When Ostrom Meets Blockchain: Exploring the Potentials of Blockchain for Commons Governance

by David Rozas[1] (drozas@ucm.es), Antonio Tenorio-Fornés[2] (antoniotenorio@ucm.es), Silvia Díaz-Molina[3] (smdmolina@ucm.es), and Samer Hassan[4] (shassan@cyber.harvard.edu)

Abstract

Blockchain technologies have generated excitement, yet their potential to enable new forms of governance remains largely unexplored. Two confronting standpoints dominate the emergent debate around *blockchain-based* governance: discourses characterised by the presence of techno-determinist and market-driven values, which tend to ignore the complexity of social organisation; and critical accounts of such discourses which, whilst contributing to identifying limitations, consider the role of traditional centralised institutions as inherently necessary to enable democratic forms of governance. Therefore the question arises, can we build perspectives of *blockchain-based* governance that go beyond markets and states? In this article we draw on the Nobel laureate economist Elinor Ostrom's principles for self-governance of communities to explore the transformative potential of blockchain. We approach blockchain through the identification and conceptualisation of affordances that this technology may provide to communities. For each affordance, we carry out a detailed analysis situating each in the context of Ostrom's principles, considering both the potentials of algorithmic governance and the importance of incorporating communities' social practices. The relationships found between these affordances and Ostrom's principles allow us to provide a perspective focussed on blockchain-based commons governance. By carrying out this analysis, we aim to expand the debate from one dominated by a culture of competition to one that promotes a culture of cooperation.

[1] GRASIA research group of Complutense University of Madrid, Madrid, Spain.
[2] GRASIA research group of Complutense University of Madrid, Madrid, Spain.
[3] GRASIA research group of Complutense University of Madrid, Madrid, Spain.
[4] Berkman Klein Center for Internet & Society (Harvard University), Cambridge, USA and GRASIA, Complutense University of Madrid, Madrid, Spain.

1. Introduction

In November 2008 a paper published anonymously presented Bitcoin: the first cryptocurrency based purely on a peer-to-peer system (Nakamoto, 2008). For the first time, no third parties were necessary to solve problems such as double-spending. The solution was achieved through the introduction of a data structure known as a blockchain. In simple terms, a blockchain can be understood as a distributed and append-only ledger. Data, such as the history of transactions generated by using cryptocurrencies, can be stored in a blockchain without the need to trust a third party, such as a bank server. From a technical perspective, blockchain enables the implementation of novel properties at an infrastructural level in a fully decentralised manner.

The properties most cited by blockchain enthusiasts at this infrastructural level include immutability, transparency, persistency, resilience and openness (Underwood 2016; Wright & De Filippi 2015), among others. Certainly, some technical infrastructures could previously provide these properties, e.g. the immutability and openness provided by content repositories like Github or Arxiv.org, or the persistence and resilience provided by large web services such as Amazon or Facebook. However, the implementation of these solutions relied on a trusted third party. There have been other decentralised technical infrastructures with varying degrees of success which also reflect some of these properties, e.g. the Web has been traditionally shown as an example of openness, although with uneven persistence (Koehler 1999), or BitTorrent peer-to-peer sharing networks are considered open, resilient and partially transparent (Cohen 2003). However, none of the existing decentralised technologies have enabled all these properties (and others) at once in a robust manner, while maintaining a high degree of decentralisation. It is precisely the possibility of developing technological artefacts which rely on a fully distributed infrastructure that is generating enthusiasm, or “hype” according to some authors (Reber & Feuerstein, 2014), with regards to the potential applications of blockchain.

In this article we focus on some of these potential applications of blockchain. More precisely, we reflect on the relationship between blockchain properties and the generation of potentialities which could facilitate governance processes. Particularly, we focus on the governance of Commons-Based Peer Production (CBPP) communities. The term, originally coined by Benkler (2002), refers to an emergent model of socio-economic production in which groups of individuals cooperate with each other to produce shared resources without a traditional hierarchical organisation (Benkler, 2006). There are multiple well-known examples of this phenomenon, such as Wikipedia, a project to collaboratively write a free encyclopedia; OpenStreetMap, a project to create free/libre maps of the World collaboratively; or Free/Libre Open Source Software (FLOSS) projects such as the operating system GNU/Linux or the browser Firefox. Research carried out drawing on crowdsourcing techniques (Fuster Morell et al., 2016a) found examples of the broad diversity of areas in which the collaborative work on commons is present. This includes open science, urban commons, peer funding and open design, to name but a few. Three main characteristics of this mode of production are salient in the literature on CBPP (Arvidsson et al., 2017). Firstly, CBPP is marked by decentralisation, since authority resides in individual agents rather than a central organiser. Secondly, it is commons-based because CBPP communities make frequent use of common resources, i.e. shared resources which are openly accessible and whose ownership is collectivised. These resources can be immaterial, such as source code in free software, or material, such as 3D printers shared in small-scale workshops known as Fab Labs. Thirdly, there is a prevalence of non-monetary motivations. These motivations are, however, commonly intertwined with extrinsic motivations. As a result, a wide spectrum of motivations and multiple forms of value operate in CBPP communities (Cheshire & Antin 2008), beyond monetary value, e.g. use value, reputational and ecosystemic value (Fuster Morell et al., 2016b).

The three aforementioned characteristics of peer production are in fact aligned with blockchain features. First, both CBPP and blockchain strongly rely on decentralised processes, thus, the possibility of using blockchain infrastructure to support CBPP processes arises. Secondly, the shared commons in CBPP corresponds to the shared ledger present in blockchain infrastructure, where data and rules are transparent, open, collectively owned, and in practice managed as a commons. This leads to the question if such blockchain commons could host or support commons resources, or "commonify" other features of CBPP communities, such as their rules of governance. Thirdly, CBPP relies on multi-dimensional forms of value and motivations, and blockchain enables the emergence of multiple types of non-monetary interactions (sharing, voting, reputation). This brings about the question of the new potentials for channelling CBPP community governance.

Overall, we strongly believe that the combination of CBPP and blockchain provides an exciting field for exploration, in which the use of blockchain technologies is used to support the coordination efforts of these communities. This leads us to the research question: what affordances are generated by blockchain technologies which could facilitate the governance[5] of CBPP communities?

2. The emergent debate on blockchain-based governance

The use of blockchain technologies to facilitate governance processes is beginning to attract the attention of social scientists (Risius & Spohrer, 2017). The emergent literature revolves around speculation on whether blockchain technologies could foster the experimentation and rise of new forms of *blockchain-based* governance[6].

[5] By "governance" we draw on Fuster Morell's (2014) analysis and characterisation of commons governance as a complex system. Her work provides a critical account of approaches focussed exclusively on decision-making systems, including as part of her characterisation several aspects which emerge as key for our analysis, such as social norms and the social construction of collaboration platforms.

[6] This paper focuses on governance through or with blockchains, rather than on governance of FLOSS communities which develop and maintain blockchain projects. This is a relevant distinction since both debates are sometimes blurred. Conceptualising a blockchain as a common good, and therefore its governance as a commons-based process, is a promising approach to further our understanding of the social aspects behind the development of these decentralised technologies, but it is out of the scope of this paper.

Two confronting standpoints dominate the emergent debate. On the one hand are perspectives characterised by a high degree of techno-determinism. These perspectives envisage the emergence of new forms of *blockchain-based* governance on the basis of the potential of these technologies for decentralisation and trustlessness. The discourses inherently embed the idea of “market”, but tend to ignore the complexity of social organisation. For example, they commonly assume that hierarchies between the participants in decision-making processes vanish thanks to the disintermediation enabled by blockchain technologies (e.g Swan, 2015; Hayes, 2016; Heuermann, 2015). Overall, they tend to provide over-reductionist accounts with regards to the distribution of power, failing to acknowledge issues such as the generation of oligarchies (Freeman, 1972; Shaw & Hill, 2014; De Filippi & Loveluck, 2016; De Filippi & Lavayssiere, 2018). These techno-determinist perspectives are not new, nor a particular issue for blockchain technologies. Similar approaches can be traced, for example, to during the popularisation of access to the Internet in the 1990s. Examples of techno-determinist perspectives similarly embedded ideas to “creat[e] a world that all may enter without privilege or prejudice accorded by race, economic power, military force, or station of birth.” (Barlow, 1996). Overall, parallels can be observed between these views and those of the Internet as a space for utopia or dystopia (Wellman, 2004). On this occasion, discourses are being generated around blockchain technologies.

On the other hand, the critical stand against these techno-determinist perspectives has identified and criticised the limitations of such approaches (Atzori, 2015; Atzori & Ulieru, 2017). Nevertheless, this critique is built upon the reinforcement of the role of traditional central authorities. These views consider traditional central authorities as inherently necessary to enable democratic governance. As a result, the potential for communities, such as the aforementioned CBPP communities, to successfully self-organise is ignored. These views reflect the traditional responses against unregulated markets from positions that reinforce the role of states. In this case, blockchain properties are envisioned in non-transformative ways to more efficiently exert the control required by traditional centralised forms of governance. For example, providing more transparency to their central institutions (Nguyen, 2016) or more efficient mechanisms to avoid tax fraud (Ainsworth & Shact, 2016).

In this article we aim to reflect on the extent to which it would be feasible to incorporate into the social construction of *blockchain-based* tools principles from commons governance. Our aim is to contribute to building perspectives which neither rely on the logics of private markets, as implicitly assumed by these former perspectives, nor on the coercion of traditional centralised institutions, as in the case of the latter accounts. To this end, we bring together the literature on governance of CBPP for the emerging debate on these new forms of *blockchain-based* governance. Recently, a few authors have attempted to link the commons with blockchain capabilities, either at a general conceptual level (O’Dwyer, 2015; Bollier, 2015; Davidson et al., 2016) or proposing specific theoretical systems (De Filippi, 2015; Pazaitis et al., 2017). In contrast, in this work we will perform a detailed and systematic analysis of the affordances of blockchain for CBPP community governance.

In this analysis we acknowledge the transformative potential of blockchain properties, and argue that they should be understood as a situated technology (Bell et al. 2003). That is, the focus needs to be placed within the situational parameters, being aware of the cultural context and incorporating social meanings into the design of artefacts of collaboration which make use of the aforementioned properties. As a result, we reflect on whether blockchain technologies could be the source of new affordances (Gibson, 1979) for commons governance. By affordances we draw on Hutchby's (2001, p. 444) definition as the "functional and relational aspects which frame, while not determining, the possibilities for agentic action in relation to an object". Thus, our approach is that of a mutual-shaping between technology and society. In this way, we are critical of the limitations of techno-determinist perspectives. However, while we consider the socially shaped character of *blockchain-based* technologies — in which choices are built and chosen socially — we follow an approach in which these technologies are understood as a possible agent of change. This is in order to discuss the role of distributed technologies as a source of affordances, as required in this type of reflection, rather than simply explaining its emergence, as pure constructivist approaches would do[7].

With this purpose, we develop from traditional studies on the organisational aspects of how commons are governed, and evaluate the potential use of blockchain technologies in this context. More specifically, we aim to contribute to this discussion by drawing on the work of the Nobel laureate economist Ostrom (1990), whose research showed that under certain conditions commons can be managed in a sustainable way by local communities of peers. Her work, therefore, enables us to reflect on the use of blockchain technologies to foster experimentation with new forms of *blockchain-based* governance in ways that go beyond markets and states.

3. Ostrom's principles: beyond markets and states

Ostrom's studies focussed on how communities manage to successfully govern communal resources by revisiting Hardin's (1968) influential article on "The tragedy of the commons". In this article, Hardin states how resources shared by individuals acting as homo-economicus, i.e. out of self-interest in order to maximise their own benefit, results in the depletion of the commons. The individuals' interests enter into conflict with the group's, and because they act independently according to their short-term interests, the result of the collective action depletes the commons. As a consequence, the traditional view was that in order to avoid this logic — "If I do not use it, someone else will" — which leads to unsustainability, it was necessary to manage these commons through either private ownership or public administration. Parallels can be found between these standpoints and those previously summarised with regards to the emergent discussion on new forms of *blockchain-based* governance: they envision forms of governance which either rely on markets or on states.

[7] The selection of the term "affordance" and, in more general terms, a mutual-shaping approach allows us to navigate the Scylla and Charybdis of technological determinism and technological constructivism present in the field of science and technology studies (Juris, 2012, p. 275). See Wellman et al. (2003), boyd (2010) and Juris (2012) for examples in the use of affordances in the context of analysis in the Internet, social media and social movements respectively.

Ostrom's work shows how, under certain conditions, commons can indeed be managed in a sustainable way by local communities of peers. Her approach takes into account that individual agents do not operate in isolation, nor are they driven solely by self interest, i.e. beyond homo-economicus approaches. Instead, she argues that communities communicate to build common protocols and rules that ensure their sustainability. This hypothesis was strongly supported by a meta-analysis of a wide range of case studies (Ostrom, 1990), and has been confirmed in later research (Ostrom, 2005; Cox et al. 2010). As part of this work, she identified a set of principles (Ostrom, 1990, pp. 88-102) for the successful management of these commons (Viégas et al., 2007; Forte et al., 2009):

1. Clearly defined community boundaries: in order to define who has rights and privileges within the community.
2. Congruence between rules and local conditions: the rules that govern behaviour or commons use in a community should be flexible and based on local conditions that may change over time. These rules should be intimately associated with the commons, rather than relying on a "one-size-fits-all" regulation.
3. Collective choice arrangements: in order to best accomplish congruence (principle number 2), people who are affected by these rules should be able to participate in their modification, and the costs of alteration should be kept low.
4. Monitoring: some individuals within the community act as monitors of behaviour in accordance with the rules derived from collective choice arrangements, and they should be accountable to the rest of the community.
5. Graduated sanctions: community members actively monitor and sanction one another when behaviour is found to conflict with community rules. Sanctions against members who violate the rules are aligned with the perceived severity of the infraction.
6. Conflict resolution mechanisms: members of the community should have access to low-cost spaces to resolve conflicts.
7. Local enforcement of local rules: local jurisdiction to create and enforce rules should be recognised by higher authorities.
8. Multiple layers of nested enterprises: by forming multiple nested layers of organisation, communities can address issues that affect resource management differently at both broader and local levels.

Although these principles were originally defined for natural commons, they have also been discussed and adapted for the study of communities which develop and maintain digital commons (e.g. Hess & Ostrom, 2007; Hess, 2008; Fuster Morell, 2010), such as Wikipedia (Viégas et al., 2007; Forte et al., 2009) or Free/Libre Open Source Software such as Drupal (Rozas, 2017). This process of employing Ostrom's principles in the study of how communities manage digital commons required, however, an analysis of how they may be re-interpreted within this different context. For example, while Ostrom's 1st principle for natural commons refers to the boundaries defined to use certain resources, in the case of digital commons this was re-interpreted in the context of the power to modify digital commons or to perform certain operations on the collaboration platforms[8] employed by these

[8] Examples of these collaboration platforms are MediaWiki for the case of Wikipedia or Drupal.org for the case of Drupal.

communities. In the case of Wikipedia, this was re-interpreted as the process of demarcation to perform certain technical operations and the relationship between technical and social power (Forte et al., 2009, pp. 64-68). Similarly, in the case of the FLOSS community Drupal, this principle was contextualised in the emergence of clearer boundaries to participate in the production and management of FLOSS subprojects (Rozas, 2017, pp. 183-192, 207-211).
Another illustrative example of these exercises of re-interpretation can be found in principle number 7, which relates to the acknowledgement of local jurisdiction to create and enforce local rules by higher authorities. In the case of natural commons, these higher authorities are commonly referred to as those of state institutions. An example could be government officials who acknowledge the creation of local rules in the context of self-organised fishing communities. Parallelisms have been established in the case of digital commons, but referring to higher authorities as the most formal and centralised institutions which commonly emerged in these communities, such as the Wikimedia Foundation (Forte et al., 2009), or the Drupal Association (Rozas, 2017), to continue with the previous cases. For example, in the emergence of autonomous WikiProjects, where jurisdiction to devise their own local rules is acknowledged by the more central authorities of Wikipedia. Also, the acknowledgement of the local jurisdiction of contributed projects with respect to Drupal core, or of local institutions with respect to the global institution, the Drupal Association.

Over the course of the next section we draw on and re-interpret these principles, but focussing in this case on the identification and exploration of affordances generated by blockchain technologies which could foster, limit or affect the governance of communities which collectively manage and produce commons.

4. Affordances generated by blockchain for commons governance

Beyond the previously introduced original properties of blockchain at an infrastructural level, the growth of the blockchain development ecosystem has encompassed the rise of a new generation of applications and capabilities which surpass those of the original Bitcoin whitepaper. This follows a common pattern in the evolution of technological artefacts: from an initial innovative invention, a period of experimentation spurs multiple alternative designs and derived works, which are often consolidated in different generations of the technology. For instance, the bicycle followed a non-linear evolution, since the invention of the “velocipede” in 1812. It experimented 50 years of extraordinary diversity of designs, until a solid second generation with connected pedals emerged in the 1860s, a third generation of high wheelers in the 1870s, and finally the modern bicycle was invented in the 1890s (Shennan 2009).

In the case of blockchain-related technologies, we are still witnessing its infancy, and thus its future potential is yet to be explored. It is often considered (Swan, 2015) that the first generation of blockchain technologies, “Blockchain 1.0”, are Bitcoin and the advent of a broad diversity of crypto-currencies that appeared after it (“altcoins”), i.e. roughly from 2009 to 2013. The second generation, “Blockchain 2.0”, was the extension of these blockchains with capabilities beyond currencies, i.e. automatic agreements in “smart contracts”, or complex tokens, from 2014 until today.

Beyond all the emergent technical concepts and jargon, the key consideration is that we incorporate these new generations of blockchain technologies, and thus their capacities, into our discussion. We identify and discuss a set of affordances, for a non-technical audience, in the context of governance through blockchain. Each affordance is situated in the context of commons governance drawing on the aforementioned principles of Ostrom’s work[9].

We use a recurring example throughout the text. We select a specific type of Commons Based Peer Production, a community network. In these communities, people share wifi signals as common resources as well as the infrastructure to provide internet access (e.g. antennas, routers, Internet bandwidth). Examples of these communities include Guifi.net[10], Ninux[11] or Sarantoporo[12]. Usually, these communities involve complex governance including online and offline interactions at several levels of organisation: from local nodes to umbrella communities.

4.1 Tokenisation

An essential feature of Blockchain technologies is their capacity for tokenisation. Tokenisation refers to the process of transforming the rights to perform an action on an asset into a transferable data element (named *token*) on the blockchain. For example, in the medical field, tokenisation has been employed to provide authorisation regarding access to reports (Liu, 2016).

In the Bitcoin blockchain, the term *token* is used as an abstraction of the actual “coin”, i.e. the cryptocurrency being transferred among users. The rise of *blockchain-based* cryptocurrencies is a product of such a feature, since blockchain’s facility for the creation, transfer and management of tokens in a distributed manner is unparalleled. This process of tokenisation facilitates the distribution of value and incentives. Third parties, such as banks or gateways, are not necessary to transfer value between individuals or across networks. Furthermore, such tokens may be used as more than holders of monetary value: they may represent equity, decision-making power, property ownership or labour certificates with similar properties (Huckle & White, 2016, pp. 7-10) as those described by Marx (1875).

Blockchain is originated in the creation and maintenance of a currency. Thus, its structure responds to such a need, where the append-only database that the blockchain entails corresponds to a ledger, and the operations are defined as transactions. In such a system, the creation of tokens is inherent to how the technology is constructed. This capacity for tokenisation of blockchain technologies provides a series of affordances for technological artefacts constructed to facilitate governance. In the context of CBPP communities, tokenisation relates to several of Ostrom’s principles.

[9] Table 5.1 summarises the relation among the affordances and Ostrom’s principles.
[10] See http://guifi.net, last accessed on 20/07/2018.
[11] See http://ninux.org, last accessed on 20/07/2018.
[12] See http://www.sarantaporo.gr, last accessed on 20/07/2018.

Ostrom's 1st principle states the importance of the definition of community boundaries for its governance. These boundaries are reflected in the rules embedded in software employed to coordinate communal activity in CBPP. This software typically defines permissions or rights to access or modify resources or community rules. In such a context, we can envision the use of tokens to construct tools, in which participation rights can be more easily and granularly defined, propagated and/or revoked. For example, in the case of a community network, access to the infrastructure could be granted with tokens, e.g. those people who contributed enough infrastructure, or who paid the agreed price, could access the Internet through the network. This specific use of blockchain has been proposed by Guifi.net, one of the most relevant community networks (Selimi et al., 2018).

Negotiations regarding the definition of boundaries and their reflection in the technical artefacts connect additionally to the 2nd and 3rd of Ostrom's principles. CBBP communities require constant processes of development of collective choice arrangements regarding their governance. They define rules based on local conditions, and seek to find ways in which those affected by these rules can participate in their modification, as understood in the 2nd and 3rd of the principles.

Overall, the capacity for tokenisation of blockchain technologies could be employed to readdress latent power relations in these communities. Negotiations in these communities, whilst maintaining a social character, would be mediated by *blockchain-based* artefacts which in turn would be communally constructed (as in the aforementioned mutual-shaping). This implies an exercise by the community to specify the tasks to be carried out providing an opportunity for certain often-forgotten tasks, such as care labour (Pérez-Orozco, 2014, pp. 92-94), to be made visible. That is, care tasks such as emotional labour, conflict management, maintenance, or events organisation, may be visibilised and acknowledged by the community – along with those undertaking such tasks. Tokenisation, therefore, provides an opportunity to rethink existing power dynamics within CBPP communities.

In this respect, some concepts from feminist economic theory, such as that of invisible labour (Pérez-Orozco, 2014, pp. 206), can be helpful for commons-based approaches towards the use of *blockchain-based* tools for governance in the need to escape from techno-determinist views. Such views envision these problems as a simple matter of atomic interactions to aggregate or disaggregate rights to access, at an individual level. This paper proposes an investigation into the potential of tokenisation to address this imbalance, such as through the visibilisation of certain forms of power, an issue which tends to become more critical when CBPP communities need to scale up their self-organisational processes.

Nevertheless, tokenisation also presents risks, such as extreme quantification and data fetishism (Sharon & Zandbergen, 2017). Techno-determinist discourses assume that "anything that can be decentralized will be" (Johnston, 2014), and at least partially tokenised as a result. On the contrary, we believe communities and further empirical research will need to explore the limits regarding what kind of actions should or should not be tokenised, what kind of mechanisms are established to change the status quo, and how communities asses the desirable degree of tokenisation in their governance. In other words, there is a need to further understand the affordance of tokenisation and explore how self-organised communities may or may not incorporate it in their technological artefacts employed for collaboration and to what extent.

4.2 Self-enforcement and formalisation of rules

Some of the most recent blockchains (e.g. Ethereum[13]) have introduced the ability to upload small snippets of code (so-called *smart contracts*) directly onto the blockchain, for them to be executed in a decentralised manner by every node of the network. The rules embedded in the code are automatically enforced by the underlying technology, the blockchain. Self-enforcement refers precisely to this process of encoding clauses into source code in a manner which is automatically enforced and executed without the need for a central authority (Szabo, 1997). The potential of smart contracts for governance is perhaps an area in which the affordances regarding the use of blockchain-based artefacts to facilitate governance have been more widely discussed in the emergent literature (e.g. Wright & De Filippi, 2015; De Filippi & Hassan, 2016).

Two main aspects can be identified as intertwined with Ostrom's principles in the context of the governance of CBPP communities. Firstly, an affordance for the self-enforcement of rules. Examples of these rules are those which regulate the monitoring and graduated sanctions, as reflected in Ostrom's 4th and 5th principles. Blockchain technologies could partially embed some of these governance rules in technological artefacts. Scenarios in which communities define certain rules regarding the allocation of common resources — through actions such as pooling, capping or mutualising — and in which these rules are automatically enforced can be envisioned. Following previous examples, one can imagine a capping rule agreed by a community network which automatically enforces a previously negotiated internet bandwidth limit, or which automatically penalises a misuse of the common network. Another example could consist of a set of self-enforced rules for a redistribution mechanism that grants Internet access to those in the communities with fewer resources. It can be envisioned how at least a significant part of the monitoring could be embedded into the code, instead of requiring participants to manually perform some of these monitoring operations. As in the case of tokenisation the issue resides in improving our understanding of the limitations of automatic self-enforcement in the context of these communities.

Secondly, the affordance of self-enforcement generated by blockchain technologies requires the rules to be unambiguously understood by machines. This implies a need to formalise the governance rules which are usually expressed in the inherently ambiguous natural language. Thus, this explicitation could lead to the need to discuss these rule changes in order to formalise and encode them. It therefore provides an affordance for formalising rules which presents several limitations, which will be subsequently discussed, but also a set of potentialities. Research on how self-organisation occurs in CBPP communities has shown that, counterintuitively to the initial oversimplified accounts criticised by authors such as Viégas et al. (2007) or Mateos-García & Steinmueller (2008), the changes experienced in the self-organisational processes of CBPP communities tend to show an increase in the degree of formalisation around decision-making over time when they grow, which is

[13] See https://www.ethereum.org, last accessed on 20/07/2018.

explained as a means to achieve decentralisation and to scale up communities (e.g. Viégas et al., 2007; Forte et al., 2009; Schweik & English, 2013; Wang & Cheliotis, 2016). This has been identified even in cases with a generally anti-bureaucratic attitude, such as communities with a strong hacker culture which aim to avoid formal and bureaucratised systems (Rozas, 2017). Thus, the process of explicitation of rules which is encompassed in the development of smart contracts related to the use of distributed technologies also provides opportunities to make these rules more available and visible for discussion, as noted in the 2nd of Ostrom's principles. Furthermore, formalisation in combination with self-enforcement relates to the 7th of Ostrom's principles: local nodes of CBPP communities could more easily ensure that the local jurisdiction[14] and enforcement of local rules is acknowledged by higher authorities or by other nodes. For example, an organisational structure of a large community network in which a set of local nodes are federated, and each node possesses local autonomy to develop its own rules regarding the management of the local infrastructure. A node might be based in Barcelona and another in Madrid. Rules can be envisioned in which the autonomy to take decisions regarding the node in Barcelona belongs, by code, to the participants of that node, and vice-versa. Furthermore, if higher authorities exist in this context, such as an Iberian federation of nodes, to continue with our example, we can imagine rules which are self-enforced by code to ensure that the local aspects are only decided by participants of the local nodes. Overall, blockchain technologies provide affordances to foster the formalisation and enforcement of this type of agreements.

Several issues, however, require further exploration with regards to the affordances of self-enforcement and formalisation in the context of governance of CBPP communities. Firstly, rules embedded in smart contracts rely on an *ex-ante* nature, rather than *ex-post* (De Filippi & Hassan, 2016). Instead of third parties or community members monitoring and enforcing them, the rules would be automatically enforced according to agreements previously negotiated by the community. While this theoretically increases the difficulty to breach them, it also presents problems with regards to the difficulty to define exceptions (De Filippi & Hassan, 2016). Ongoing blockchain projects of the new generation, such as DAOStack[15] or Aragon[16], provide capacities to more easily upgrade the rules embedded in smart contracts over time, in congruence with the 2nd of Ostrom's principles. Thus, this increasing capacity for upgradability which is being developed in the new generation of blockchain technologies could help to incorporate these exceptions over time. However, even if a rule is updated after reaching an agreement in the community, the original code will have been applied and the new rules will only be applicable the next time. For instance, a person could lose Internet access due to a strict community rule that is later relaxed. From these limitations, we envision at least two questions which require further empirical research: what are the consequences for CBPP communities of moving from *ex-post* forms of regulation towards *ex-ante*? Which aspects should remain in/off the blockchain, or furthermore completely in/out of code?

---

[14] In this context we refer to jurisdiction as the area over which the members of the node have control (Sullivan, 2009).
[15] See https://daostack.io, last accessed on 13/07/2018.
[16] See https://aragon.one, last accessed on 13/07/2018.

Secondly, the process of formalisation of these rules requires, at least with the most current technology, a high degree of technical knowledge in the translation of these rules into source code. Thus, while formalisation might help to make these rules more visible and available for discussion in the community, the power to specify these rules may now be shifted to those coding the rules. In this context, it is necessary to consider the biases — such as gender, race and class (Platero, 2014, pp. 79-95) — of those possessing this technical knowledge. Another issue to be considered is the tendency towards accommodation or less reflexivity over time as a consequence of automation (De Filippi & Hassan, 2015). Commons-based approaches should, as a result, take into account these aspects, and draw on inclusive methodologies to constantly co-design artefacts in order to address these issues.

Thirdly, in a similar way as with the risk of extreme tokenisation presented in the previous section, there is a risk of extreme formalisation in the rules that regulate the behaviour of participants in these communities. The effects are unknown. Ostrom's work highlighted, for example, the relevance of informal social norms (Ostrom, 2000) for the successful self-management of resources. The effects of an excessive formalisation of norms into explicit rules self-enforced "by code" might become a source of distortions within the dynamics of the communities which requires further exploration.

In sum, and continuing with our previous critique of techno-determinist views illustrated by the motto "anything that can be decentralized will be" (Johnston, 2014) — and at least partially formalised and self-enforced as a result —, commons-based approaches will require further understanding of these affordances regarding formalisation and self-enforcement in ways which are situated within the context of these communities. Rather than "one-size-fits-all" situations, the aim is to find ways to integrate the social culture and practices into platforms employed for collaboration, while exploring how they may achieve this and what the limits are.

4.3 Autonomous Automatisation

The rules embedded in smart contracts may interact with humans, but also with other smart contracts, as long as they belong to the same blockchain ecosystem (e.g. Ethereum). It is analogous to software communicating with or depending on other software today. Thus, a complex set of smart contracts may be set up in such a way as to make it possible for multiple parties to interact with each other. This combination of smart contracts may be regarded as a decentralised autonomous organisation (DAO): a self-governed organisation controlled exclusively by its embedded set of rules, implemented in the form of a smart contract. This may be understood as analogous to a legal organisation, with legal documents (bylaws) which define the rules of interaction among members. Similarly, the DAO members' interactions are mediated by the rules embedded in the DAO code.

DAOs present multiple, unparalleled characteristics. The level of autonomy of these pieces of code surpasses all forms of autonomous software agents (Franklin & Graesser 1996). Since DAOs do not rely on central servers, DAOs cannot be shut down, unless explicitly programmed in their code. Thus, they are fully autonomous including with respect to their creator, and they function as long as a user (human or software) continues to interact with them. This may prevent censorship and the halt of malicious code, e.g. a virus. In addition, DAOs may interact as autonomous users in the network, holding tokens and assets, or purchasing services from other DAOs. In fact, they can even *hire* users to perform tasks for them, and *sell* their own services or resources to third-parties. Hence, individuals can transact with a DAO in order to benefit from the service it provides, or to be paid for a contribution. Thus, DAOs may be self-sufficient, to the extent that they can charge users for their own services (or assets) in order to pay for the services they need (De Filippi & Hassan 2016).

There are a few existing DAO examples: the venture capital fund with the (confusing) name, "TheDAO[17]"; the prediction market, Augur[18]; the digital assets platform focused on gold assets, Digix[19]; or the cryptocurrency issuer and insurer, MakerDAO[20]. As it is true for the vast majority of projects in the blockchain field, they are directly related to finance. These DAOs are designed to work in a decentralised manner without central intermediaries, yet their governance model is strictly market-driven. For instance, in TheDAO, voting power is correlated with the number of tokens possessed, i.e. it works as a plutocracy, controlled by the wealthy minority (as opposed to a democracy).

However, DAOs provide new possibilities with regards to CBPP. In fact, we may envision scenarios in which DAOs aid several of Ostrom's principles in the context of the governance of CBPP communities. As mentioned in the previous section, smart contracts may help in the monitoring and application of sanctions for those violating the community rules (4th and 5th principles). When DAOs are considered, this feature is strengthened, since communities may rely on an automated entity for such monitoring and sanctioning. The agency of this entity, which may take the initiative and react upon circumstances, may have multiple implications. On the one hand, its impersonalisation may be positive to see that sanctions come from a community decision, preventing the common effect of reacting against the enforcer ("killing the messenger"). On the other hand, the same impersonalisation may trigger frustrations and impotence (Postman 1992) similar to the reactions against machines.

DAOs may also contribute to higher degrees of automatisation of the processes in communities, facilitating scaling up and thus the creation of layers of nested entities, as the 8th principle states. Since we are aware that scaling up communities involves an increase of formalisation and bureaucratisation (e.g. Viégas et al., 2007; Forte et al., 2009; Schweik & English, 2013; Wang & Cheliotis, 2016; Rozas, 2017), a higher degree of automatisation of processes could reduce the burden of bureaucracy, accelerate processes and facilitate scaling up. For instance, in a community network with multiple nodes, it is common to have multiple spaces for coordination, monitoring, verification, transfers of payments and resources, etc. Despite clear rules, the need remains for humans to carry out multiple actions. Many communities rely on software to automate parts of this process, although this implies either governance of such software/infrastructure, or dependence on third-parties and their rules for their inner processes. In such a context, a DAO can be set up to facilitate interaction and coordination across nodes. Once the rules are agreed and clear, they may

[17] See https://daohub.org, last accessed on 20/07/2018.
[18] See https://augur.net, last accessed on 20/07/2018.
[19] See https://digix.io, last accessed on 20/07/2018.
[20] See https://makerdao.com, last accessed on 20/07/2018.

be embedded in the DAO code, which may automate a large proportion of the processes, monitoring the nodes' actions, facilitating coordination, even transferring payments/resources in relation to the nodes' contributions. In fact, this may be scaled up easily, with DAOs coordinating other "smaller" DAOs. And if other communities have their own DAOs, it may be easier to establish cooperation across communities.

To continue with previous examples, we could envision collaboration among different community networks, granting Internet access to all members of any other community. These communities could share information about unconforming users to prevent network abuses and could even negotiate exchanges to account for the differences in use of the networks.

Finally, DAOs provide a space in which governance is digitalised and formalised, and where most organisational processes should be tackled in some way, including conflicts. That is, governance formalisation demands an exploration of the different potential conflicts that may occur, and their possible resolution. This is directly related to Ostrom's 6th principle. Combined with the aforementioned automatisation and scaling up, we may observe a space in which conflicts are made explicit, between members of a DAO, across DAOs, and between DAOs and humans. This encourages communities to establish clear mechanisms for conflict resolution, which may be at least partially tackled by automated processes. In fact, Aragon is already working on creating digital jurisdictions for conflict resolution within, and across, DAOs.

There are, however, some shortcomings of this affordance. Indeed, such a "DAO world" has multiple potentials, and yet, it is worth remembering that DAOs are constrained to the digital world. That is, digitalisation is expanding quickly, and affecting the physical world in multiple ways, and yet the physical world continues to operate with its own rules. Although techno-determinist views often disregard this fact, humans have bodies, which are constrained by their physical reality, and cannot be ignored or "disappear" in cyberspace (Le Breton, 2015). Thus, DAOs may allow digital voting, but a DAO cannot know if a person is being coerced into a certain vote option. DAOs may allow the transfer of digital assets, and yet laptops can be stolen. Moreover, DAOs' acceleration of digitalisation has direct effects on people with functional diversity, e.g. with special needs or disabilities, who may have difficulties to adapt to such a context.

In the same line, DAOs may hire services or resolve conflicts, and yet there is a legal framework that humans are subject to that may contradict the DAOs' decisions. In fact, DAOs open up multiple unresolved challenges with respect to Law (De Filippi & Wright, 2018). For instance, on liability: who is liable for a DAO misaction, such as the loss of money? The creator of the DAO, who may not control it? The members of the DAO, who could influence its evolution? The project managing the blockchain where the DAO operates? Or is it worth considering the DAO itself as a subject of liability?

Summing up, the use of DAOs for commons governance is currently highly speculative and it may imply challenges and risks. However, multiple opportunities may arise from using these new "agents" as automatic helpers for communities, which would enable the automatisation of bureaucratic processes, facilitate scaling up, and make conflict resolution mechanisms more explicit.

4.4 Decentralisation of power over infrastructure

This affordance refers to the process of communalising the ownership and control[21] of the technological artefacts employed by the community through the decentralisation of the infrastructure they rely on.

This affordance can be illustrated when exploring the relationships between technical and social power (Forte et al., 2009, pp. 64-68) which occur in CBPP communities together with the forms of pressure that relate to them. The control over the infrastructure which sustains, for example, the main platforms of collaboration, commonly emerges as a point of tension and conflict. When CBPP communities start to grow substantially, they normally try to decentralise control over this infrastructure, which is commonly achieved by incrementing the degree of formalisation. For example, defining more explicit and rigid organisational processes, roles and even formal institutions, such as the Wikimedia Foundation (Forte et al., 2009) or the Drupal Association (Rozas, 2017, pp. 67-87) returning to our previous examples. These organisational changes entail constant negotiation. When framed through Ostrom's principles, these negotiations can be understood as part of the generation of collective-choice arrangements, the 3rd of the principles previously discussed. Contrary to romanticised views, these negotiations do not commonly occur in a scenario of equality in terms of power.

In the case of FLOSS projects, for example, these differences of power are illustrated by the existence of roles such as the Benevolent Dictator For Life (BDFL). BDFL (Benkler, 2013, pp. 225-226) refers to an informal title received by community leaders in FLOSS communities with high social capital — commonly the founders. BDFLs have the final word in the community regarding disputes lacking consensus. In addition to higher social capital, BDFLs also tend to have full power over infrastructure in the early stages of the project. Over the course of the constant processes of negotiation, the "right to fork" plays a significant role (Nyman, 2015). Forking, in FLOSS communities, occurs when participants take a copy of source code from one project and start a new, independent and distinct version of it[22]. The "threat of forking" conditions the processes of negotiation, since participants holding more power are expected to maintain a general direction of the project which acknowledges and

---

[21] As discussed in footnote 6, in this article we focus our analysis on governance through blockchains. For this reason, we will not tackle the relationships between technical and social power in the underlying protocols. Examples or these are the identification of strategies regarding the mining protocol to control the system by Ittay & GünSirer (2014), and the inequalities generated by the accumulation of hashing-power. See Atzori (2015, pp. 16-19) for further details on these risks and limitations.

[22] This right is based on one of the main freedoms of FLOSS (Stallman, 2002). However, it is typically left as a last resource, since this might provoke the division of the community. The meanings have, however, evolved over the years. See Nyman (2015) for a detailed analysis of the changes in the meaning of fork in FLOSS communities over time.

includes the main desires of the community. In simplified terms, the threat of forking the code conditions the BDFLs, or the more participatory institutions which might emerge over time, to "maintain their benevolence". BDFLs and/or institutions need to be perceived as accountable and legitimate in the eyes of the community, and they commonly respond by limiting and distributing their power over time.

While, in technical terms, forking code has become a simple operation, forking the infrastructure remains a complex matter which is significantly costly in terms of effort. Indeed, when forks in FLOSS communities occur, those who decide to fork the code usually need to create a new infrastructure from scratch[23]. The use of decentralised technologies offers, in this respect, a promising field of experimentation and exploration of potential changes in these dynamics. The inherent properties of decentralised technologies facilitate the forking of the whole infrastructure and even the communitarian rules which have been encoded in them, as discussed in the previous section. In other words, BDFLs or institutions might not only fear the forking of code, but of the whole infrastructure and a large set of the (codified) community rules. While the "right to fork" may be perceived as an aspect unique to FLOSS communities, a similarity has been observed in other CBPP communities, such as communities maintaining wikis (Tkacz, 2014; Jemielniak, 2016). Continuing with the case of Wikipedia, for example, a similar fork occurred in 2002. In this case, the fork relates to the Spanish version of Wikipedia through a project known as the *Enciclopedia Libre Universal en Español*[24]. This episode marked the first detailed account of "post-software" forking (Enyedy & Tkacz, 2011, p. 111): a fork outside of purely software-based projects, which entailed a manual, difficult, and sometimes precarious (Enyedy & Tkacz, 2011, p. 116) process of replication of contents and infrastructure. The tension reached its apex when one of the co-founders of Wikipedia announced the intention to study the inclusion of advertisements in the encyclopedia (Enyedy & Tkacz, 2011, p. 113), leading to the fork. What would have been the scenario if Wikipedia's infrastructure had been running as part of a DAO in 2002? Unfortunately, we can only speculate. We could expect, however, that the relationships between social and technical power would probably be different. Those responsible for the fork argue[25] that its impact was substantial for how Wikipedia currently operates (Enyedy & Tkacz, 2011, pp. 115-117):

[...] the International Wikipedia that you all know and have come to take for granted, might have been impossible without the Spanish fork. Wales was worried that other foreign

---

[23] The case of Backdrop (see https://backdropcms.org/, last accessed on 26/06/2018), the first fork of Drupal core to continue with our example, illustrates these usual scenarios well.

[24] The project can be translated as the "Free and Universal Encyclopedia in Spanish". See http://enciclopedia.us.es, last accessed on 26/06/2018.

[25] This argument was admitted by Larry Sanger, one of the co-founders of Wikipedia who proposed the addition of advertisements as a reply to this article:
"[...]But to give credit where it is due, Mr. Enyedy is correct that the fork of the Spanish Wikipedia might well have been the straw that finally tipped the scales in favor of a 100% ad-free Wikipedia. [...]" (see http://www.wired.co.uk/article/wikipedia-spanish-fork, last accessed on 26/06/2018).
However, this was denied by Jimmy Wales, the other co-founder (see http://larrysanger.org/2011/01/jimmy-wales-on-advertisement/ last accessed on 26/06/2018). In any case, the purpose of this article is not to analyse the polemic, but rather to refer to this episode in order to illustrate the existence of these tensions, and the role played by the forms of pressure generated by "the thread of forking" in CBPP communities beyond FLOSS.

communities would follow our fork. He learnt from us what to do and what not to do in future. [...] The project [Enciclopedia Libre Universal en Español] itself was not intended to last. It was merely a form of pressure. [...]

These examples allow us to imagine scenarios of the possible opportunities gained by decentralising power over infrastructure in CBPP. Decentralised technologies may shape these dynamics by offering a higher degree of pressure for negotiation on those holding more power in the community and fostering permissionless innovation (Thierer, 2016). Continuing with our community network example, part of the centralised infrastructure, such as that related to monitoring contributions (e.g. to provide an antenna to connect 5 houses), could be decentralised. This would facilitate the deployment of alternative networks able to operate as the former, and to reuse and adapt the encoded rules of the community while still using the shared infrastructure. Thus, decentralisation of the infrastructure reduces the technical cost to fork the community, reducing the power within the community of those previously in control of the infrastructure.

When we analyse this affordance through Ostrom's principles, we identify a set of aspects which relate to them. Firstly, those holding more power within the community may experience higher pressure with regards to the constant processes of negotiation of collective choice arrangements — the 3rd of the principles. Secondly, in connection with the 4th of Ostrom's principles, those monitoring the commons could also experience new forms of pressure regarding their expected accountability in the eyes of the community. Thirdly, within this scenario, the decentralisation of power over infrastructure could facilitate permissionless innovation and thus, a higher degree of autonomy[26] to the local spaces which emerge over time. Thus, the differences in the forms of pressure may provide new conditions for the negotiations that relate to having their local contexts and jurisdictions acknowledged by higher authorities — in congruence with the 2nd and 7th of Ostrom's principles respectively.

Nevertheless, this affordance for decentralisation of power over infrastructure is not free of risks and requires further exploration. A risk which can be clearly envisioned is that of the shift of power to those coding the rules, as previously discussed for the cases of tokenisation, self-enforcement and formalisation of rules. Additionally, the aforementioned higher degree of pressure for negotiation or permissionless innovation could result in increasing risks of the constant fragmentation of the community. The issue is not new. Large CBPP communities, for example, constantly aim to navigate these tensions to "loosen control without losing control[27]" while trying to scale up (Rozas, 2017, pp. 297-318). The key aspect resides in furthering our understanding on how to integrate this affordance for decentralisation of power over the infrastructure into the day-to-day practices of these communities.

[26] The coordination of different local groups would tentatively require a higher degree of interoperability. Interoperability will be discussed in further detail as part of the affordance of codification of trust.

[27] This motto was coined by Dries Buytaert, founder of the Drupal project, when explaining his views on how FLOSS communities manage to scale up while continuing to innovate. See https://opensource.com/open-organization/15/12/how-open-source-solves-innovation-problem, last accessed on 26/06/2018.

4.5 Transparentisation

Transparentisation refers to the process of opening the organisational processes and the associated data by relying on the persistency and immutability properties of blockchain technologies. Blockchain enthusiasts envision a blockchain governance as one that “takes advantage of the public record-keeping features of blockchain technology: the blockchain as a universal, permanent, continuous, consensus-driven, publicly auditable, redundant, record-keeping repository.” (Swan, 2015, p.44).

As previously argued, commons-based approaches towards the use of blockchain technologies may want to consider treading cautiously regarding these techno-determinist views. Firstly, opening processes is a far more complex social organisational problem than simply opening data. Secondly, as Atzori (2015, p.16) shows, techno-determinist views tend to be based on “claims [that] are somehow overstated, since they do not take enough account of the several performance risks at stake”. Blockchain technologies provide, however, a potential for CBPP communities to socially construct software in which certain actions and operations are more easily trackable, auditable and communally fiscalised by their participants. CBPP communities have, indeed, a long tradition of aiming to make their processes as open and participative as possible. Examples of these data are the materials generated as a result of the encounters when decisions are made, or the indicators of the degree of participation in the community. This strong culture of openness and participation in CBPP communities connects with the 4th and 6th of Ostrom’s principles. The opening of the data generated in the collaboration processes in the communities is a useful means for CBPP communities to successfully carry out and scale up their processes of monitoring. They increase the legitimacy of these processes and provide means of accountability for those who participate in them in the eyes of the community. These data are also commonly employed as part of conflict resolution mechanisms as well as in the constant processes of negotiation. One can think, for example, of the enormous amount of contents which can be found in the discussion pages of Wikipedia; or in the issues lists of FLOSS communities. These large amounts of data are not commonly solely related to the objects of the efforts, but also to the organisational processes themselves.

The experimentation with software drawing on blockchain technologies provides new possibilities for CBPP communities to track and communally fiscalise new aspects of their processes. Continuing with the example of community networks, this transparency can help to identify who uses more resources, the community can then either try to grant these resources or to penalise excessive usage; those who contributed more can also be rewarded or recognised accordingly.

As with the previously discussed affordances, however, commons-based approaches towards the use of *blockchain-based* tools for governance should be aware of the limitations. Khan (2016, p. 132), for instance, places this discussion into the more general one of privacy and the right to be forgotten in the digital age (Mayer-Schönberger, 2011). The permanent nature of blockchain opens up scenarios in which “everything is recorded” and "will forever tether us to all our past actions, making it impossible, in practice, to escape them" (Rosen, 2010). Extreme transparency in the context of self-governance of CBPP communities raises similar questions: what kind of participation information should be permanently stored? Or, how might a scenario with a higher degree of transparency shape the development of participants' identities in the communities? As with the case of the previously discussed affordances, transparentisation through blockchain will require commons-based approaches to explore and experiment to determine the limits and how to integrate and situate a potential higher degree of transparency into the day-to-day practices of these communities.

4.6 Codification of trust

Trustlessness is one of the most cited characteristics by blockchain enthusiasts to argue for the disruptive potential of this technology. When framed in terms of processes, it can be understood as that of codifying trust into "trustless systems" developed under a blockchain. In simple terms, trustless systems are those which enable participants to enter into an agreement, without requiring a third party, to provide a certain degree of trust between them.

In the context of technological artefacts to facilitate governance, commons-based approaches should be aware of the limitations and underlying values incorporated by dominant techno-determinist views. Thus, commons-based approaches could aim to re-interpret "trustlessness" as a partial property which may act as a potential source of affordances in the context of commons governance. An example of these limitations relates to the transfer of trust encompassed in the design and development of these trustless systems. For example, when considering the use of smart contracts to facilitate governance, trust is transferred to the code that defines them, and subsequently to those who write the code. This shift of trust has been framed by blockchain enthusiasts by re-interpreting the well-known Lessig's (1999) dictum "Code is Law" motto. Even in predominant techno-determinist discourses, however, an awareness of the shift of trust from code to those who code is starting to emerge. Trustlessness is discussed more as a partial than an absolute property (BTC Studios, 2017):

"[...] Even an open-source project like Bitcoin that is constantly being reviewed can have trust issues, not from the code but by the developers and reviewers of the code. So trustlessness is more of a term describing an ideal state on the blockchain where code is law with the caveat that humans write code and to err is human."

Secondly, techno-determinist views tend to emphasise contractual transactions between individuals as the key pillar for the foundation of the society and invisibilise, or even abhor, collective action (Flood & Robb, 2017). On occasions, these views fall on hobbesian values, in which the blockchain acts as a "crypto-leviathan" (Reijers et al., 2016) enforcing a social contract between inherently selfish and power-seeking individuals. Commons-based approaches could focus on the affordances generated by this partial property of trustlessness to foster collective action and the scaling up of self-organisational processes of CBPP communities.

From this process of codification of trust, and returning to the context of Ostrom's principles, an affordance regarding interoperability in CBPP communities can be envisioned. In technical terms, interoperability refers to the property of a system to operate with other systems through a series of interfaces. Blockchain provides affordances to increase the degree of collaboration not only through the generation of interfaces, but also by providing a full communal infrastructure: a shared decentralised database. This affordance for the codification of trust relying on a communal infrastructure allows us to envision potentialities at several levels. Firstly, and in connection with the 7^{th} and 8^{th} of Ostrom's principles, to facilitate internal interoperability among the different groups or nodes that form part of CBPP communities, or the multiple layers of nested enterprises in Ostrom's terms. Thus, and returning again to our previous example of a community network, with local nodes in Madrid and Barcelona, one can envision artefacts designed to facilitate the governance of CBPP communities in the form of different locally-shaped platforms. These platforms could be autonomously governed by the participants who belong to each of the nodes, but interoperate between them and/or with a federal platform at a broader level. Thus, the process of codification of trust would not simply refer to the individuals and their atomic interactions. Instead, it could include the agreements arranged between the nodes that form part of the community, fostering the capacity of these communities to scale up some of their self-organisational processes, as in the example of the collaboration of networks.

Secondly, a blockchain as a common database infrastructure generates affordances for interoperability beyond the boundaries of a particular CBPP community. In the context of governance, this affordance for codification of trust could be envisioned as a source of experimentation and exploration of initiatives intended to increase interoperability between different CBPP communities. For example, a set of smart contracts which encode agreements between community networks, or by reflecting the decisions made by different community networks with regards to their different notions of value and ways to make them interoperable (De Filippi & Hassan, 2015). Nevertheless, as with the previously discussed affordances, the processes related to the codification of trust in ways that facilitate interoperability between and within CBPP communities will remain as social processes of negotiation. As such, they are not exempt from similar risks.

In sum, while blockchain technologies provide capabilities to improve trust in transactions, the key for commons-perspectives may reside in experimenting and finding ways to employ them to foster collective action. This process encompasses the need to integrate social culture and practices, while exploring and furthering understanding of what these risks and limits are.

5. Discussion and concluding remarks

This article contributes to the emergent debate on *blockchain-based* governance by providing a perspective focussed on commons governance, namely that of CBPP communities. This perspective is novel because it performs a systematic analysis which does not rely on techno-determinist views and logics of private markets (e.g Swan, 2015; Hayes, 2016; Heuermann, 2015), nor on the assumption of the need for coercion by traditional centralised institutions (Atzori, 2015). As mentioned in section 2, several authors have recently made some initial attempts to link the commons with blockchain technologies. In fact, Calcaterra (2018) mentions how Ostrom's 8 principles could be applied to DAOs, and Shackelford & Myers (2017) review the applicability of the 8 principles focusing on governance of blockchains (instead of *with* blockchains). Other authors, without mentioning blockchain, consider how Ostrom's principles could be formalised and mathematised (Pitt et al., 2012; Pitt et al., 2014), or applied to algorithmic governance (Pitt & Diaconescu, 2014). However, none of them carry out a systematic and in-depth analysis of blockchain affordances with respect to CBPP communities, nor do they tackle how each affordance may support Ostrom's principles, nor how community governance may be affected, positively or otherwise.

In this article we bring together literature on the governance of commons within that of *blockchain-based* governance to identify a set of affordances which could facilitate the governance of CBPP communities. In turn, we discuss the identified affordances in the context of Ostrom's (1990) classic principles for commons governance. Table 5.1 provides a summary of the relationships discussed between the identified affordances and the principles.

	Tokenisa-tion	Self-enforce-ment and formalisation	Autonomous automatisati-on	Decentralisation of power over infrastructure	Transparenti-sation	Codification of trust
(1) Clearly defined community boundaries	✔					
(2) Congruence between rules and local conditions	✔	✔		✔		
(3) Collective choice arrangements	✔			✔		
(4) Monitoring		✔	✔	✔	✔	
(5) Graduated sanctions		✔	✔			
(6) Conflict resolution mechanisms			✔		✔	
(7) Local enforcement of local rules		✔		✔		✔
(8) Multiple			✔			✔

layers of nested enterprises						

Table 5.1: Summary of the relationships between the identified affordances of blockchain technologies for governance and Ostrom's (1990) principles.

The congruences identified between the affordances and these principles allow us to speculate on the impact that decentralised *blockchain-based* technologies could have on governance processes in these communities. These decentralised technologies could facilitate coordination, help to scale up commons governance or even be useful to share agreements and different forms of value amongst various communities in interoperable ways. The identified affordances are, however, not to be considered as an exhaustive list. Instead, they should be interpreted as a set of potential processes which may help these communities to tackle issues related to the problems faced while trying to decentralise their organisational processes in order to scale up. Examples of issues previously identified in the literature (e.g. Viégas et al., 2007; Forte et al., 2009; Schweik & English, 2013; Wang & Cheliotis, 2016; Rozas, 2017) that relate to the identified affordances are the need to increase the degree of formalisation of their processes to provide higher degrees of legitimacy, transparency and trust.

As in the case of most of the emergent literature on governance through blockchain, our analysis is theoretical and speculative. This is not an uncommon issue when analysing the impact of novel and potentially disruptive technologies. The contribution of analyses as those presented in this article resides, however, in facilitating the emergence and identification of categories which, by drawing on classic literature as in the case of Ostrom's studies, allows us to more clearly open new research questions to explore. Examples of these research questions are those discussed with regards to the limits of the processes of the tokenisation or formalisation of rules: which aspects should remain in/off the blockchain, or furthermore completely in/out of code? Thus, by providing a perspective focussed on commons governance we do not simply identify the potentialities, but also possible drawbacks and limitations which have not been acknowledged by predominant techno-determinist views, nor identified and analysed in-depth by critical approaches which have not considered the power of self-organisation of communities. All of these aspects, and the related research questions, require further exploration. In addition, further analysis to explore approaches focussed on commons governance could draw on different literature on self-organisation beyond Ostrom's. A similar analysis drawing on the principles of platform cooperativism (Scholz, 2016) — as in the call made by De Filippi & Lavayssière (2018) — could help us to identify new affordances, drawbacks, risks and limitations of the use of blockchain technologies in this context. In this sense, this article represents an initial effort and a call to systematically bring together literature on self-organisation to the emerging debate on blockchain-based governance.

Furthermore, a better understanding of the capabilities of blockchain technologies for commons governance will require further empirical research. The co-design of technological artefacts for governance will need to be carried out together with those who may potentially use them for collective action. This should enable the development of situated technology, with an awareness of the cultural context and aiming to incorporate particular social practices into the design. In this sense, CBPP communities provide radically differing values and practices when compared with those in markets. CBPP communities show us how cooperation can triumph over competition, although today they represent a minority view. As we have attempted to show, blockchain may facilitate cooperation in new ways. We hope this combination may open a new path for the popularisation of CBPP and the much needed cooperation in our societies.

Acknowledgments

This work was partially supported by the project P2P Models (https://p2pmodels.eu) funded by the European Research Council ERC-2017-STG (grant no.: 759207). We would also like to thank Mayo Fuster Morell, Primavera De Filippi, David Bollier and Maria T. Vidal for their helpful comments and suggestions. We are also grateful to all the participants at the congress “Science, politics, activism and citizenship” organised by Redes CTS & the Catalan Society for the History of Science and Technology at the University of Valencia (Spain) in May 2018. Finally, we would like to thank Tabitha Whittall for her help reviewing, proofreading and improving the structure of this article.

References:

- Ainsworth, R. T., & Shact, A. (2016). Blockchain (Distributed Ledger Technology) Solves VAT Fraud. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2853428
- Arvidsson, A., Caliandro, A., Cossu, A., Deka, M., Gandini, A., Luise, V., & Anselmi, G. (2017). Commons based peer production in the information economy (Report). https://www.academia.edu/29210209/Commons_Based_Peer_Production_in_the_Information_Economy
- Atzori, M. (2015). Blockchain Technology and Decentralized Governance: Is the State Still Necessary? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2709713
- Atzori, M., & Ulieru, M. (2017). Architecting the eSociety on Blockchain: A Provocation to Human Nature. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2999715
- Barlow, J. (1996). A declaration of the independence of cyberspace. http://www.eff.org/~barlow/Declaration-Final.html
- Bell, G., Blythe, M., Gaver, B., Sengers, P., & Wright, P. (2003, April). Designing culturally situated technologies for the home. In *CHI'03 extended abstracts on Human factors in computing systems* (pp. 1062-1063). ACM
- Benkler, Y. (2002). Coase’s Penguin, or, Linux and “The Nature of the Firm”. The Yale Law Journal, 112 (3), 369–446. http://www.jstor.org/ stable/1562247
- Benkler, Y. (2006). The wealth of networks: How social production transforms markets and freedom. Yale University Press.

- Benkler, Y. (2013). Practical Anarchism. Peer Mutualism, Market Power, and the Fallible State. Politics & Society, 41 (2), 213–251. https://doi:10.1177/003232921348310
- Bollier, D. (2015, March 3). The blockchain: A promising new infrastructure for online commons. News and Perspectives on the Commons. http://www.bollier.org/blog/blockchain-promising-new-infrastructure-online-commons
- boyd, d. (2010). Social network sites as networked publics: Affordances, dynamics, and implications. In *A networked self* (pp. 47-66). Routledge
- BTC Studios (2017, September 3). Trustlessness in Action: Particl's Model, Bitcoin Magazine. https://bitcoinmagazine.com/articles/trustlessness-action-particls-model/
- Calcaterra, C. (2018). On-Chain Governance of Decentralized Autonomous Organizations: Blockchain Organization Using Semada. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3188374
- Cheshire, C., & Antin, J. (2008). The social psychological effects of feedback on the production of Internet information pools. Journal of Computer-Mediated Communication, 13(3), 705-727
- Cohen, B. (2003). Incentives build robustness in BitTorrent. In Workshop on Economics of Peer-to-Peer systems (Vol. 6, pp. 68-72)
- Cox, M., Arnold, G. & Tomás, S. V. (2010). A review of design principles for community-based natural resource management. Ecology and Society 15(4): 38
- Davidson, S., De Filippi, P., & Potts, J. (2016). Economics of blockchain. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2744751
- De Filippi, P. (2015). Translating commons-based peer production values into metrics: Toward commons-based cryptocurrencies. In Handbook of Digital Currency (pp. 463-483).
- De Filippi, P., & Hassan, S. (2015). Measuring Value in Commons-Based Ecosystem: Bridging the Gap between the Commons and the Market. In Lovink, G., Tkacz, N. (eds.) The MoneyLab Reader. Institute of Network Cultures, University of Warwick, 2015. https://ssrn.com/abstract=2725399
- De Filippi, P. & Hassan, S. (2016). Blockchain technology as a regulatory technology: From code is law to law is code. *First Monday*, 21(12). http://firstmonday.org/ojs/index.php/fm/article/view/7113/5657
- De Filippi, P., Lavayssière, X. (2018). Blockchain technology: toward a decentralized governance of digital platforms? In Bollier, D. & Grear, A. (eds.) The Great Awakening (forthcoming)
- De Filippi, P., & Loveluck, B. (2016). The invisible politics of bitcoin: governance crisis of a decentralized infrastructure. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2852691
- De Filippi, P., & Wright, A. (2018). Blockchain and the Law: The Rule of Code. Harvard University Press
- Enyedy E., & Tkacz N. (2011). Good Luck With Your 'WikiPAIDdia': Reflections On The 2002 Fork Of The Spanish Wikipedia. In: Lovink G. & Tkacz N. (eds.) Critical Point of View: A Wikipedia Reader. Amsterdam: Institute of Network Cultures.
- Flood, J., & Robb, L. (2017). Trust, Anarcho-Capitalism, Blockchain and Initial Coin Offerings. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3079888

- Forte, A., Larco, V., & Bruckman, A. (2009). Decentralization in Wikipedia Governance. *Journal of Management Information Systems*, *26*(1), 49–72. https://doi.org/10.2753/MIS0742-1222260103
- Franklin, S., & Graesser, A. (1996). Is it an Agent, or just a Program?: A Taxonomy for Autonomous Agents. In International Workshop on Agent Theories, Architectures, and Languages (pp. 21-35). Springer, Berlin, Heidelberg.
- Freeman, J. (1972). The tyranny of structurelessness. *Berkeley Journal of Sociology*, 151-164.
- Fuster Morell, M. (2010). Governance of Online Creation Communities: Provision of infrastructure for the building of digital commons (Doctoral dissertation, European University Institute). Retrieved from http://cadmus.eui.eu//handle/1814/14709
- Fuster Morell, M. (2014). "Governance of Online Creation Communities for the Building of Digital Commons: Viewed through the framework of the institutional analysis and development". In Madison, M. J., Strandburg, K., Frischmann, B., Strandburg, K., & Madison, M. (eds.). *Governing knowledge commons* (2014). Oxford University Press
- Fuster Morell, M., Martínez, R., & Salcedo, J.L. (2016a). *Mapping the common based peer production: A crowd-sourcing experiment.* The Internet, Policy & Politics Conference
- Fuster Morell M., Salcedo J.L., & Berlinguer M. (2016b). Debate About the Concept of Value in Commons-Based Peer Production. In: Bagnoli F. et al. (eds) Internet Science. INSCI 2016. Lecture Notes in Computer Science, vol 9934. Springer, Cham
- Gibson, J. J. (1979). *The ecological approach to visual perception: classic edition*. Psychology Press
- Hardin, G. (1968). The tragedy of the commons. *Science*, *162* (3859), 1243–1248
- Hayes, A. (2016). Decentralized Banking: Monetary Technocracy in the Digital Age. In Tasca, P., Aste T., Pelizzon, L., & Perony, N. (Eds.), *Banking Beyond Banks and Money* (pp. 121–131). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-42448-4_7
- Hess, C. (2008). Mapping the New Commons. Governing shared resources: connecting local experience to global challenges. International Association for the Study of the Commons, University of Gloucestershire. doi:http://dx.doi.org/10.2139/ssrn.1356835
- Hess, C., & Ostrom, E. (2007). Introduction: An Overview of the Knowledge Commons. In C. Hess & E. Ostrom (Eds.), Understanding Knowledge as a Commons: From Theory to Practice (Chap. 1, pp. 3–26). MIT Press
- Heuermann, C. (2015) Governance 2.0: a Hayekian approach to (r)evolutionary self-governance by cryptocurrencies (Bachelor thesis). University of Konstanz. Retrieved from https://staatenlos.ch/wp-content/uploads/2015/12/Final_Thesis_BT_CH.pdf
- Huckle, S., & White, M. (2016). Socialism and the blockchain. *Future Internet*, *8*(4), 49
- Hutchby, I. (2001). Technologies, texts and affordances. *Sociology*, *35*(2), 441-456
- Ittay E. & GünSirer E. (2014). Majority is not Enough: Bitcoin Mining is Vulnerable. In Christin N., & Savafi-Naini R. (Eds.), Financial Cryptography and Data Security. 18th International Conference, FC 2014, Christ Church, Barbados, March 3-7, 2014,

Revised Selected Papers (1st ed., pp.436-454). http://www.cs.cornell.edu/~ie53/publications/btcProcArXiv.pdf

- Jemielniak, D. (2016). Wikimedia movement governance: the limits of a-hierarchical organization. *Journal of Organizational Change Management*, *29*(3), 361-378
- Jonhston, A. (2014, August 29). Everything Will Be Decentralized. https://medium.com/@DJohnstonEC/everything-will-be-decentralized-d7dcedca45e
- Juris, J. S. (2012). Reflections on #Occupy Everywhere: Social media, public space, and emerging logics of aggregation. *American Ethnologist*, *39* (2), 259-279
- Khan, J. (2016). To What Extent Can Blockchain Be Used as a Tool for Community Guidance. *Edinburgh Student L. Rev.*, *3*, 114
- Koehler, W. (1999). Digital libraries and World Wide Web sites and page persistence. Information research, 4(4), 4-4
- Le Breton, D. (2015). Disparaître de soi: une tentation contemporaine. Anne-Marie Métailié
- Lessig, L. (1999). Code and Other Laws of Cyberspace
- Liu, P. (2016). Medical record system using blockchain, big data and tokenization. In *International Conference on Information and Communications Security* (pp. 254-261). Springer, Cham
- Marx, K. (1875). *Critique of the Gotha programme*. Part I. https://www.marxists.org/archive/marx/works/1875/gotha/ch01.htm
- Mateos-García, J., & Steinmueller, W. E. (2008). The institutions of open source software: Examining the Debian community. *Information Economics and Policy*, *20*(4), 333-344.
- Mayer-Schönberger, V. (2011). *Delete: The virtue of forgetting in the digital age*. Princeton University Press
- Nakamoto, S. (2008) Bitcoin: a peer-to-peer electronic cash system. http://bitcoin.org/bitcoin.pdf
- Nguyen, Q. K. (2016). Blockchain - A Financial Technology for Future Sustainable Development (pp. 51–54). IEEE. https://doi.org/10.1109/GTSD.2016.22
- Nyman, L. (2015). Understanding Code Forking in Open Source Software: An examination of code forking, its effect on open source software, and how it is viewed and practiced by developers (Doctoral dissertation, Hanken School of Economics, University of Helsinki). Retrieved from http://hdl.handle.net/10138/153135
- Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press
- Ostrom, E. (2000). Collective action and the evolution of social norms. *Journal of economic perspectives*, *14* (3), 137-158
- Ostrom, E. (2005). Understanding Institutional Diversity. Princeton: Princeton University Press
- O'Dwyer, R. (2015, June 11). The Revolution will (not) be Decentralized: Blockchains. http://commonstransition.org/the-revolution-will-not-be-decentralised-blockchains/
- 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.

- Pérez-Orozco, A. (2014). Subversión feminista de la economía: Aportes para un debate sobre el conflicto capital-vida. Traficantes de sueños
- Pitt, J., Schaumeier, J., & Artikis, A. (2012). Axiomatization of socio-economic principles for self-organizing institutions: concepts, experiments and challenges. ACM Transactions on Autonomous and Adaptive Systems (TAAS), 7(4), 39.
- Pitt, J., & Diaconescu, A. (2014). The algorithmic governance of common-pool resources. From Bitcoin to Burning Man and Beyond. The Quest for Identity and Autonomy in a Digital Society, 130-142.
- Pitt, J., Diaconescu, A., & Bollier, D. (2014). Technology for Collective Action. IEEE Technology and Society Magazine, 33(3), 32-34.
- Platero, R. (2014). ¿Es el análisis interseccional una metodología feminista y queer. Otras formas de (re) conocer: Reflexiones, herramientas y aplicaciones desde la investigación feminista, 79-95
- Postman, N. (1992). The Ideology of Machines: Computer Technology. *Technopoly: The Surrender of Culture to Technology*
- Reber, D., & Feuerstein, S. (2014). Bitcoins-hype or real alternative. *Internet Economics VIII*, *81*.
- Reijers, W., O'Brolcháin, F., & Haynes, P. (2016). Governance in Blockchain Technologies & Social Contract Theories. *Ledger*, *1*, 134-151
- Risius, M., & Spohrer, K. (2017). A Blockchain Research Framework: What We (don't) Know, Where We Go from Here, and How We Will Get There. *Business & Information Systems Engineering*, *59*(6), 385–409. https://doi.org/10.1007/s12599-017-0506-0
- Rosen, J. (2010, July 21). The Web Means the End of Forgetting. https://www.nytimes.com/2010/07/25/magazine/25privacy-t2.html
- Rozas, D. (2017). Self-organisation in Commons-Based Peer Production: Drupal : "the drop is always moving". (Doctoral dissertation, University of Surrey). Retrieved from http://epubs.surrey.ac.uk/845121/
- Scholz, T. (2016). Platform cooperativism. Challenging the corporate sharing economy. New York: Rosa Luxemburg Stiftung
- Schweik, C., & English, R. (2013). Preliminary steps toward a general theory of internet-based collective-action in digital information commons: Findings from a study of open source software projects. International Journal of the Commons, 7 (2), 234–254. http://doi.org/10.18352/ijc.397
- Selimi, M., Kabbinale, A. R., Ali, A., Navarro, L., & Sathiaseelan, A. (2018). Towards Blockchain-enabled Wireless Mesh Networks. In *Proceedings of the 1st Workshop on Cryptocurrencies and Blockchains for Distributed Systems* (pp. 13-18). ACM
- Shackelford, S. J., & Myers, S. (2017). Block-by-block: leveraging the power of blockchain technology to build trust and promote cyber peace. Yale JL & Tech., 19, 334.
- Sharon, T., & Zandbergen, D. (2017). From data fetishism to quantifying selves: Self-tracking practices and the other values of data. *New Media & Society*, *19* (11), 1695-1709
- Shaw, A., & Hill, B. M. (2014). Laboratories of oligarchy? How the iron law extends to peer production. *Journal of Communication*, *64* (2), 215-238.

- Shennan, S. (Ed.). (2009). Pattern and process in cultural evolution, (2). Univ of California Press
- Stallman, R. (2002). Free software, free society: Selected essays of Richard M. Stallman (1st ed.) (J. Gay, Ed.). SoHo Books.
- Sullivan, L. E. (Ed.). (2009). *The SAGE glossary of the social and behavioral sciences*. Sage
- Swan, M. (2015). *Blockchain: Blueprint for a New Economy*. Sebastopol, CA, USA: O'Reilly
- Szabo, N. (1997). Formalizing and securing relationships on public networks. First Monday, 2 (9)
- Thierer, A. (2016). Permissionless innovation: The continuing case for comprehensive technological freedom. Mercatus Center at George Mason University
- Tkacz, N. (2014). *Wikipedia and the Politics of Openness*. University of Chicago Press
- Underwood, S. (2016). Blockchain beyond bitcoin. Communications of the ACM, 59 (11), 15-17
- Viégas, F. B., Wattenberg, M., & McKeon, M. M. (2007). The Hidden Order of Wikipedia. Online Communities and Social Computing: Second International Conference, OCSC 2007, held as part of HCI International 2007, Beijing, China, July 22-27, 2007, Springer, 445–454. https://doi:10.1007/978-3-540-73257-0-49
- Wang, R. & Cheliotis, G. (2016). Institutional and Entrepreneurial Engagement in Commons-Based Peer Production. International Journal of Communication, 10 , 22. http://ijoc.org/index.php/ijoc/article/view/4248
- Wellman, B., Quan-Haase, A., Boase, J., Chen, W., Hampton, K., Díaz, I., & Miyata, K. (2003). The social affordances of the Internet for networked individualism. *Journal of computer-mediated communication*, *8* (3), JCMC834.
- Wellman, B. (2004). The glocal village: Internet and community. *Idea&s: The Arts & Science Review*, *1*, 26-29
- Wright, A., & De Filippi, P. (2015). Decentralized blockchain technology and the rise of lex cryptographia