Understanding the Role of Actor Heterogeneity in Blockchain Splits: An Actor-Network Perspective to Bitcoin Forks

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Abstract

This paper investigates the focal actors and their heterogeneity in blockchain splits. Disagreements in blockchain communities often lead to splits in the blockchain and the community. For example, disagreements within the Bitcoin community on increasing the block size led to the blockchain split and creation of Bitcoin Cash. We build on actor-network theory to investigate blockchain split as a translation process, and employ case study methodology to examine Bitcoin splits. We identify several human actors, such as miners, developers, merchants, and investors, as well as non-human actors including ideologies, exchanges and computer programs involved in Bitcoin splits. Our results show that actor heterogeneity, that is, the complex constellation of diverse actors, plays a key role in blockchain splits. We further describe how the human and non-human actors' fluid moves into micro and macro positions in the network affect the development of the split. We also discuss the role of these actors and their engagement in forming micro and macro agencies in blockchain splits. Our study adds to the understanding of actor behavior and network dynamics in decentralized information systems such as blockchain and open source software.

1. Introduction

Blockchain-based services are run in a peer-to-peer network of computers without a central authority [39, 37]. A characteristic feature of blockchain is nodes or miners who collectively validate and bundle batches of transactions into blocks and add these blocks into a chronological chain [37]. Instead of a central server, the chain is stored and synchronized on each node in the network [39]. Consequently, blockchain-based services are not maintained by a central authority, but by a community of miners and developers [37]. Thus,

resolving disagreements within the community represents a particular challenge.

The disagreements within blockchain communities often lead to a technical event known as a *fork*, which refers to the divergence of a blockchain into two or more potential paths [26]. For example, Bitcoin Cash (BCH) was created as a result of a successful fork from Bitcoin (BTC) due to the disagreement among the communities on increasing the block size. In a similar vein, Ethereum was also forked to create two separate crypto currencies: Ether (ETH) and Ethereum Classic (ETC) after the system was hacked [7]. ArcadeCity, a carpooling platform, much like Uber but without a central authority, was forked to create Swarm City. In essence, a blockchain split is a consequence of a fork, which is in turn a consequence of critical incidents such as performance issues, catastrophic bugs, and cyber attacks [7].

Despite the increasing managerial interest in applications of blockchain technologies alongside the booming cryptocurrency market, academic research focusing on blockchain forks is somewhat limited [6, 23]. While the prior literature has examined open source software (OSS) forks [10, 26, 29, 30], we hold that for two reasons the findings from those studies are not directly applicable to the blockchain context. First, the studies are *atheoretical* and thus of limited value in developing theoretically generalizable insights. Second, blockchain forks differ from OSS forks, as executing a blockchain fork requires attracting miners to ensure sufficient computing power in order to make the forked blockchain viable. OSS forks can occur simply when developers move to supporting a new project. Understanding forks and their impact is critical for the stakeholders of a blockchain business ecosystem to accurately evaluate the potential risks and benefits. From a theoretical standpoint, forks are complex in nature, and often associated with contradictory sociotechnical interactions such as network attacks, community disagreements, and market confusion and uncertainties. Thus, as a first step towards understanding the forks, research is

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necessary to investigate the actors involved in the blockchain ecosystem.

As a result, this study investigates *what are the focal actors and how does their heterogeneity manifest itself in blockchain splits?* We build on Actor-Network Theory (ANT) [3, 15] as the theoretical foundation of the study, and use the literature on OSS forks and community splits [10, 25, 29] as our point of departure. We employ case study methodology [8, 38] and collect data from online sources and in-depth semi-structured interviews with Bitcoin community members, namely miners, developers, and investors. Our study contributes to the nascent IS literature on blockchain [23] as well as the research on OSS forks [10, 25, 29], providing a theoretically grounded empirical analysis of the actors involved in blockchain forks.

2. Blockchain fork

A blockchain fork refers to a change of rules that separates the blockchain into two or more potential paths [26]. There are three kinds of blockchain fork, namely, soft-fork, hard-fork, and user-activated soft-fork [32]. A *soft-fork* is a backward compatible software upgrade that splits the blockchain temporarily. During the soft-fork process, the original chain accepts blocks from both non-upgraded and upgraded nodes. The forked chain would contain blocks only from upgraded nodes. The upgraded nodes must reach a consensus and gain a certain percentage of the network processing power within a time limit, otherwise the soft-fork fails and the original chain continues. If the consensus is reached, the new rules are implemented in the network. All nodes need to upgrade or will be mining unrecognized blocks. Bitcoin's BIP 66 (signature validation) and P2SH (address formatting) are examples of soft-forks.

A *hard-fork* is not backward compatible and permanently creates two separate blockchains. Both chains run in parallel but with a different set of rules. Hard-forks are executed to handle acute issues such as increasing block size, serious network abuse, and theft. For example, BCH was created as the result of a hard-fork from Bitcoin to increase block size. ETH and ETC were created from Ethereum as the result of a hard-fork.

Finally, a *user-activated soft-fork* is the controversial concept of upgrading a blockchain without the support of those who provide the network processing power. Instead of relying on achieving the threshold power for the fork, the user-activated soft-fork relies on the economic majority of the ecosystem. BIP 148 is an example of a user-activated soft-fork on the Bitcoin network, which took place between midnight 1 August 2017 and midnight 15 November 2017.

Blockchain forks are widely discussed in the news. However, to date, there is little academic research on blockchain forks [6]. As blockchain projects are open source, we conducted a literature review on open source project forks. A few prior studies focused on forks in the OSS context. Table 1 summarizes these studies.

Table 1. Summary of prior research on OSS forks

Study	Research Method	Theory	Key Findings
Rastogi & Nagappan [29]	Statistical analysis on 2217 projects from GitHub	None	One in every five projects observes a decline in the sustainability of community participation after a fork
Gamalielsson & Lundell [10]	Data from LibreOffice community after a fork from OpenOffice.org. The data include log data and 12 interviews	None	LibreOffice community sustainable and no sign of project stagnation even 33 months after the fork. Perceived by its community as supportive, diversified, and independent
Nyman et al. [26]	Theoretical	None	Fork ensures the code remains open, and the code that best serves the community lives on. The fork provides a mechanism to safeguard against despotic decisions by the project lead
Robles & Gonzalez-Brahona [30]	In-depth analysis of 220 forks	None	Forks occur in every software domain. They have become more frequent in recent years, and very few merge with the original project
Viseur [34]	26 forks in open source projects	None	42% of forks were motivated by technical specialization. In 54% of the cases studied, both the fork and original projects survived

The literature review presented in Table 1 drew two interesting observations. First, most of the research on OSS forks investigates the survival of the original and forked projects after the split. The survival and community sustainability of the forked as well as original projects is not self-evident. In some cases,

both the fork and the original project survive and secure community support. Second, most studies on OSS forks lack the application of theory, which inevitably limits the theoretical contribution. We argue that the actors (and their network) involved in the project are critical to the survival of the blockchain project. Thus, research applying a solid theoretical foundation to identify the actors and examine the underlying network can significantly extend the current understanding of why blockchains fork.

While the blockchain literature has started to burgeon, there is little research theorizing on blockchain evolution. Mostly, the extant literature is based on a selected technology focus [39], or debating the dark side of blockchain such as enabling anonymous actors to cover their illegal trades [12]. Our focus in this paper is to understand the different actors and their contradictory roles in developing Bitcoin forks, and their further contribution to the Bitcoin evolution.

3. An Actor-Network perspective on blockchain splits

We employ ANT [3, 5, 15] as the theoretical foundation to study Bitcoin splits. ANT provides a sociotechnical perspective [18] to analyze the complex interactions between technology and human processes [2, 20], which is pertinent in the context of Bitcoin. ANT does not distinguish between human and non-human actors [17]. In fact, it places a higher emphasis on non-human actors, enabling the investigation of the role of technology, for instance [14]. Furthermore, ANT does not distinguish between micro (individual) and macro (group of individuals or organizational) actors in advance [5, 19]. This allows researchers to consider the sociotechnical collective as a single actor or group of actors, depending on the level of analysis [5].

The ANT literature describes how heterogeneous networks are created by a number of actors that can be human or non-human [5, 27]. An *actor* is defined as "any element which bends space around itself, makes other elements dependent upon itself and translates their will into the language of its own" [5: p. 286]. Actors include, for example, both social and technical elements, such as individuals, a group of individuals, organizations, ideologies, methodologies, concepts, hardware, software, and other technical artifacts or a part of any of them [17].

Accordingly, any actor, whether an individual, object, or organization, is equally important in creating a network [17]. The fundamental goal of the ANT is to explore how networks are built or assembled by the

actors to reach a certain objective [14]. ANT has been widely applied in IS research to understand the complex social interactions with IT as well as processes associated with IT implementations [31]. Consequently, we apply ANT in the blockchain domain to interpret the complex social processes associated with Bitcoin forks.

We rely on a number of concepts that guide us in interpreting the complex processes associated with blockchain forks. As stated, ANT emphasizes the network and assumes nothing lies outside of it. Thus, each actor can be defined and understood only in relation to other actors in the network [19]. This implies any actor can be considered a sum of smaller actors. For example, a computer is a complex system (a network) containing many electronic elements (actors), which are hidden from the user, who simply uses the computer as a single object (actor). This simplification is known as *punctualization* [4: p. 153], and allows a researcher to understand a network at different levels of complexity or granularity depending on the research objective.

In this paper, we view and explain blockchain splits as a *translation* process of ANT, one that creates "a temporary social order, or movement from one order to another, through changes in the alignment of interests in a network" [31: p. 54]. There are four phases or moments in translation, namely problematization, interessement, enrollment, and mobilization [3]. In *problematization*, the *focal actor*, that is the key actor behind the process of gathering other actors' support for a change initiative, defines the problem, identifies relevant actors, explains how the problem affects those actors, and outlines strategies to address the problem.

The focal actor establishes itself as an *obligatory passage point* (OPP) between the other actors and the network to render itself "indispensable" [3]. OPP refers to the process of forming a shared focus among the relevant actors to successfully pursue the interest. The second phase of translation is *interessement*, which involves convincing other actors through *negotiation* to have interest that is *aligned with* the focal actor. Incentives can be given to the other actors so that they pass through the OPP and align their interest with the focal actor [31].

Successful interessement is followed by *enrollment,* which involves defining the roles of each actor in the transformed or newly created actor-network. As a part of the enrollment process, the commitments of enrollment can be recorded in a shared memory through *inscription*. In general, "an inscription is the result of the translation of one's interest into material form" [4]. It should be noted that enrollment is temporary; *betrayal* by enrolled actors (failing to act as promised), is a possibility. On the other hand, if actors

enrolled in the network adequately represent the masses, enrollment manifests as active support, and *mobilization* occurs.

4. Methodology

We employed case study methodology [8, 38] to investigate blockchain forks, adopting a single case approach [21, 38] and focusing specifically on Bitcoin. We chose Bitcoin because it was the first blockchain-based application, and has undergone a number of forks since its introduction in 2009. These events have attracted considerable attention on traditional as well as social media, thereby enabling us to collect rich data from several sources, including online discussions.

The single-case approach is suitable when the case is particularly exemplary [38] and examined over time [21]. Bitcoin can be considered an exemplary case [38], since cryptocurrencies are an important application of blockchain technology and Bitcoin is the most valuable and widely used cryptocurrency. Second, with respect to the longitudinal nature of the phenomenon under investigation [21], a blockchain essentially contains a record of past events, and meticulously describing blockchain splits requires examining the events preceding the split.

As is typical in case study research, the empirical data were collected from multiple sources [38], in this instance between November 2017 and June 2018. We first extracted secondary data on Bitcoin forks from coindesk.com, a cryptocurrency-focused online news source, and from bitcointalk.com, a Bitcoin- and cryptocurrency-focused discussion forum using the search keyword "fork". Thereafter, we conducted five in-depth, semi-structured interviews among Bitcoin community members, including developers, miners, and investors, to understand the fork as a process from different actors' vantage points. The interviewees were recruited using a snowball approach, and all were men. The interviews lasted from 30 to 90 minutes, and all authors were present at the interviews.

The data were analyzed in accordance with the interpretative actor-network lens [9, 19]. This included several rounds to make sense of the sociotechnical mess [19] of actors' obvious and hidden traces in the collected data. The mess is problematic for the researcher, as it makes it difficult to comb the data into clear categories. As a part of the interpretive analysis, we conducted several iterative sketches in understanding the micro and macro actor constellations and their motives.

5. Case description

Bitcoin was the first application developed on blockchain technology [11]. Common belief is that Bitcoin was invented by an unknown person or group of persons under the pseudonym Satoshi Nakamoto [24]. The genesis block of Bitcoin emerged in January 2009.

Bitcoin was developed as a decentralized digital currency to revolutionize the traditional intermediary-based financial industry. At this time, Bitcoin continues to be developed and maintained as an open source project by a community. Thus, the community members decide the stages of Bitcoin evolution. However, the basic set of rules and functions allowed in Bitcoin could not be changed without changing the source code considerably.

In principal, blockchain-based applications such as Bitcoin evolve by actor negotiation. A major change in Bitcoin's source code requires sufficient support from the community. Such changes may lead to member disagreement and trigger splits in the original network. Once a split occurs, the two resulting blockchains become incompatible with each other, and the one that attracts enough community members survives.

Since Bitcoin's inception in 2009, there have been two coin splits, namely Bitcoin Cash and Bitcoin Gold, although there have been several instances of major changes (or hard forks) to the Bitcoin core client. Notable changes include Bitcoin XT, Bitcoin Unlimited, and Bitcoin classic. A timeline of the Bitcoin hard forks is presented in Figure 1.

An update to the Bitcoin source code or protocol requires that Bitcoin Improvement Proposals (BIPs) are submitted by an individual or group of individuals in the Bitcoin community (mostly developers). The team maintaining the Bitcoin core reviews the proposal with the community, and looks for general approval. If the community signals approval, the update is pushed to the next version of the Bitcoin core. Next, it is up to the miners whether or not they run the updated client. If they decide not to run it, the update fails. Thus, with respect to Bitcoin, miners are very important members of the community and play a key role in splits.
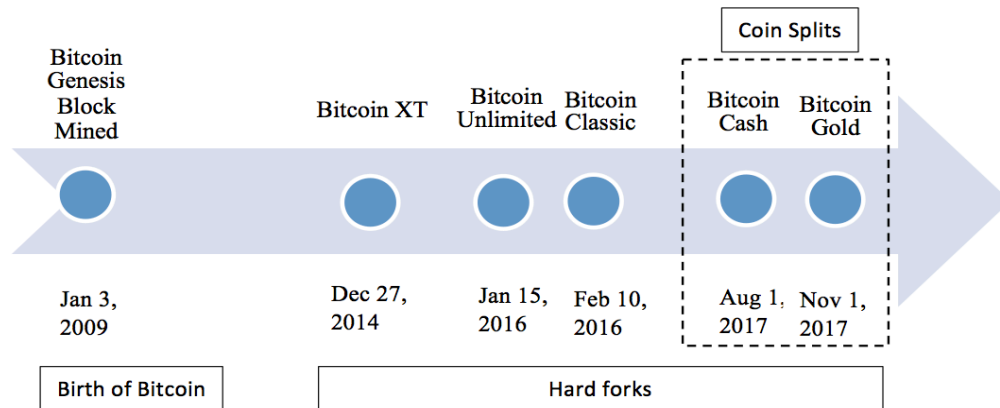
Figure 2. Timeline of major events in Bitcoin history

6. Understanding Bitcoin splits through the lens of ANT

According to ANT, all components of a network, such as objects, ideas, processes, and any other relevant factors, are considered as important as humans in creating social situations [5, 18]. An actor-network, i.e. *assemblage* [11], is a moving entity whose articulations produce effects, leaving traces of its passage in the form of rigid and fluid structures and relationships [2, 14]. The choice of ANT as our theoretical foundation has some specific assets in terms of explaining how complex things change. First, the focus is on the network and constant flux of relations - instead of counting and categorizing of end states or things – which helps us keep an eye on the shifts of relations in the various contexts and the diverse roles of players. For instance, categorizing complex phenomena may lead to prematurely ignoring significant aspects. Second, according to ANT, the network [13] is all that exists; nothing exists outside the network of relations, also known as flat ontology. Consequently, even researchers, such as the three authors of this paper, while trying to understand Bitcoin forks are part of the network, as we direct our intellectual inquiry to Bitcoin, which could influence other actors. With the ANT lens, we join the interpretive research tradition in qualitative IS research [35, 36, 38].

6.1. Actors and the network

We identified eight types of focal *actor* in the Bitcoin network that can influence a split: *the blockchain, miners, core developers, exchange/marketplace owners, investors, merchants, hardware manufacturers*, and *wallets*. These can be micro level actors such as humans, technology (including code scripts) or ideologies, and the diverse interests of individuals; and at the macro level, institutions, companies, banks, regulators, and tax authorities, amongst others.

The first actor is Bitcoin *blockchain*, which defines the set of rules through algorithms. The algorithm also reflects the ideological foundations of Bitcoin, such as decentralization, democracy and anonymity.

Miners range from individuals with limited computing power to large companies with considerable computing power at their disposal. Bitcoin mining is a competitive and risky endeavor. Miners need to wait very long periods to confirm a block and receive the reward for identifying the block. To reduce revenue variance, miners join *mining pools* and bundle together their computing power. Revenues depend on the amount of work the miner contributed to finding the block. As noted earlier, miners are powerful and important actors in the network, since the continuation of the blockchain depends on them. Mining pools may have informal voting mechanisms about which version of the coin to mine.

Bitcoin *core developers* are those who develop the Bitcoin source code. As Bitcoin is an open source project, anyone with sufficient programming skills can become a developer to contribute to the source code. However, approval is needed to become a core developer. As described earlier, updates to the Bitcoin protocol are developed as BIPs, and submitted for review to the approval community. Thus, Bitcoin core developers are also powerful actors in the network who can contribute to split.

Exchange/marketplace owners provide the marketplace to connect Bitcoin buyers and sellers. They are also important actors that may trigger splits

indirectly. The marketplaces make it easy to buy and sell Bitcoin in real money. They may play an important role in a split by supporting and including the forked coin in their marketplace. Such information can be used to promote the newly created coin among investors. If the exchange supports a split, the traders generally receive an equivalent amount of new coin (known as "air drop") after the split. If the split is not supported, customers are not awarded the new coin.

Investors, particularly large institutional investors, are also important in split decisions, as they can manipulate the price of Bitcoin.

Merchants are those who adopt Bitcoin as a payment method in their business. They typically need a fast and secure payment system or want to differentiate themselves from competitors by providing the option to pay with Bitcoin. While Bitcoin may be seen as a secure payment method, it is often slow due to scalability issues. Thus, merchants may not adopt Bitcoin as a *payment method*, which may in turn trigger a split in Bitcoin to make it faster.

Mining hardware manufacturers produce the specialized hardware to mine Bitcoin. At the beginning, CPU- based mining was possible for Bitcoin. As time passed, the complexity of mining algorithm increased and even GPU-based mining

become impossible. Today, specialized ASIC miners are needed for mining due to high complexity.

Finally, a *wallet* is the software or app where people keep their Bitcoins. Wallets include desktop wallets, mobile wallets, and hardware wallets. Wallets allow consumers pay Bitcoin for their purchases. Thus, they play an important role in wider adoption of Bitcoin.

Table 2. illustrates the various actors and their heterogeneity from *social*, *technological*, and *economic* dimensions in the Bitcoin community. For example, from social dimension point of view, miners can be individuals or even organizations and they may become part of a mining pool and collaborate with each other for mining. From technological point of view, the miners need to own computers, applications, cooling hardware, and electricity for mining. Finally, from the economic point of view, the miners want to earn money from mining.

Furthermore, it should be noted that the actors might play multiple roles in the network. For example, an individual can be a developer, miner, and investor. A mining hardware manufacturer produces and sells the equipment but also acts as a miner. These all reflect the heterogeneity of the involved actors in the Bitcoin ecosystem.

Table 2. Illustration of heterogeneity of actors

Actor type	Identified heterogeneity of actor types		
	Social	Technology	Economic
Blockchain	Ideologies, motivations, collaboration, competition	Algorithms, Internet, computing power, electricity, storage space	Incentives
Miners	Individual miners, mining pools, interactions and collaborations within community	Computers, computer programs, electricity, cooling hardware, web-based applications	Money
Bitcoin core developers	Individual developers, groups and networks of developers, developer societies	Computers, programs, education forums on the web	Employment, asset ownership
Exchanges/ Marketplaces	Individual company, network of companies	Technology for trading	Information, trading volume
Investors	Individual investors, institutional investors	Technology for trading	Money
Merchants	Individual merchants, retailers, wholesalers	Technological infrastructure for payment systems	Payment processing fees, processing speed
Hardware manufacturer	Individual manufacturer, networks of manufacturers	Mining algorithms, specialized hardware for mining (e.g., ASIC)	Money, amount and price of hardware sold
Wallets	Consumers, merchants	Desktops, mobile devices including software and hardware technology, security	Revenue model

6.2. The fork as a translation process

First, we describe *problematization* in the Bitcoin case. Bitcoin suffers from a scalability problem due to its wider adoption. In short, as the currency grows,

so does the number of transactions. Thus, the one-megabyte block size limit became a bottleneck, with transactions waiting a long time for confirmation. During the worst periods of these performance issues in January-February 2018, the average transaction processing times exceeded 10,000 minutes[1], obviously limiting the currency's commercial use.

As Bitcoin is open-source, anyone can put forward proposals for improvement. For example, in order to solve the scalability issue, two possible (and opposing) paths were identified. Bitcoin core-developers were the focal actors for the first path, and their proposal was to allow some data to be moved outside of the main network, creating multiple ledgers or side chains. This is known as Segregated Witness (SegWit). Some miners viewed activating SegWit without increasing the block size would not help and is just a temporary solution to the scalability problem. Although many developers were against increasing the block size, a significant portion of the Bitcoin community decided to increase the block size to two megabyte (this is known as SegWit2x). This can be seen as *enrollment* in the ANT terminology. However, SegWit2x ultimately failed to find consensus among the community and core developers. This reflects what ANT refers to as *betrayal*.

Another competing solution was simply to increase block size to accommodate more transactions per block. The focal actors were Bitmain, an ASIC Bitcoin mining hardware manufacturer, and its mining pool. They established themselves as the OPP by promising mining support (*interessement*). Thus, some developers also took interest in the option (*enrollment*). In addition, this group of the community believed that SegWit2x might eventually fail or at least would not be executed in the near future. Thus, the community decided to split and make the new coin, BCH (i.e., *mobilization* occurred).

The Bitcoin gold split unfolded in a different way. While BCH was created to tackle Bitcoin's scalability problem, Bitcoin Gold aimed to mitigate the increasing centralization of the Bitcoin mining industry. As described earlier, Bitcoin mining has become increasingly processor-heavy, and custom-built ASICs are a popular solution. Bitcoin mining became an industry, where the leading companies accounted for a huge amount of network processing power. As shown in Table 3, just a few big mining players hold the majority of that power. Thus, a

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[1]   (https://blockchain.info/charts/avg-confirmation-time, accessed on 15 June, 2018 at GMT 13:24)

developer team became the focal actor and introduced an alternative mining algorithm (equihash), which is suitable for GPUs, and they claimed that creating Bitcoin gold made mining democratic again.

Table 3. Computing power distribution among mining pools

Mining pool	Computing power %	Progressive %
BTC.Com	26.7	26.7
AntPool	12.9	39.6
SlushPool	12.0	51.6
ViaBTC	11.7	63.3
Unknown	9.0	72.3
BTCTOP	8.4	80.7
F2Pool	7.2	87.9
BTCC Pool	3.1	91.1
BW.com	2.2	93.3
BitFury	1.5	94.8
BitClub Network	1.5	96.3
58COIN	1.2	97.5
GBMiners	1.0	98.5
Bitcoin.com	0.7	99.2
KanoPool	0.3	99.5
ConnectBTC	0.2	99.7
BitcoinRussia	0.2	99.9
Total	100.0	~100

Source: https://blockchain.info/pools, accessed on June 15, 2018 at GMT 13:00

7.1. Key findings

We highlight three main findings from the study. The first relates to actor heterogeneity. We found that each actor type includes heterogeneous features, which could be classified into three broad categories: social, technological, and economic. Our findings show the Bitcoin actor-network comprises key non-human actors such as the blockchain itself and wallets. Other non-human actors, such as technology (e.g. code, algorithm, electricity), as well as institutions (regulators, central banks, global financial system) and ideologies (e.g. an inclusive and democratic global payment system) influence the split process as embedded in the focal actors.

Our second key finding focuses on the role of actor heterogeneity, particularly related to the translation process. We observed that many of the actors involved in the process could have both a micro and macro nature. For example, a miner can be an individual (micro actor) as well as a mining pool (macro actor). We also observed there is a constant flux between micro and macro positions, as individual miners aggregate their resources and form

mining pools. Furthermore, certain mining companies have become heavily involved in hardware manufacturing. By moving into a macro actor position they can exert considerable power in the network. Altogether, Bitcoin mining has become an oligopolistic market, dominated by a small number of large mining companies. As a result, miners without ASIC technology and/or affordable electricity at their disposal have largely abandoned Bitcoin.

The third key finding relates to the dynamic nature of the non-human actors, as ideologies may contribute to a blockchain split. For example, one interviewed miner reported he had engaged in mining primarily due to intellectual curiosity in the technology, but had lost much of his interest due to the shift to ASIC mining. Similarly, a blockchain entrepreneur said the hype around Bitcoin has had a profound influence on the community dynamics, as economic interests and incentives have overridden idealism.

7.2. Contributions

Our study extends the current literature in three specific areas. First, in its principal area of contribution, the study advances the understanding of blockchain forks by elaborating on the actors involved and their heterogeneity in a cryptocurrency context. To this end, our results suggest the actors in Bitcoin forks are considerably more heterogeneous and their networks more complex than has been reported in the prior literature on OSS forks [10, 25, 29]. We identified eight types of actor involved in Bitcoin forks. We have further elaborated on their behavior in micro and macro settings for negotiations related to forking the blockchain. Moreover, our findings highlight the fluidity of actors' roles prior to, during and after the blockchain split. We believe the actor types that we found in this study are generic in nature and thus are applicable for other cryptocurrencies such as Ethereum. Furthermore, we believe a similar approach can be followed to investigate OSS forks to identify communalities and differences with blockchain forks.

Second, pertaining to a more theoretical sphere, the present study adds to the current ANT research focusing on blockchain [6, 33, 37]. To this end, our findings increase the understanding of the role and constant fluid constellation of the blockchain network, caused by actor heterogeneity. Moreover, in analyzing their heterogeneity, we provide a fine-grained account of the actors involved in blockchain forks. As our specific contribution to the ANT literature [6, 33], we have described how the micro actors engage with, and even fuse with, other micro

and macro actors, and elaborated on the consequences of these fusions. They are poorly understood theoretically as well as in practice due to their complex nature. For instance, rather than considering blockchain as a single technology, ANT provides specific assets to understand blockchain as a network of heterogeneous agents with diverse ends.

Third, our findings advance the understanding of cryptocurrencies as actor-networks. Our analysis revealed the actor-network involved in Bitcoin forks comprises not only human but also non-human actors and interplay between the two. For example, the constantly increasing algorithmic complexity in Bitcoin mining requires significant amounts of computing power and electricity. This has led to a situation where institutional miners with significant financial investment acquired the required computing power and now dominate Bitcoin mining (see Table 3). This, in turn, fundamentally questions the open, decentralized nature and ideology underlying Bitcoin.

In sum, the study contributes to the discussion on the roles and interplay of human and non-human elements of information systems [e.g. 1, 21, 31]. Furthermore, we ask to what extent agency could and should be attributed to non-human actors [28], and what are the potential consequences of non-human agency. From a broader perspective, our study contributes to growing the discussion on interplay and power relations between technology and humans [7, 16, 22].

7.3. Limitations and future research

The study has a number of limitations. First, the empirical research focused solely on Bitcoin forks. However, we hold that the actors and the nature of their heterogeneity identified in Bitcoin, provide meaningful insights into other cryptocurrencies (e.g. Ethereum), where mining and miners play a key role. Nevertheless, there are also cryptocurrencies such as Ripple (XRP) that have been pre-mined by the developer team. This implies the applicability of our findings to other contexts and instances of blockchain forks requires additional research. Thus, we suggest future research could extend the scope of empirical investigation to other instances of blockchain forks, to specifically focus on investigating the potential commonalities and differences between blockchains.

Second, our study comprises empirical data from two online sources and five interviews. Yet, the aim of the study was to address a new theoretical opening in decentralized technologies, so obtaining additional empirical data is essential to reinforce the trustworthiness of the interpretations.

Third, the choice of theoretical lens obviously has a profound influence on the interpretations drawn from the empirical data. For the present study, we adopted specific elements of ANT as our theoretical lens. In order to obtain different perspectives and interpretations of blockchain forks, we suggest additional research should scrutinize the advantages and disadvantages of different theoretical lenses in understanding blockchain splits.

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9. References

[1] Benbasat, I., and R.W. Zmud, "The Identity Crisis Within the IS Discipline: Defining and Communicating the Discipline's Core Properties," MIS Quarterly, 2003, 27 (2), pp. 183-194.

[2] Bijker, W.E., T.P. Hughes, T. Pinch, and D.G. Douglas, The social construction of technological systems: New directions in the sociology and history of technology, MIT Press, Boston, MA, 2012.

[3] Callon, M, "Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieux Bay". In J. Law (ed.), Power, Action and Belief: A New Sociology of Knowledge. Routledge and Kegan Paul, London, 1986, pp. 197–225.

[4] Callon, M, "Techno-economic networks and irreversibility." In J. Law (ed.), A sociology of monsters. Essays on power, technology and domination, Routledge, London, 1991, pp. 132-161.

[5] Callon, M., and E. Latour, "Unscrewing the big leviathan: How actors macro-structure reality and how sociologists help them to do so." In K.D. Knorr-Cetina and A.V. Cicourel (eds.), Advances in Social Theory and Methodology: Towards an Integration of Micro and Macro Sociologies. Routledge and Kegan Paul, London, 1981, pp. 277–303.

[6] De Filippi, P, and B. Loveluck, "The Invisible Politics of Bitcoin: Governance Crisis of a Decentralized Infrastructure." Internet Policy Review, 2016, 5 (4) pp. 1-28.

[7] DuPont, Q, Experiments in algorithmic governance: A history and ethnography of "The DAO," a failed decentralized autonomous organization, Bitcoin and Beyond, Routledge, London, 2017, pp. 157-177.

[8] Eisenhardt, K. M, "Building theories from case study research," Academy of Management Review, 1989, 14 (4), pp. 532-550.

[9] Freeman, M, Modes of thinking for qualitative data analysis, Routledge, New York, NY, 2017.

[10] Gamalielsson, J., and B. Lundell, "Sustainability of open source software communities beyond fork: How and why has the LibreOffice project evolved?" Journal of Systems and Software, 2014, 89, pp.128-145.

[11] Iansiti, M., and K.R. Lakhani, "The Truth about blockchain", Harvard Business Review, 2017, 95 (1) pp. 118-127.

[12] Kow, Y. M., and C. Lustig, "Imaginaries and Crystallization Processes in Bitcoin Infrastructuring," Computer Supported Cooperative Work (CSCW), 2017, pp. 1-24.

[13] Latour, B, "On actor-network theory: A few clarifications," Soziale Welt, 1996, 47 (4), pp. 369-381.

[14] Latour, B, Reassembling the social: An introduction to actor-network-theory, Oxford University Press, Oxford, 2005.

[15] Latour, B, Science in action: How to follow scientists and engineers through society, Harvard University Press, Cambridge, 1987.

[16] Latour, B, "Some experiments in art and politics," In: Aranda J, Wood BK, Vidokle A (eds) The Internet does not exist—e-flux Journal, Sternberg Press, Berlin, 2015, pp. 40–53.

[17] Latour, B, Technology is society made durable, A Sociology of Monsters. Essays on Power, Technology and Domination, Law, J. (Ed), Routledge, London, 1991, pp. 103-131.

[18] Latour, B, "The Powers of Association. Power, Action and Belief. A new sociology of knowledge?" Sociological Review Monograph 32, Law, J. (Ed), Routledge & Kegan Paul, London, 1986, pp. 264-280.

[19] Law, J, After method: Mess in social science research, Routledge, New York, NY, 2004.

[20] Law, J, "Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity", Systems Practice, 1992, 5 (4) pp. 379-393.

[21] Leonard-Barton, D, "A dual methodology for case studies: Synergistic use of a longitudinal single site with replicated multiple sites," Organization Science, 1990, 1(3), pp. 248-266.

[22] Leonardi, P. M., and S.R. Barley, "Materiality and Change: Challenges to Building Better Theory about Technology and Organizing," Information and Organization, 2008, (18), pp. 159-176.

[23] Lindman, J., V. K. Tuunainen, and M. Rossi, "Opportunities and risks of blockchain technologies - A research agenda," In Proceedings of the 50th Hawaii International Conference on System Sciences (HICSS) 2017.

[24] Nakamoto, S, Bitcoin, A peer-to-peer electronic cash system, https://Bitcoin.org/Bitcoin.pdf Retrieved April, 20, 2018.

[25] Nyman, L., and J. Lindman, J, "Code forking, governance, and sustainability in open source software," Technology Innovation Management Review, January 2013, 7-12.

[26] Nyman, L., T. Mikkonen, J. Lindman, and M. Fougere, "Perspective of code forking and sustainability in open source software," In Hammouda, I., Lundell, B., Mikkonen, T., and Scacchi, W. (eds.), Open Source Systems: Long-term sustainability, Proc. 8th IFIP WG 2.3 International Conference, OSS, 2012, 378, pp. 274-279.

[27] Orlikowski, W. J, The sociomateriality of organisational life: considering technology in management research, Cambridge Journal of Economics, 2009, 34 (1), pp. 125-141.

[28] Pickering, A, "The Mangle of Practice: Agency and Emergence in the Sociology of Science," American Journal of Sociology, 1993, 99 (3), pp. 559-589.

[29] Rastogi, A., and N. Nagappan, "Forking and the sustainability of the developer community participation – An empirical investigation on outcomes and reason," In IEEE International Conference on Software Analysis, Evolution, and Reengineering, Suita, Japan, 2016.

[30] Robles, G., and J. Gonzalez-Barahona, "A comprehensive study of software forks: Dates, reasons, and outcomes," In Proceedings of the 8th IFIP WG 2.13 International Conference, Hammamet, Tunisia, 2012.

[31] Sarker, S., S. Sarker, and A. Sidorova, "Understanding business process change failure: An actor-network perspective." Journal of Management Information Systems, 2006, 23 (1), pp. 51-86.

[32] Severeijns, L,"What is blockchain? How is it going to affect Business?" 2017, Available at https://beta.vu.nl/nl/Images/werkstuk-severeijns_tcm235-869851.pdf

[33] Venturini, T., D. Ricci, M. Mauri, L. Kimbell and A. Meunier, "A, Designing Controversies and Their Publics," Massachusetts Institute of Technology Press (MIT Press), Design Issues, 2015, 31 (3), pp. 74 - 87.

[34] Viseur, R, "Forks impacts and motivations in free and open source projects," International Journal of Advanced Computer Science and Applications, 2012, 3 (2), pp. 117-122.

[35] Walsham, G, "Doing interpretive research," European journal of information systems, 2006, 15(3), pp. 320-330.

[36] Walsham, G, "Interpretive case studies in IS research: Nature and method," European Journal of Information Systems, 1995, 4 (2), pp. 74–81.

[37] Wright, A. and P. De Filippi, "Decentralized Blockchain Technology and the Rise of Lex Cryptographia" (March 10, 2015), Available at SSRN: https://ssrn.com/abstract=2580664 or http://dx.doi.org/10.2139/ssrn.2580664

[38] Yin, R. K, Case study research and applications: Design and methods, 6th ed., Sage publications, London, 2018.

[39] Yli-Huumo, J., D. Ko, S. Choi, S. Park, and K. Smolander, "Where is current research on blockchain technology?—a systematic review," PloS ONE, 2016, 11(10), pp. 1-27.