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Why do blockchains split? An actor-network perspective on Bitcoin splits

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ABSTRACT

This paper investigates the focal actors in a blockchain network and their heterogeneity in splits. Disagreements in blockchain communities often lead to splits in both the blockchain and the community. We use three key elements of the actor-network theory — punctualization, translation, and actor heterogeneity—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 blockchain, exchanges, hardware manufacturers, and wallets, involved in Bitcoin splits. Our results show that the consolidation of actors in homogeneous groups plays a key role in blockchain splits. We further describe how the human and non-human actors' fluid moves into micro and macro actor positions in the network affect the development of the split. In addition, we discuss the roles of these actors and their engagement in forming micro and macro agencies in blockchain splits.

1. Introduction

Disagreements within public blockchain communities often lead to a split that permanently diverges a blockchain into two or more potential paths (Nyman et al., 2012). Bitcoin Cash (BCH), for instance, resulted from a Bitcoin (BTC) split due to a disagreement among the communities about increasing the block size. In a similar vein, a split took place in Ethereum to create two separate blockchains, Ether (ETH) and Ethereum Classic (ETC), after the blockchain was hacked (DuPont, 2017). Public blockchains are permissionless, and anyone can join the network. They also are decentralized: no central authority or administration has control over the network (Wright and De Filippi, 2015). In contrast, private or consortium blockchains, such as Hyperledger, are permissioned and therefore impose restrictions on who is allowed to participate and make transactions.

The prevalence of splits in public blockchains can be attributed to the fact that blockchain-based services run in peer-to-peer networks of computers without a central authority (Wright and De Filippi, 2015; Yli-Huumo et al., 2016). Blockchain characteristically features nodes or miners that collectively validate and bundle batches of transactions into blocks and then add these blocks to a chronological chain (Wright and De Filippi, 2015). Instead of being stored on a central server, the chain containing the transaction history is stored and synchronized on each node in the network (Yli-Huumo et al., 2016).

In this paper, we are interested in public blockchain-based services that are maintained a community of miners and developers (Wright and De Filippi, 2015). As a result, resolving disagreements and reacting to major incidents such as catastrophic bugs, cyber-attacks, or performance issues (DuPont, 2017) within the heterogeneous community involves challenges that can ultimately lead to a blockchain split.

A blockchain split represents a major change in the evolution of a blockchain that creates uncertainty among developers, miners, and investors. At the same time, splits can create new opportunities for the actors involved. Understanding the events that lead to a split helps practitioners better evaluate the associated risks and benefits.

Despite the increasing managerial interest in the applications of blockchain technologies, there is nascent research on blockchain splits (De Filippi and Loveluck, 2016; Islam et al., 2019; Lindman et al., 2017). In particular, current literature lacks theoretical and conceptual tools with which to scrutinize and describe the key events and actors involved in blockchain splits.

To fill this theoretical and empirical void, this study addresses a threefold research question: *Why do blockchains split, who are the focal actors involved, and how does their heterogeneity manifest itself?* To this end, we employ the actor-network theory (ANT) (Callon, 1986; Latour, 1987; Law, 1992) as our theoretical and conceptual foundation. We present a longitudinal case study (Pettigrew, 1990; Van de Ven and Huber, 1990; Yin, 2018) of Bitcoin splits to theorize blockchain splits as

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a translation process (Callon and Latour, 1981) and to identify the key actors involved and the changes in the actors' roles and positions in the network. We further describe the role of actor heterogeneity (Law, 1992) in blockchain splits. As its principal theoretical contribution, our study advances the understanding of blockchain splits by mapping the key events and incidents that lead to a split and by identifying the key actors involved in the different stages of the process.

The remainder of the paper is structured as follows: after this introductory section, we describe blockchain splits. Next, we discuss how ANT and the concept of actor heterogeneity can be leveraged to study blockchain splits. We then present the methodological underpinnings of the study, followed by a description of our case. The fifth section covers the analysis and results. In the sixth and final section, we discuss the main findings and the contribution of the study, consider its limitations, and provide suggestions for future research.

2. Blockchain splits

Blockchain was originally developed to serve as the distributed ledger of Bitcoin (Lindman et al., 2017). Due to the growing interest in Bitcoin, new blockchains have emerged that use the source code originally developed for Bitcoin. In practice, developers active in the Bitcoin ecosystem have adapted and extended the original Bitcoin protocol to create new blockchain. In this sense, the creation of a new Altcoin can be viewed as a split in the community.

With respect to splitting a blockchain and preserving its transaction history, forking the blockchain is the only way to execute a split. A blockchain fork refers to a change in the blockchain's rules that effectively leads to a separation into two or more potential paths (Nyman et al., 2012). Forks can split a blockchain on either a temporary or permanent basis (Islam et al., 2019). For example, 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 upgraded and non-upgraded nodes. The forked chain, in turn, contains blocks only from the 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 else they will be mining unrecognized blocks. In contrast, a *hard-fork* is one that may lead to a permanent split in a blockchain (Islam et al., 2019). A hard-fork is not backward compatible; it 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. Ether and Ethereum Classic were created from Ethereum as the result of a hard-fork.

Building on Nyman et al.'s (2012) research on open-source project forks, we define a blockchain split as changes in a blockchain's rules that lead to permanent divergence of the blockchain and its development into two or more potential paths. The implications of blockchain splits can be scrutinized from technological, social, and economical perspectives (Islam et al., 2019). From a technological perspective, a split diverges the development path by accommodating the features of the community that supports the split. From a social perspective, the split triggers disagreements and uncertainty among the community. From an economic perspective, the split can bring large profits to some members of the community if the new chain attracts support from the community and survives.

Blockchain splits have been widely discussed, both in the news and in social media. Despite this considerable media coverage, little academic research has been focused on blockchain splits. While the blockchain literature has started to burgeon (Marsal-Llacuna, 2018; Pazaitis et al., 2017), there is little research theorizing blockchain evolution. The extant literature largely focuses on a selected technology focus (Yli-Huumo et al., 2016) or debates the dark side of blockchain, such as enabling anonymous actors to cover their illegal trades (Kow and Lustig, 2017).

As public blockchain projects are open-source, we conducted a literature review on open-source project splits. While a few prior studies focus on splits in an open-source context, most of the research (e.g., Gamalielsson and Lundell, 2014; Rastogi and Nagappan, 2016; Viseur, 2012) on open-source project splits investigates the survival of the original and forked projects after the split. The survival and community sustainability of the forked and original projects is not self-evident. In some cases, both the forked and the original projects survive and secure community support. We also observed that most studies on open-source project splits lack the application of theory, which inevitably limits their theoretical contributions (Islam et al., 2019).

We believe that the actors (and their network) involved in the ecosystem are critical to the survival of the blockchain project. Thus, research that applies a solid theoretical foundation to identifying the actors and examining the underlying network can significantly extend the current understanding of why blockchains split.

3. Actor-network theory

We draw on ANT (Callon, 1986; Callon and Latour, 1981; Latour, 1987, 2005; Law, 1992) as the theoretical foundation to study blockchain splits. The fundamental goal of ANT is to explore how networks are built or assembled by the actors to reach a certain objective (Latour, 2005). ANT provides a sociotechnical perspective (Latour, 1986, 1987, 2005) through which to analyze the complex interactions between technology and human processes (Bijker et al., 2012; Callon and Latour, 1981; Law, 1992). Thus, it has been widely applied to: 1) understand complex sociotechnical processes (Shin, 2010, 2016) associated with technology development, implementations, and assessments, 2) support these processes with relevant empirical data (Doolin and Lowe, 2002; Lamb and Kling, 2003; Sarker et al., 2006; Shim and Shin, 2019; Shin et al., 2011; Tatnall and Gilding, 2005), and 3) describe causal trajectory where “change occurs through the importation of heterogeneous new elements (e.g., ideas, actors, resources) into an entity (or loss of elements preexisting in the entity) and by the creation of new linkages among the entity's elements” (Markus and Rowe, 2018, p.1267). As a result, ANT provides a well-established set of theoretical tools and the vocabulary to describe and theorize blockchain splits.

In ANT, 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” (Callon and Latour, 1981, p. 286). In ANT, actors can include both social and technical entities (such as individuals, a group of individuals, organizations, ideologies, methodologies, and concepts) and artifacts, such as hardware and software (Latour, 1991). In addition, actors can be combinations of social and technical elements (Latour, 1987, 1991). According to ANT, “an actor is what is made to act by many others” (Latour, 1987, p. 46). This holds that actors cannot be classified into micro and macro actors. Rather, it is how a *micro actor* is translated into a *macro actor* by other actors using power (Callon and Latour, 1981)—for instance, a successful code script that other programmers adopt in their work or an institution such as a hardware manufacturer that receives appropriation by many actors. A macro actor position is achieved as others homogenize their will to one actor, but it does not hold until another network assemblage or translation of the movement occurs (Callon and Latour, 1981; Latour, 1991).

ANT does not make an a priori distinction between human and non-human actors (Latour, 1991; Law, 1992). Rather, it naturally emphasizes the role of non-human actors such as technology (Latour, 2005), which enables investigation into complex sociotechnical processes such as blockchain splits. Nor does ANT make an a priori distinction between micro (individual) and macro (groups or organizations) actors in advance (Callon and Latour, 1981; Law, 2004). Accordingly, any actor—whether an individual, object, or organization—is equally important in creating a network (Latour, 1991). This equality allows the actors in the network to be scrutinized with different levels of analysis (Callon and Latour, 1981), which can lead in turn to a more nuanced understanding of the actors and their roles. Hence, ANT provides both a well-established theoretical perspective and analytical flexibility, facilitating the development of a new theory on blockchain splits.

For these reasons, we apply ANT to the blockchain domain to interpret, describe, and understand the complex social processes associated with blockchain splits. We adopt relational, aka *flat*, ontology (Latour, 1987, 2005), which highlights the centrality of the network, and a *process* view (Garud and Turunen, 2017; Langley et al., 2013), which focuses on becoming, change, and flux and acknowledges, rather than reduces, the complexity of organizing. We employ three key elements of ANT: *punctualization*, *translation*, and *actor heterogeneity*.

3.1. Punctualization

ANT emphasizes the network and assumes that nothing lies outside it. Thus, each actor can be defined and understood only in relation to other actors in the network (Law, 2004). This implies that any actor can be considered a network of smaller actors—for example, a computer is a complex system (a network) that contains many electronic elements (actors) that are hidden from the user, who simply uses the computer as a single object (actor). In ANT, this simplification is referred to as *punctualization* (Callon, 1991, p. 153), and it allows a researcher to understand a network at different levels of complexity or granularity, depending on the research objective.

3.2. Translation

We apply the concept of *translation* from ANT to describe blockchain splits as a process. Translation is a process that creates “a temporary social order, or movement from one order to another, through changes in the alignment of interests in a network” (Sarker et al., 2006, p. 54). There are four phases or moments in translation: problematization, interessement, enrollment, and mobilization (Callon, 1986).

In *problematization*, the *focal actor* (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* between the other actors and the network to render itself “indispensable” (Callon, 1986). An obligatory passage point refers to the process of forming a shared focus among the relevant actors to successfully pursue an interest. The second phase of translation is *interessement*, which involves convincing other actors through *negotiation* to have an interest that is *aligned with* the focal actor. Incentives can be given to the other actors so that they pass through the obligatory passage point and align their interest with the focal actor (Sarker et al., 2006).

Successful interessement is followed by *enrollment,* which involves defining the roles of each actor in the transformed or newly created actor-network. As 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” (Callon, 1991). It should be noted that enrollment is temporary; *betrayal* by enrolled actors (failing to act as promised) is a possibility (Sarker et al., 2006). Betrayal refers to a situation where actors do not abide by the agreements arising from the enrollment (Callon, 1986; Sarker et al., 2006). On the other hand, if the actors enrolled in the network adequately represent the masses, enrollment manifests as active support and *mobilization* occurs (Shin, 2016).

3.3. Actor heterogeneity

Heterogeneity is “the quality or state of being diverse in character or content” (Oxford English Dictionary, 2018). The concept of heterogeneity maintains a fundamental stance in the actor-network perspective (Law, 1992; Latour, 2005, 1989). In general, the terms *heterogeneous network* and *sociotechnical network* are used to overcome what actor-network scholars consider to be an unnecessary duality between humans and non-humans (Law, 1992; Latour, 2005, 1989). For instance, John Law (1992, p. 380) describes any end-product, such as a scientific fact, as “a process of heterogeneous engineering in which bits and pieces from the social, the technical, the conceptual and the textual are fitted together, and so converted (or ‘translated’) into a set of equally heterogeneous scientific products.” Law (1992) further argues that what is true for science is also valid for things such as family, the economy, social institutions, technology, and computing systems. According to Law (1994), human and non-human actors play equally important roles in the construction of actor-networks. This particular aspect of ANT is called *generalized symmetry* (Callon, 1986), and it recognizes that the social is materially heterogeneous and the technical is socially heterogeneous. Therefore, ANT emphasizes studying the *associations* between heterogeneous actors (Latour, 2005). These associations reflect how a network becomes durable as well as larger and more influential than others in terms of power (Latour, 1999). It is important to note, however, that power is a final state only—not a substance—and therefore it does not mean durability (Latour, 2005: 64–66). The idea of a heterogeneous network can be used to describe that everything—-people, machines, social institutions, organizations, and politics—is the product or effect of heterogeneous networks (Law, 1992). This implies that a blockchain is nothing other than patterned networks of heterogeneous materials. In this view, the task of researchers is to characterize these networks in their heterogeneity and explore how they come to be patterned to generate effects such as splits in blockchain. The idea of a heterogeneous network can be used to describe the constellation of actors during Bitcoin evolution and key events that trigger splits.

4. Methodology

4.1. Research method and data

We employed case study methodology (Eisenhardt, 1989; Yin, 2018) to investigate blockchain splits. We adopted a longitudinal single-case approach (Leonard-Barton, 1990; Yin, 2018) and focused specifically on Bitcoin, as it was the first blockchain-based application and has undergone several splits. These events have attracted considerable attention on traditional and social media, thus enabling us to collect rich data from several sources.

The single-case approach is suitable

when a case is particularly exemplary (Yin, 2018) and when it is examined over time (Leonard-Barton, 1990; Pettigrew, 1990). Bitcoin can be considered an exemplary case (Yin, 2018) because cryptocurrencies are an important application of blockchain technology and because Bitcoin is the most valuable and widely used cryptocurrency. Blockchain splits also require examining the events preceding the splits, and thus the phenomena need longitudinal research attention (Leonard-Barton, 1990).

As is typical in case study research, the empirical data were collected from multiple sources (Yin, 2018: Pettigrew, 1990). Table 1 summarizes the data used.

The first phase of empirical research activities included netnography (Kozinets, 2010) of Bitcoin-related discussion groups and online forums. During 2015–2017, two of this study's authors were involved in trading Bitcoin, and the lead author was involved in the Bitcoin ecosystem as a miner and developer. The authors collected a data repository of articles, field notes, images, texts, memos of informal discussions on popular news sites, social media platforms, and discussion forums during this period. The netnographic engagement of the Bitcoin community enabled us to obtain a solid initial understanding of the focal phenomena as well as the key actors involved. This initial understanding also enabled us to reflect on and critically evaluate the

Table 1
Empirical data.

Data source	Nature of collected data	Type and quantity of collected data
Netnography in the Bitcoin ecosystem	Informal discussions with the ecosystem actors in discussion forums and on social media	Field notes, images, texts, memos of informal discussions with the ecosystem actors
Crypto news sites forums (CoinDesk, news.bitcoin.com)	News article titles and article content	288 news articles
Technical documentation	Descriptions of proposed updates related to the hard-fork (split)	Documentations corresponding to two splits (BCH and Bitcoin Gold)
Interviews	In-depth interviews with 5 Bitcoin experts	6 h and 30 min of interviews. Each interview lasted 30–90 min. Transcriptions of the interviews; interview field notes from the 3 interviewers of each interview

findings from other sources of data.

Next, we extracted secondary data on Bitcoin splits from coindesk.com and news.bitcoin.com (Bitcoin-focused online news sources) using the search keywords “fork” and “split.” We also obtained technical documentation of the protocol changes that took place within the splits.

Between February 2018 and June 2018, we conducted five in-depth, semi-structured interviews with expert members of the blockchain community, including developers, entrepreneurs, miners, and investors. The purpose of the interviews was to deepen the understanding of splits as a process from the key actors' vantage points. The interviewees were recruited using a snowball approach, and all were men. The interviews lasted from 30 to 90 min, and all authors were present at the interviews.

4.2. Case description

Bitcoin was the first application developed with blockchain technology (Iansiti and Lakhani, 2017). It is commonly believed that Bitcoin was invented by an unknown person or a group of persons under the pseudonym Satoshi Nakamoto (Nakamoto, 2008). Its genesis block emerged in January 2009.

Bitcoin was developed as a decentralized digital currency to revolutionize the traditional intermediary-based financial industry (Nakamoto, 2008). It continues to be developed and maintained as an open-source project maintained by a community. While the community members decide on the stages of Bitcoin evolution, the basic set of rules and functions allowed in Bitcoin cannot be changed without changing the source code considerably.

In principle, blockchain-based applications such as Bitcoin evolve by actor negotiation. A major change in Bitcoin's source code requires support from the community. Such changes may lead to member disagreement and may trigger splits in the original network. Once a split occurs, the two resulting blockchains become incompatible with one another. However, both blockchains can coexist if they can attract enough community members.

From Bitcoin's inception in 2009 to the end of 2017, there have been two coin splits (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 Fig. 1.

An update to the Bitcoin source code or protocol requires that Bitcoin Improvement Proposals are submitted by an individual or group of individuals in the Bitcoin community (which includes mostly developers). The team that maintains the Bitcoin core reviews the proposal with the community and seeks general approval. If the community signals approval, the update is pushed to the next version of the Bitcoin core. It is then up to the miners whether they run the updated client. If they decide not to run it, the update fails. Miners, therefore, are critical members of the Bitcoin community and play a key role in splits.

4.3. Data analysis

We used ANT to guide the data analysis. According to ANT, all components of a network (such as objects, ideas, processes, and any other relevant factors) are as important as humans in creating social situations (Callon and Latour, 1981; Latour, 1986). An actor-network is essentially an evolving entity whose articulations produce effects, leaving traces of its passage in the form of rigid and fluid structures and relationships (Bijker et al., 2012; Latour, 2005) referred to as *assemblage* (Latour, 2005: 217). Because ANT places its focus on the network and the constant flux of relations (instead of counting and categorizing end states or things), using ANT to guide the analysis is advantageous for explaining how complex things change (Latour, 1987, 2005). This helps us scrutinize the shifts in the actors' motives and positions as well as the associations between the actors.

We began the analysis by using the data extracted from online sources and the notes from the netnographic engagement with the Bitcoin community to identify the actors and their roles in Bitcoin splits and thus understand the actor-network involved. In other words, we used the ANT lens to analyze and interpret the data (Freeman, 2017; Law, 2004). We followed Latour's (1987, 2005) relational (flat) ontology and investigated the different actors in their natural settings, their constant process of making new associations with other actors,

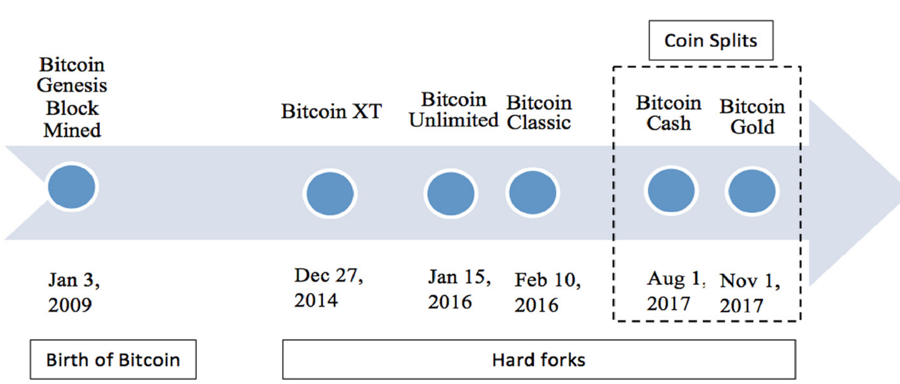

Fig. 1. Timeline of major events in Bitcoin history.

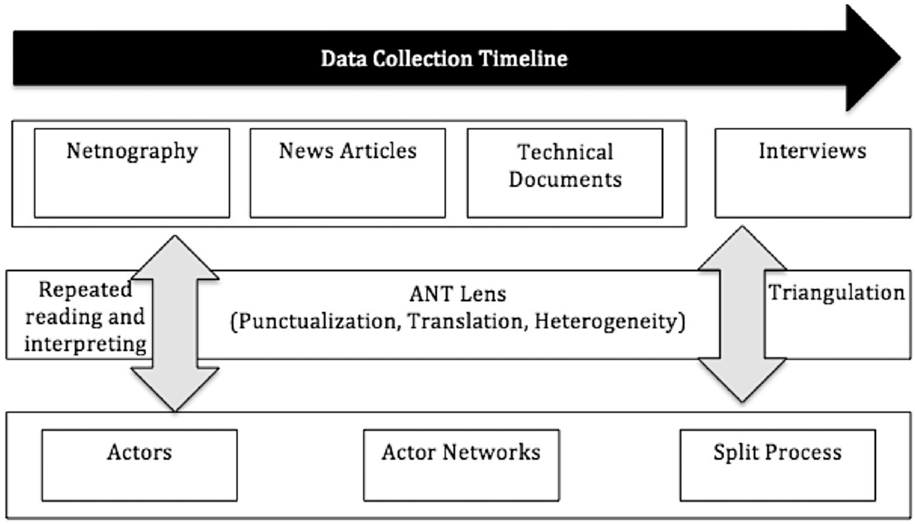

Fig. 2. Data analysis process.

and the manifestation of these associations (cf. Garud and Turunen, 2017). We read archival materials (articles, news forums), interacted with actors—both human (i.e., individuals, such as miners, developers, and investors) and non-human (i.e., codes, algorithms, and electricity)—in their natural settings (i.e., participating in mining, interacting in discussion forums) and tried to learn from them during the research process (Latour, 1987, 2005). This analysis included several rounds of reading the data, which was done independently by the authors for the purpose of making sense of the sociotechnical mess (Law, 2004) of the actors' visible and hidden traces (Latour, 1987, 2005) in the data. We used the data from the interviews to triangulate the findings and obtain a deeper understanding of the actor-network, actors' sense-making (such as motives and conflicting roles), and the key events of the splits. The data analysis process is described in Fig. 2.

5. ANT perspective on Bitcoin and its splits

5.1. Actors and the network

We identified eight types of focal *actors* in the Bitcoin network*: the blockchain, miners, core developers, exchange/marketplace owners, investors, merchants, hardware manufacturers*, and *wallets*. The actors in the Bitcoin network comprise micro actors such as people, ideologies, technology (such as code scripts), and the diverse interests of individuals, while the macro actor positions included institutions, companies, banks, and tax authorities. According to ANT, there is constant flux in actor positions—for example, a micro actor who moves into a macro actor position, such as a script that the community agrees to adopt, traditional investors who invest large amounts into the Bitcoin market, and others.

Drawing on the concept of punctualization (Callon, 1991), Table 2 illustrates the main actor types and their respective actor-networks. For presentation purposes, we have classified the actors involved into *social*, *technological*, and *economic* categories. This categorization is to illustrate the nature of actors' heterogeneity, such as *a code* that might usually be identified as *an outcome of a human actor*—such as a *developer*—or as a *technical*, such as a programming script that stresses that the social, technological, and economical spheres would happen in isolated realms. In this table, we want to emphasize that a *blockchain* is not only a technology but also an actor itself and an actor-network of heterogeneous actors such as ideologies, codes, coders, ethics, money, electricity, mining pools, institutions, and so on that is constantly moving and changing. We also want to emphasize the heterogeneous positions the actors can take, such as miners, investors, coders, electricity, regulators, revenue models, manufacturers, etc.

The first actor in Table 2 is the Bitcoin *blockchain*, which defines the set of rules through algorithms. The Bitcoin blockchain is an actor itself but also involves other heterogenous actors, such as rules, ideologies, algorithms, internet, computing power, storage space, and incentives, in a simplified form of granularity. The social dimension includes the rules and ideological foundations of Bitcoin, such as decentralization, democracy, and anonymity. From a technological viewpoint, the Bitcoin ideologies are implemented using algorithms that run over a network of computers with varying computing power. The chain is not stored in a single storage device but is distributed throughout the network of computers running a Bitcoin client. From an economic perspective, the Bitcoin blockchain provides the mechanism that determines the incentives to the miners.

Miners comprise individuals with limited computing power as well as large companies with considerable computing power at their disposal. The actor-network around miners may contain heterogeneous actors such as computers, cooling hardware, electricity, applications, and money. Bitcoin mining is, essentially, a competitive and risky endeavor. Miners need to wait lengthy periods to confirm a block in order to receive the reward for identifying that block. From a technology perspective, the miners need to acquire technical resources such as computers, cooling hardware, electricity, and web applications.

To reduce the variance in revenue and decrease the investment in obtaining the required resources, miners join *mining pools* and bundle their computing power together. Mining pools represent a key social dimension of miners as actors and act as a means by which to mitigate the economic risks associated with mining. The distribution of revenues in mining pools typically depends on the amount of resources (e.g., computing power, money) the miner has allocated to the pool. Ultimately, for most miners, mining is about making money. However, miners interviewed in this study described Bitcoin mining as no longer being profitable for individual miners due to the high cost of electricity. As a group, miners are powerful and important actors in the network because the continuation of the blockchain ultimately depends on them. The following interview quote illustrates the importance of miners:

> "Basically, the miners have the power. Miners decide which blockchain solution is going to stay alive. I can come up with my supercool blockchain solution, but if no one is going to mine, which means, no one is going to approve and create new blocks, it's not gonna fly. Miners decide what they want."
>
> (Blockchain entrepreneur and developer)

Bitcoin *core developers* are actors who develop the Bitcoin source

Table 2
Illustration of actor heterogeneity.

Actor type	The simplified actor-network		
	Social	Technology	Economic
Blockchain	Rules, ideologies	Algorithms, internet, computing power, storage space	Incentives, price of electricity
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, software programs, education forums on the web	Employment, asset ownership
Exchanges/marketplaces	Individual company	Technology for trading	Fees, trading volume
Investors	Individual investors, institutional investors	Technology for trading	Money
Merchants	Individual merchants, retailers, wholesalers	Technological infrastructure for payment systems	Payment processing fees
Hardware manufacturers	Individual manufacturers, networks of manufacturers	Mining algorithms, specialized hardware for mining (e.g., ASIC)	Price of hardware sold
Wallets	Consumers, merchants	Computers, mobile devices, security	Revenue model

code. The actor-network around the core developers involves other actors, such as computers, software, education forums, employment, and assets as reward. As Bitcoin is an open-source project, anyone with enough programming skills can become a developer, join the network of core developers, and contribute to the source code. However, approval is needed to become a core developer. As discussed previously, updates to the Bitcoin protocol are developed as Bitcoin Improvement Proposals and are submitted for review and approval by the core developer community. The mechanism for reviewing and approving changes in the protocol thus represents a key social dimension of core developers as actors. With respect to the technological dimension, the core developers need to have computers, network connectivity, the required software tools, and educational forums to learn about coding on the Bitcoin platform. From an economic standpoint, being a core developer can translate into employment opportunities in companies developing blockchain technologies and applications as well as opportunities to leverage the insider view in obtaining assets or in trading Bitcoin.

Exchanges/marketplaces allow connecting Bitcoin buyers and sellers. They are also important actors that may indirectly trigger splits. Essentially, marketplaces facilitate buying and selling Bitcoin with real money. Exchanges can play a key role in a split by supporting the forked coin and including it in their selections. 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 after the split (known as “air drop”). If the split is not supported, customers are not awarded the new coin. The role of exchanges also includes a technological dimension, as they provide trading tools for their customers. Finally, with respect to the economic dimension, the exchanges generate revenue through trading via volume-based customer fees. The simplified actor-network therefore involves actors such as the technology for trading, revenue, and trading volume.

Investors are actors and comprise both individual and institutional investors. They can establish formal and informal relationships and social networks that, for example, exchange investment- and trading-related information. Investors, particularly large institutions, play an important economic role in split decisions because they can manipulate the price of Bitcoin. With respect to the technology dimension, investors need to own computers and technologies for trading. Therefore, the other actors relevant for investors are computers, technologies for trading, and money.

Merchants are businesses that accept Bitcoin as a means of payment. 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 a secure payment method, it is often slow due to scalability issues. Thus, merchants may not adopt Bitcoin as a *payment method*; in turn, this may trigger a split in Bitcoin to make it faster. Technological infrastructure for payment processing is needed to foster the adoption of Bitcoin. Therefore, other actors relevant for merchants are payment processing infrastructure, processing fees, and processing speed.

Mining hardware manufacturers produce specialized hardware to mine Bitcoin. The actor-network around mining hardware manufacturers involves actors such as mining algorithms, specialized mining hardware, and revenue. In the beginning, CPU-based mining was possible for Bitcoin. Over time, however, the complexity of mining algorithms increased until even GPU-based mining became impossible. Today, specialized ASIC miner computers are needed for mining due to its high complexity. Only a few hardware manufacturers produce these special ASIC miners.

Finally, a *wallet* is the software or app in which people keep their Bitcoin. The simplified actor-network around a wallet involves actors such as consumers and merchants. The non-human actors include computers, mobile devices, security, and revenue models. Both consumers and merchants need to own wallets for transactions. Wallets include desktop wallets, mobile wallets, and hardware wallets. They allow consumers to pay for their purchases with Bitcoin. As such, they play a key role in the wider adoption of Bitcoin as a means of payment.

It should be noted that actors may play multiple and conflicting roles and can move into both micro and macro actor positions in the network. For example, a single individual can be a developer, a miner, and an investor. A mining hardware manufacturer can produce and sell mining equipment and also act as a miner. These possibilities reflect the conflicts of motives by the actors involved in the Bitcoin ecosystem. In addition, new actors can enter the actor-network or move into macro actor positions. Electricity, for example, can be considered an example of such a transfer from a micro to a macro actor position since the availability of affordable electricity has become a critical prerequisite for mining.

5.2. Bitcoin split as a translation process

In ANT (Callon, 1986; cf. Sarker et al., 2006), problematization refers to a moment in the translation process when a focal actor defines the identities and interests of other actors that are consistent with its own interests and establishes itself as an obligatory passage point. At this point, the actor makes itself indispensable.

Due to increased user adoption, Bitcoin has suffered from scalability problems. In practice, 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 and February 2018, the average transaction processing time exceeded 10,000 min, which obviously limited the currency's commercial use by the end users. One of our interviewees stated that the problem was related to the core algorithm because it artificially slows down when there are more transactions:

> "…the real problem is with some core algorithm. So they are artificially slowing down the network. Because if it was faster, that algorithm would fail. So in order to actually verify that the transactions are real, and nothing bad happens, they have to slow it down. So the more power comes to the network, the difficulty rises in order to keep the transaction volume at a low level."
>
> (Blockchain entrepreneur and developer)

As Bitcoin is open-source, anyone can put forth proposals for improvement. To solve the scalability issue, for example, two possible yet largely opposing future paths were identified by the community members. One of our interviewees considered the tendency to create opposing paths as characteristic of open-source communities such as public blockchains. As the interviewee explained:

> "It's [the] same with open-source movements…people can be really fanatic about something, so if you support something, you are against something else."
>
> (Blockchain developer)

Bitcoin core developers were the focal actors in one of the proposed paths. Their proposal was to allow some data to be moved outside the main network, thus creating multiple ledgers or side chains. This approach is known as Segregated Witness (SegWit). However, some miners believed that activating SegWit without increasing the block size would not help—they considered it only a temporary solution to the scalability problem. Although many developers were against increasing the block size, a significant proportion of the Bitcoin community decided to increase the block size to two megabytes (this is known as SegWit2x). Through the ANT lens, this change can be seen as *enrollment,* or a moment of translation wherein other actors in the network accept (or become aligned to) interests defined for them by the focal actor (Callon, 1986; Sarker et al., 2006). SegWit2x ultimately failed to find consensus among the community as the core developers cited a lack of replay protection (an algorithm that ensures a transaction in chain A is not valid in chain B after the fork). This lack of consensus reflects what ANT refers to as *betrayal*. For example, several mining pools (including F2Pool) and exchanges initially agreed on SegWit2× but later rescinded their support. Josh Scigala, the founder of Vaultoro exchange and eWallet, tweeted, "*As any good businessman, I stick to my word/signature and would have followed through with 2× but I cannot without replay protection.*" In an official announcement, Wayniloans cofounder and CEO Juan Francisco Salviolo explained, *"On Wayniloans part or our business is achieved thanks to Bitcoin, and on May we agreed to a sentence to reach consensus for the good of the ecosystem. … At the time we didn't know that existing developers wouldn't support it, or that most Latin American Bitcoin users, our customers, would view it as an contentious proposal".*

The second proposed path to fix the performance problem was simply to increase the block size to accommodate more transactions per block. The focal actor in these events was Bitmain, an ASIC Bitcoin mining hardware manufacturer, and its mining pool. Bitmain promised mining support, which we can view as *interessement,* or negotiation with actors to accept the definition of the focal actor (Callon, 1986; Sarker et al., 2006). With this interessement, Bitmain established itself as an *obligatory passage point.*

Bitmain was a big hardware manufacturer with a large mining pool. It homogenized the miners and accumulated significant mining power by manufacturing specialized hardware for miners and running a mining pool. As a result, some developers decided to support Bitmain's proposed path. In ANT, this represents another instance of *enrollment.* This segment of the community also believed that SegWit2x might eventually fail or that it would not be executed soon. Thus, the community decided to split and make a new coin (BCH). In ANT terms, reaching this decision can be described as *mobilization*, or the final phase of the translation process in which the key actors ensure that supposed spokespersons for relevant collective entities adequately represent all members of the network that are acting as a single agent (Callon and Latour, 1981). The role of Bitmain as a focal actor and its impact on the creation of Bitcoin Cash was highlighted by an interviewee:

> "[Bitmain is] a huge corporation. It's in some ways like an umbrella corporation. They do all sorts of things. I think they changed the pricing of some of these—some of the miners [mining machines] that you could only buy with Bitcoin Cash. So, people suddenly wanted to buy Bitcoin Cash in order to buy the hardware…So, they actually caused that rate of Bitcoin Cash to go up. It was quite a significant increase"
>
> (Bitcoin miner)

Although the Bitcoin Gold split emerged in a different way, it can also be attributed to the consolidation of actors in homogeneous groups. 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 above, Bitcoin mining has become increasingly processor-heavy, and custom-built ASICs are the only solution. It has become an industry in which the leading companies account for a significant amount of network processing power. In other words, the Bitcoin mining industry has been homogenized and is, in fact, dominated by a few major players. As Table 3 illustrates, only a few big mining players hold the majority of mining power. One developer team became the focal actor and introduced an alternative mining algorithm (Equihash) that is suitable for GPUs. They claimed that creating Bitcoin Gold made mining democratic again.

Taken together, Bitcoin splits can be seen as attempts to restore social order in the newly diverged chain. Due to the nature of blockchain technology, anyone—even micro actors—can (in principle) attempt to cause a split, but the success of the diverged chain depends on the participation of other actors, especially macro actors. Both BTC and BCH continue to exhibit a considerable consolidation of actors in homogeneous groups. This means that a key reason for the split that created them remains and may lead to new splits in the future.

5.3. Development of actors and the actor-network

The ideology of public blockchains embraces heterogeneity. By design, a public blockchain supports the participation of a wide variety of actors (e.g., miners, developers, investors, hardware manufacturers, rules, rewards, and specialized mining hardware, among others) and can be considered a heterogeneous network (Law, 1992). In addition,

Table 3
Computing power distribution among mining pools.

Mining pool	Computing power %	Cumulative %
BTC.com	26.2	26.2
AntPool	12.8	39.0
SlushPool	12.1	51.1
ViaBTC	12.0	63.1
Unknown	9.2	72.3
BTCTOP	8.0	80.3
F2Pool	7.4	87.7
BTCC Pool	3.3	91.0
BW.com	2.1	93.1
BitFury	1.6	94.7
BitClub Network	1.4	96.1
58COIN	1.3	97.4
GBMiners	1.1	98.5
Bitcoin.com	0.6	99.1
KanoPool	0.3	99.4
ConnectBTC	0.2	99.6
BitcoinRussia	0.2	99.8
Total	100.0	~100

Source: https://blockchain.info/pools, accessed on May 27, 2019at GMT 17:30.

the blockchain defines the roles of the actors in the network. The actors' roles are fundamentally different from one another. For instance, the miners' role is to use computing power to verify new blocks and add them to the blockchain, while the developers' role is to enhance the efficiency and functionality of the protocol. However, by obtaining the required resources (actors such as mining hardware, electricity, and programming knowledge), developers can also mine, and miners can also develop. This convergence of actors decreases heterogeneity by consolidating actors in homogeneous groups in the actor-network. Public blockchains were originally developed with the idea that mining can be done with general-purpose computers. In other words, anyone with a computer could become a miner. Thus, the mining network includes computers of varying processing power and architectures. For miners, however, the blockchain also contains a competitive element—the miner who wins the competition by verifying a particular block receives a reward. The difficulty of the mining algorithm increases as more miners compete to identify the blocks, and thus it may also reinforce consolidation of the miners in homogeneous groups. Because the difficulty and the computing power required to verify a block increase, miners work together and mine in a pool—an indication of the consolidation of miners in homogeneous groups. In Law's (1992) term, this can be viewed as an association that becomes durable as well as larger and more influential than others in terms of power. If mining is economically profitable, there is also an incentive to develop and build specialized hardware for mining. Because the mathematical complexity of verifying a block increases constantly, mining with a personal computer ultimately becomes impossible. By being the first to build the latest mining technology, hardware manufacturers have a considerable first-mover advantage in mining. Hardware manufacturers can also establish mining companies and mining pools, which further reinforce the trajectory toward the increased consolidation of miners into homogeneous groups.

Taken together, the ideologies behind a public blockchain essentially embrace heterogeneity and decentralization. However, the technological design of the blockchain may, in turn, support a trajectory toward the increased consolidation of actors into homogeneous groups. This increases the relative power of a small number of key actors and makes the blockchain more susceptible to changes.

In the case of Bitcoin, the actors and their networks have been constantly changing since its inception. In the beginning, developers and miners were the main actors, and they were originally involved in the network as individuals. In other words, the individual miners were able to mine Bitcoin with their own personal computers, so the network exhibited high degrees of actor heterogeneity. Over time, however, Bitcoin became more valuable, and new types of actors such as mining pools, investors, wallets, and merchants emerged. As the complexity of the mining algorithm increased, actors began to consolidate in larger entities. We found several instances of consolidation in our research. First, miners today operate predominantly in mining pools rather than as individual micro actors. Mining individually was the dominant approach until mid-2011. Until the end of 2012, more than 50% of overall mining power was attributed to individual miners. At this point, significant consolidation among the miners started to take place. Second, the consolidation of actors manifests itself in a way that allows an actor to play multiple roles. For example, mining hardware manufacturers (such as ASIC miners) run mining pools and own mining companies. The Bitcoin network has thus evolved from heterogeneity toward a network dominated by a small number of powerful macro actors. Due to their power in the network, the dominant actors can ignite splits to maximize their profits. To illustrate this, one of our interviewees termed the splits as a "greed-driven approach." As discussed, the mining machine manufacturer Bitmain played a strong role in creating BCH. Micro actors can also trigger a split and create a new coin with which to restore social order. Bitcoin Gold is such an attempt by a group of micro actors. One interviewee described the invisible power game of the split:

> "Bitcoin Cash was a precedent, and people say 'Oh, we can now fork, let's fork. I have this idea; I believe that would be better for Bitcoin—let's fork it.' The first question—why do you want to fork Bitcoin—why don't you create your own cryptocurrency from ground zero in the first place? The problem that these guys are solving doesn't need to keep the whole history of Bitcoin transactions, but [they] still keep Bitcoin transaction history. Why? It's very simple. It's all about greed-driven, mostly."
>
> (A blockchain developer)

Taken together, the increased centrality of power in the network creates disagreements in the community, which may lead to a split. After a split, however, the resulting new blockchain may still contain consolidated groups of actors. This is what happened in the cases of BTC and BCH.

6. Discussion

The purpose of this study was to examine why blockchains split, identify the focal actors involved, and determine how their heterogeneity manifests itself. To answer our research question, we have conducted and presented a longitudinal case study of Bitcoin splits during 2015–2018. We have analyzed data from online sources, technical documentation, netnographic engagement with the Bitcoin community, and in-depth interviews with Bitcoin experts. We employed ANT as a lens through which we interpret and analyze the data to identify the actors, the actor-networks, and their roles in the split process. In particular, we have considered the Bitcoin evolution according to relational ontology (Latour, 1987, 2005) and process view (Langley et al., 2013; Garud and Turunen, 2017) in order to better understand both the process and the outcomes of the blockchain evolution. In this way, we have increased the knowledge of the complexity of causal relationships (Markus and Robey, 1988; Markus and Rowe, 2018) in information sciences and society. We have focused on the translation processes (Callon & Latour, 1981) of two splits in Bitcoin history (i.e., BCH and Bitcoin Gold).

The results from the case study show that public blockchains such as Bitcoin are a network of heterogeneous actors. However, the increased centrality of power among the macro actors and their tendency to create a network with consolidated actors leads to splits. The splits may open new opportunities in the blockchain community but can simultaneously make some opportunities less favorable to some actors. The Bitcoin blockchain was revealed to be a complex constellation of human and non-human actors in constant flux and change. Therefore, Bitcoin is a complex social endeavor (De Filippi and Loveluck, 2016) related to technological development.

In the following sections, we highlight two key findings of our case study and discuss the three main contributions to the theorizing of blockchain technology.

6.1. Key findings

We will highlight two main findings from the study. The first relates to identifying and describing the actors involved in the Bitcoin ecosystem and unpacking their roles in the splits. Through our analysis, we identified eight focal actor types involved in Bitcoin splits: blockchain, miners, core developers, exchanges, investors, merchants, manufacturers, and wallets. However, each of these focal actors comprises other heterogeneous actors and their networks. Importantly, our findings show that the heterogeneous actor-networks of blockchain comprise non-human and human actors—both of which are key actors. Although the actor-networks are constantly changing, a momentary materialization of the actor-network can be recognized in the negotiations of splits.

Our second key finding is that the consolidation of actors into homogeneous groups appears to have a key influence on splits. To this end, we have observed that many of the actors involved in the ecosystem exhibit both a micro and a macro nature (Callon and Latour, 1981). For example, a miner can be an individual (a micro actor) and belong to a mining pool (a macro actor). We also observed that there is a constant flux between micro and macro positions, particularly from micro to macro, as individual miners aggregate their resources and form mining pools. Other examples of becoming powerful macro actors are a manufacturer who invests in developing mining hardware, such as ASIC, that has become a requirement of Bitcoin mining. By moving into a macro actor position, the manufacturer can exert considerable power in the network. Further, the consolidation of actors manifests in the consolidation of mining hardware manufacturers and miners. In fact, as our observations demonstrate, Bitcoin mining has become an oligopoly with a very small number of dominant actors. As a result, miners without ASIC technology and/or affordable electricity at their disposal have largely had to abandon Bitcoin mining. Overall, the increasing consolidation of actors into groups' contrasts starkly with the ideological origins of public blockchains that promote decentralization and democracy.

6.2. Contributions

Our study extends the current literature in three specific areas. First, in its principal area of contribution, the study advances the nascent (thus far) understanding of blockchain splits by elaborating on the actors involved and their natures in the context of Bitcoin. We identified eight focal actors involved in Bitcoin splits and further elaborated on their behavior in micro and macro settings for negotiations related to splitting the blockchain. Moreover, our findings highlight the fluidity of actors' roles prior to, during, and after the blockchain split.

Second, pertaining to a more theoretical sphere, the present study adds to the current ANT research focused on blockchain (De Filippi and Loveluck, 2016; Venturini et al., 2015; Wright and De Filippi, 2015). To this end, our findings increase the understanding of the role and the constant fluid constellation of the blockchain network caused by the actors. In analyzing their heterogeneity, we provide a fine-grained account of the actors involved in blockchain splits. As our specific contribution to ANT literature (De Filippi and Loveluck, 2016; Venturini et al., 2015), we have described how the micro actors engage with, and even fuse with, other micro and macro actors, and we have elaborated on the consequences of these fusions. Due to their complex nature, they are poorly understood, both theoretically and in practice. 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 a blockchain ecosystem as actor-networks. Our analysis reveals the actor-network involved in Bitcoin splits—which comprises both human and non-human actors—and the interplay between the two. For example, the continually increasing algorithmic complexity in Bitcoin mining requires significant amounts of computing power and electricity. This has led to a situation in which institutional miners with significant financial investment have obtained the required computing power and now dominate Bitcoin mining (see Table 3). This situation fundamentally questions the open, decentralized nature and ideology underlying Bitcoin.

In sum, this study contributes to the discussion on the roles and interplay of human and non-human elements of information systems (e.g., Benbasat and Zmud, 2003; Leonard-Barton, 1990; Sarker et al., 2006). Further, we ask to what extent agency could and should be attributed to non-human actors (Pickering, 1993) and what the potential consequences of non-human agency could entail. From a broader perspective, our study contributes to expanding the discussion on the interplay and power relations between technology and humans (DuPont, 2017; Latour, 2015; Leonardi and Barley, 2008).

6.3. Limitations and future research

This study has focused on a largely unexplored territory of blockchain splits. Like any empirical research, the results are subject to interpretation and are limited to the data available. Thus, the limitations of this study provide avenues for future research.

First, the empirical research focused solely on Bitcoin splits. However, our findings, identified in Bitcoin, provide meaningful insights into public blockchains in which mining and miners play a key role. Nevertheless, there are also blockchains such as Ripple that have been pre-mined its native token (XRP) by the developer team. This implies that splits in such blockchains may unfold in a different way. Thus, we suggest that future research should extend the scope of empirical investigation to other instances of blockchain splits, specifically focusing on investigating the potential commonalities and differences between blockchains. Second, we investigated two splits in the Bitcoin blockchain. Indeed, there has been a recent instance of Bitcoin split, namely Bitcoin Satoshi's Vision (BSV). There also have been splits in other blockchains. Future research could investigate the roles of relevant actors and their networks in these splits.

Finally, the chosen 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. To obtain different perspectives and interpretations of blockchain splits, we suggest that additional research should scrutinize the advantages and disadvantages of different theoretical lenses in understanding blockchain splits.

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