis, N., Niedenzu, D., Simonetto, M., Dora, M. & Kumar, M. (2021), 'Supply network design to address united nations sustainable development goals: A case study of blockchain implementation in thai fish industry', *Journal of Business Research* **131**, 495–519.

Vith, S., Oberg, A., Höllerer, M. A. & Meyer, R. E. (2019), 'Envisioning the 'sharing city': Governance strategies for the sharing economy', *Journal of Business Ethics* **159**(4), 1023–1046.

Wang, S., Ding, W., Li, J., Yuan, Y., Ouyang, L. & Wang, F.-Y. (2019), 'Decentralized autonomous organizations: Concept, model, and applications', *IEEE Transactions on Computational Social Systems* **6**(5), 870–878.

West, J. (2003), 'How open is open enough?: Melding proprietary and open source platform strategies', *Research policy* **32**(7), 1259–1285.

Williamson, O. E. (1979), 'Transaction-cost economics: the governance of contractual relations', *The journal of Law and Economics* **22**(2), 233–261.

Xi, N., Chen, J., Gama, F., Riar, M. & Hamari, J. (2022), 'The challenges of entering the metaverse: An experiment on the effect of extended reality on workload', *Information Systems Frontiers* pp. 1–22.

Ye, Y., Yu, Q., Zheng, Y. & Zheng, Y. (2022), 'Investigating the effect of social media application on firm capabilities and performance: The perspective of dynamic capability view', *Journal of Business Research* **139**, 510–519.
URL: *https://www.sciencedirect.com/science/article/pii/S0148296321007347*

Yermack, D. (2017), 'Corporate governance and blockchains', *Review of finance* **21**(1), 7–31.

Zyda, M. (2005), 'From visual simulation to virtual reality to games', *Computer* **38**(9), 25–32.