Money/Code/Space: Bitcoin, Blockchain, and Geographies of Algorithmic Decentralisation

Jack Parkin

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

Institute for Culture and Society
Western Sydney University

2018

Acknowledgements

This thesis would not have been possible without attentive guidance from Donald McNeill and Ned Rossiter who have managed to repeatedly pull my writing back into focus when the vivid research topic was exploding and running off in all directions. I am specifically grateful to Donald for keeping my work both geographic and ethnographic, and to Ned for meticulously driving the development of concepts. It has been with great difficulty but immense pleasure that I have navigated their, sometimes quite contrasting, inputs and this thesis is only stronger for that balance.

I would also like to thank Liam Magee for his generous feedback regarding Chapters 4 and 5 as well as his consistent interest in other areas of my work. My thanks to Susan Mowbray who has helped develop the logic and flow of my writing in what has proven to be a complex project. I must also pay tribute to my colleagues at the Institute for Culture and Society (Western Sydney University) who have provided a fantastic support network: Andrea Pollio, Ilia Antenucci, Cecelia Cmielewski, Luigi Di Martino, Oznur Sahin, Alexandra Coleman, Harriette Richards, Daniel Musil, Tsvetelina Hristova, Mithilesh Kumar, Giulia Dal Maso, Sebastián Martín Valdez, Christiane Kühling, Jasbeer Musthafa Mamalipurath, Alejandra Villanueva, and Andrea Del Bono.

My gratitude is extended to the thesis examiners, Andrew Leyshon and Nathanial Tkacz, whose encouraging comments have been extremely constructive for future iterations of the work. I look forward to developing their ideas in full and extending them beyond the confines of the PhD.

It is certain that I would not be in this position today if not for Ian Cook who saw something in my work as an undergraduate, inspired me to pursue an intellectual journey, and encouraged me to follow the thing. So I thank Ian for his infectious enthusiasm.

Finally, I would like to thank everyone within the Bitcoin and blockchain communities who animated my research.

Statement of Authentication

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

....

(Signature)

Contents

List of Figures

List of Tables

Abstract

Newly emerging cryptocurrencies and blockchain technology provide a challenging research problem for human geographers. Bitcoin, the first widely implemented cryptocurrency and example of a blockchain architecture, seemingly separates itself from the existing territorial boundedness of nation state currencies via a digital process of algorithmic decentralisation. Proponents declare that utilisation of cryptography to advance blockchain transactions will disrupt the modern centralised structures by which capitalist economies are currently organised: corporations, commercial banks, and central banks. I contest this perspective. The core argument of this thesis is that blockchains must be understood as a spatial problem where power is unevenly distributed across their networks. Secondly, and building upon this principle, it is proposed that algorithmic decentralisation is inherently a contradictory concept by highlighting a number of distinctive points across Bitcoin's architecture where forms of centralised control are competed for. Thirdly, the thesis describes how online communities, start-up companies, and existing financial institutions exercise power from these many centres by paying close attention to the political ideologies and practices that combine to form a unique technoculture. This research analyses these sociotechnical dynamics, systems, and conditions to make intelligible the political, cultural, and economic geographies of blockchains. In doing so the thesis builds on existing literatures and empirical research pertaining to money/space and code/space to critically evaluate the postulation of blockchain decentralisation.

An actor-network inspired 'follow the thing' methodology enables the thesis to navigate and trace some of the primary connections between diverse sociotechnical actors that create blockchain economies. The method of 'following' extends into an examination of the Bitcoin source code, online forums, and social media activity so as to develop a critical understanding of blockchain's cultural economic geographies. By tracing both the humans and non-humans of Bitcoin's infrastructure the way in which transactions are materially tied together through space is outlined. Additionally, the technique of snowball sampling was used to conduct participant observation and semi-structured interviews in the burgeoning Bitcoin/blockchain ecosystem of Silicon Valley, supported by an investigation of key entrepreneurial spaces, such as start-up companies and meet-up groups, in London and New York City. These methods help develop an analytical framework that demonstrates how the technical parameters of blockchains—block size, private key control, mining operations—are altered by people in varied cultural settings and thus practise and shape blockchains in competing ways.

The analysis of empirical data frames different 'spaces' as strategic passage points through which various practices are increasingly funnelled (Callon, 1986). Examining these bottlenecks from a cultural economic geography perspective, this thesis demonstrates how the codified architectures of blockchains are (re)centred on a number of levels: governance mechanisms that organise their

programmers; materialities of infrastructure that execute their code; bureaucratic business models built by start-up companies to profit from their transaction structures, and; the embeddedness of technical knowledge within industrial agglomerations. These empirical observations provide the foundation for a critique of blockchain 'solutionism' that envisions distributed algorithmic software as the harbinger of more stable and democratic economies by transferring governance to the mathematical constraints of computer code. Subsequent analysis contributes to spatial theory by outlining a cultural economic geography of Bitcoin and copycat blockchain projects where a hybrid form of human-machine governance shapes their algorithmic structures. While blockchain economies transform the relationships between money, code, and space, the study and analysis of key points where money/code/space is produced, contested, and monitored shows how algorithmic decentralisation is predicated on centralised actors, practices, and forces.

Introduction

Algorithmic Decentralisation

Banks, governments, and the financial press are scrambling to understand the ramifications of emerging digital architectures such as cryptocurrencies and blockchain technology. These software systems are largely misunderstood outside of the boutique industries of micro-finance, technology start-ups, and the cutting edge of digital media research, yet they are fast moving into the mainstream. A burgeoning economic sector is currently developing different blockchains as algorithmic tools to transform, reorganise, and, most importantly, decentralise a plethora of industries from real estate to voting, stock trading to health care, and supply chain management to the Internet of Things (Swan, 2015; Raval, 2016; Mougayar, 2016; Tapscott & Tapscott, 2016; CB Insights, 2017). The implications of these new code structures could substantially effect the spatial organisation of future global economies. Bitcoin, the first blockchain-based cryptocurrency designed as an alternative to state-based money, was first presented to the world in 2009 as a non-hierarchical mechanism for administering transactions of value by a group of libertarian-leaning 'hackers'.[1] Subsequent blockchain proponents, from anarchist programmers to national governments, share a perception of a flattened, egalitarian software model forming the basis of a driving political ideology that steers the development of these architectures with ambitions for creating fairer economies.

This thesis traces some of the key power structures that emerge through these 'decentralised' systems by illuminating a geography of Bitcoin and other blockchains such as Ethereum. These geographies are examined to unpack the contradictions at play in a world governed by the mathematical constraints of computer code. Bitcoin, by its very design, masks geographic connections between people who engage with(in) its network. This thesis works to unwind some of the inherent obscurities presented by blockchain architectures and highlight instances where cryptography conceals the spatiality between its users. This unravelling becomes an important contribution to spatial theory as it demonstrates the material limitations of digital, distributed software in terms of start-ups, business models, code, humans, and machines. What is meant by material is not so much the Marxian legacy of materialism that pursues an analytical study of historical change wrought by economic and institutional forces, but rather materiality as a method that is prominent within actor-network theory, science and technology studies, and non-representational theory. While this may include a 'loose materiality' of the people and places researched, the term is used more as a following, framing, and focusing device with respect to

[1] I empathise with David Golumbia's (2016a) frustration with the neologism 'hacker': it "has so many meanings, and yet it is routinely used as if its meaning was unambiguous… [and] as if these ambiguities are epiphenomenal or unimportant" (124). The nuances of the term hacker that I use here will become clear as the thesis develops.

the socialised tangibilities of blockchains (version control, silicon chips, servers, Bitcoin mines, software) as technical systems (Kittler, 1995; Packer & Wiley, 2011; Harvey, 2012; Parikka, 2015). In other words, materiality is the collection of physical objects around, or through, which cultural-economic practice is performed. It is this understanding of materiality as an assemblage of things (with affordances and limitations) that informs the method of this thesis: by tracing out the technical capacities and properties of blockchains as digital architecture and tangible infrastructure their spatial scales and connectivities are better understood.

Many of the early builders of blockchains, who utilised open source models or created entrepreneurial start-ups, continue to champion a form of algorithmic decentralisation where dispersed, networked code can organise certain aspects of society (money, voting, trading, identity) without the need for centralised institutions such as governments, corporations, or banks. This necessarily presents blockchains as dehumanised machine spaces where the mathematics of computer code can suddenly be trusted to organise societies without centralised oversight or control from humans. At a time when there is a certain degree of obsession and fear concerning 'robots taking over the world' with the rise of artificial intelligence (Tett, 2018), it is appropriate to distinguish what the human and non-human parts—or hybridities—of blockchains are.[2] In response to the anxieties of automation, the question is asked whether anyone is in control of these contemporary codified systems or if they truly are autonomous data structures on a never-ending, tamper-proof, mechanical loop?[3] The aim is to grapple with both the technical non-human infrastructure at the same time as injecting the human back into blockchain analysis to understand where the power to influence certain aspects of their architectures resides.

Taking inspiration from works that examine the "social life" of things (Appadurai, 1986), information (Brown & Duguid, 2000), money (Dodd, 2014), financial derivatives (LiPuma, 2017), and Bitcoin itself (Dodd, 2017), the algorithmic (de)centralisation of code/money via blockchains is examined through a socio-spatial analytical lens (Lesyhon & Thrift, 1997; Kitchin & Dodge, 2011). By delving into the social life of Bitcoin and (some other) blockchains, the thesis highlights a persistence of certain practices (like code governance, Bitcoin mining, and network transactions) that are funnelled through centralised bottlenecks (lead developers, mining pools, start-up companies) where specific actors have control over pieces of the network on different levels. Practically speaking, the dynamics and shortcomings of algorithmic decentralisation are relevant findings for blockchain programmers, tech start-ups, global banks, accountancy and legal firms, speculators, policy makers, and the general public.

---

[2] The rhetoric of TED Talks, for example, often reverberate notions of technological sensationalism: in a talk entitled "The Future of Money", Neha Narula (2016) claims in a "programmable world we remove humans and institutions from the loop".

[3] Incidentally, blockchains have also been posed as a basis for distributed memory from which to build artificial intelligence (Volpicelli, 2017; Corea, 2017; Marr, 2018).

These actors are, after all, performing and affecting decentralisation in different ways and so shedding light on their role in (re)constructing economies with code is an important line of investigation.

The astronomical escalations in the value of cryptocurrencies over 2017 (such as Bitcoin, Litecoin, and Ether) suggest the role cryptocurrencies are playing in the global economy is more pressing than ever: the value of a single bitcoin rose to over $19,500 USD with a total market capitalisation of $326 billion while cryptocurrencies as a whole pushed well over $800 billion. With such speculation comes a need to understand how these codified architectures are working beneath the surface as well as the political motivations that got them there. At the heart of Bitcoin is a motive to redistribute monetary control. As an open source software project built by a community of (initially) voluntary contributors, Bitcoin was first programmed and championed as a form of anarchist money harnessed by a distributed algorithmic protocol that can be accessed by anyone with an Internet connection from anywhere in the world. Rhetorically, it challenges the monopoly of centralised institutions that were blamed for the 2008 financial crisis (and other economic catastrophes that echo throughout history). Instead of trusting people inside the brick and mortar organisations of Wall Street or the Federal Reserve, money—as cryptocurrency—could be released from its institutional and geographical constraints, empowering the individual by transferring the governance of their money to a transparent, 'decentralised', peer-to-peer network executed by computer code. Encryption techniques secure the Bitcoin protocol, leaving administrative authority to the integrity of mathematics as opposed to corruptible or incapable third parties. It is with this aspiration that start-up companies located in global technology hubs are looking to decentralise a plethora of management systems including currency, contracts, law, trading, equity, supply chains, voting, interbank settlements, licensing, file storage, identification, and record keeping. This shift has already widely been referred to as the second generation, or layer, of the Internet because blockchains, for the first time ever, provide a distributed consensus of trust between peers widely separated by time and space (Tapscott, 2015; Dale, 2016).

Central to this study is a close examination of the 'decentralised forms' that arise algorithmically through the organisational architectures of blockchains. In politics, decentralisation, as both a vision and a tool, has gathered momentum over the last fifty years in an attempt to achieve more effective democratic governance structures (Smith, 1985). Yet there has not been a consensus or unification of views or discourses that coalesce around the question/problematic/condition of decentralisation. Indeed, it has become a "slippery term" (Burns et al., 1994, 6) used by many different institutions to mean very different things (Fernando, 2002). The advent of blockchain technology is adding to the equivocal and transitory meanings of decentralisation as it is put into practice via the mechanisms of code. Originating as a bottom-up hacker backlash to government-corporate structures, blockchain models are now being absorbed by the technological elites of Silicon Valley in the form of 'disruptive' financial technology start-ups. This is rather remarkable given the opposite direction that high technology firms, such as Google, Apple, Amazon, and Facebook, have been moving in over the last two decades: the centralised capture and monetisation of big data (Srnicek, 2017).

Algorithmic decentralisation manifests in Bitcoin and wider implementations of blockchain technology more generally. This thesis interrogates how these architectures spatially and culturally take shape. An ethnographic research methodology informed by actor-network theory is designed to explore how different actors in the Bitcoin/blockchain ecosystem employ decentralisation. It describes governance mechanisms that coordinate the builders of blockchains, the material hardware infrastructures that execute code, and the high technology agglomeration economies that build business models on the back of these new architectures, demonstrating how control is not distributed evenly amongst people in blockchain economies but rather consolidates around a small number of centres from which they are ordered.[4]

Charting a Mode of Enquiry

The thesis is situated at the intersection of three influential scholarly fields of recent years. First, it contributes to debates about the nature of centralisation/spatiality of the financial system, currency, and banking, which has been discussed by economic geography, sociology, and anthropology scholars, among others (Tsing, 2004; Knorr Cetina & Bruegger, 2002; Hall, 2011, 2012, 2013). This has become an increasingly important area of research following the 2008 global financial crisis and subsequent developments in financial technology. To build a rationale for exploring decentralised digital currencies the thesis draws from works on the geography (Leyshon, 1995, 1997, 1998; Leyshon & Thrift, 1997), sociology (Baker & Jimerson, 1992; Dodd, 1994, 1995, 2014; Callon, 1998a, 1998b, 2007; Mackenzie, 2004, 2006, 2014a; Knorr Cetina & Preda, 2005), and anthropology of money (Maurer, 2005, 2006, 2012, 2015). As such, it navigates the interdisciplinary realm of economic geography to thicken accounts of algorithmic decentralisation by recognising that "all economies must take place" (Lee, 2006, 430). Leaving blockchain analysis to the abstract models of neoclassical economics would not only overlook their complexity (Dicken & Lloyd, 1990; Hudson, 2005; Pike et al., 2006; Knox & Agnew, 2008), but also externalise them from social relations (Granovetter, 1985; Becker, 1997; Thrift, 2000).

Second, the thesis contributes to a growing body of knowledge that examines the increasing role of software in mediating and conditioning social practice and human experience (Manovich, 2001, 2008; Fuller, 2003, 2008; Mackenzie, 2005, 2006; Chun, 2011; Berry, 2011). As blockchains take on a degree

---

[4] I use architecture to mean the mathematical and algorithmic structure of code (akin to software) whereas infrastructure relates to the material networks of silicon chips, cables, wires, and electricity (akin to hardware) that allows computer programs to run. It will become clear throughout the thesis that this is not a binary distinction.

of autonomy in the form of algorithmic ledgers, important questions are posed around how they work, both culturally and technically. This research contributes most significantly to works that have both developed a material account of digital media (Kittler, 1995; Galloway, 2004; Starosielski, 2015; Rossiter, 2016) and the geographies of code (Graham, 2005; Kitchin & Dodge, 2011; Kitchin & Perng, 2016). However, the arguments also find relevance in the subdiscipline of network cultures that has been making a significant scholarly impact over the last fifteen years towards understanding the interface(s) of humans and software (Lovink, 2002; Terranova, 2004, Rossiter, 2006, 2016; Golumbia, 2009; Lovink et al., 2015; Tkacz, 2015).

Third and finally, the thesis commits to the methodological pursuit of detailed ethnographies surrounding the production and nuances of technocultures (Miller & Slater, 2000; Zaloom, 2006; Downey & Fisher, 2006; Boellstorff, 2008; Miller, 2011). This body of knowledge has worked hard to reject the ontological bifurcation between the cultural and the technological that repeatedly proves to be an unproductive theoretical chasm: "[l]eaving technology out of analyses of culture has the unintended implication that it is an autonomous realm of human activity" (Fisher & Downey, 2006, 5). In opposition to this, ethnographies have looked to "undermine accounts of change that privilege technology as the sole, driving, causal agent" (ibid.). This is useful for investigating blockchain ecosystems because it provides a fine-grained narrative of their interwoven tapestries of culture, economy, and technology through space. The methods in this thesis are inspired particularly by participant observation conducted in software companies (Ross, 2003; Indergaard, 2004; O'Rian, 2004; Girard & Stark, 2005; O'Mahony, 2006; Takhteyev, 2012).

This threefold convergence of literature on finance capital, software studies, and technology/ infrastructure ethnographies is used to interrogate the nascency of Bitcoin and blockchain technology by focusing on the material-semiotic assemblages of humans and non-humans that contribute to their constitution. Here, a 'follow the thing' methodology is used as an analytical tool to trace out the social and spatial connections that form blockchain architectures. The three literatures outlined above are brought into conversation with each other through empirical observations of Bitcoin-in-and-of-the-world by examining how 'the blockchain' places the concepts of money, code, and space in a unique and novel relationship.

A core focus of this thesis is the algorithmic *geographies* that take shape through the 'decentralised' form of Bitcoin as well as subsequent examples of blockchains that it has inspired. What is meant by algorithmic geographies is the spatial and relational distribution of everyday practices, materials, capital, transactions, institutions, labour, ideologies, and regulations that work together to assemble blockchains. This term avoids slipping into some of the nebulous terminologies reminiscent of media theory in the late 1990's and early 2000's that often saturated discourse surrounding "cyberspace" (Burrows &

Featherstone, 1995; Munt, 2001; Buckingham & Willett, 2006). While on some level treating "virtual worlds" as bounded entities can be useful for understanding embodied culture (Boellstorff, 2008), such a vocabulary necessarily reinforces an imaginary of 'the digital' as an ethereal fourth dimension removed from the tangibilities of 'real space'. This can lean towards a "hyper-globalist" (Dicken, 2015) view that preaches a borderless world and begins to eradicate the need for geographical understandings. Sentiments of radical digital globalisation—that invariably pushes 'the virtual' into discursive realms of spacelessness—still echo throughout new media rhetoric today (Kinsley, 2013a) and, perhaps unsurprisingly, reverberate around Bitcoin and blockchain industry commentaries. This is, however, short-sighted, neglecting that globalisation necessarily intensifies spatial complexity and unevenness so that specific geographic connectivities actually become more relevant than ever (Sokol, 2011).

Situating Research

The enquiry of this thesis is heavily influenced by the work of Ian Cook et al. (2004, 2006, 2008, 2014, 2017) and other cultural geographers, anthropologists, and ethnographers whose research involves following things (Mintz, 1986; Appadurai, 1986; Marcus, 1995; Bestor, 2000; Scheper-Hughes, 2000; Barndt, 2002; Dibbell, 2007). As Phillip Crang (2005) explains:

> Things move around and inhabit multiple cultural contexts during their lives. Cultural Geographers are especially interested in the changes that happen to a thing in this process: material changes; and changes or 'translations' in the thing's meanings. They are also interested in the knowledges that move with the things, especially about their earlier life. How much do people encountering a thing in one context know about its life in other contexts? Who mediates this knowledge? What role do imaginative geographies of where a thing comes from... play in our encounters with objects…? (178)

The usefulness of thing-following as a methodological tool for uncovering the social relations that circumscribe, or rather permeate, money has been recently debated in economic geography (Christophers, 2011a, 2011b; Gilbert, 2011). As Brett Cristophers (2011a) notes, although problematic (but not impossible), following money can "reveal and examine the social and economic relations both underpinning and occasioned by money's creation and circulation" (1069-1070). Because Bitcoin has been proposed as an anarchist form of digital money, its peculiar character can be illuminated by tracing its "social and spatial pathways" (ibid.). Recognising the complex arrangements that create cities Donald McNeill (2017) suggests, in the context of urban theory, that "[w]e might think about world city-*making* systems rather than world city systems" (150). Borrowing and repurposing this phrase, I think about blockchain-*making* systems rather than just blockchain systems. In this sense, drawing on some of the tools associated with actor network theory for "framing field sites and research objects" (Madden, 2010, 584), I attempt to follow things, people, and ideas as they collide through blockchains.

I carve three exploratory paths to navigate and disentangle the complexity of Bitcoin and copycat blockchains. First, I examine the spatial articulations and contradictions that Bitcoin and other implementations of blockchains enact as certain practices, such as forking software or storing bitcoin, coalesce around them. Second, through this spatial organisation, I develop an understanding of algorithmic (de)centralisation and demonstrate how its internal contradictions correlate to power that is harnessed through the network. Third, I assert how different actors control certain channels in the (de)centralised networks of blockchains and examine how they (re)shape the algorithmic-material architecture with competing political ideologies.

Ultimately, all work to develop a critical understanding and theorisation of algorithmic decentralisation through money/code/space. While some technological and economic ideologies preach an impending world of distributed global transactions, the materiality of economies points to something different. Centralisation, on some level, is necessary for economies to function. This pattern is not dissimilar to the evolution of the TCP/IP protocol once dreamed up as the ultimate form of decentralisation (Galloway, 2004). This protocol sets out the rules of the Internet that machines follow in order to send and receive information to each other. The Bitcoin protocol, in turn, rests upon this network and uses it to connect separated copies of the same currency ledger together. Like the Internet before it (and, indeed, on some level because of it) the making of blockchains, shaped by a myriad of evolving actors, is turning them into architectures with some radical differences to how they were first conceptualised. While some hackers stay as true as possible to their ideologies of radical decentralisation, Silicon Valley and global banks have been steering blockchains towards traditional models of capital accumulation. Just as the Internet was moulded around centralised governments (Clayton et al., 2006; Zhang, 2006), undersea network cables (Starosielski, 2015), software platforms (Srnicek, 2017), and data centres (Rossiter, 2016), so blockchain architectures are again demonstrating the material reality of particular forms of networked communication.

Thesis Layout

Chapter 1, "Money/Code/Space", provides a theoretical discussion of these three concepts to foreground the emergence of Bitcoin as a radical response to existing economic structures. Using the history of central banking and software production, the structure of Bitcoin is compared to traditional modes of centralised governance to outline some of the political context of algorithmic decentralisation. In doing so, the traditional binary of centralised and decentralised is rendered reductive and thus impotent for describing digital networks because of the inescapable complexity inherent within them. Instead, Michel Callon's (1986) concept of "obligatory passage points" is adapted into a framework for understanding (de)centralisation in algorithmic networks. This provides an understanding of money/code/space that encapsulates the cultural and economic messiness of Bitcoin and blockchain technology that can be used for bringing places of power to the forefront of academic scholarship.

The second chapter, "Follow the (Digital) Thing", presents a methodology that accommodates the theoretical positions laid out in Chapter 1. By acknowledging that Bitcoin is geographically contingent and diverse, the research design allows for tracing the connections between different aspects of its protocol that are practised by a multitude of people in various places. This is done by documenting traditional follow the thing work and explaining how knowledge can be gathered from such a technique before adapting this research process for the task at hand. The breakdown then shifts into sketching a specific, yet malleable, research method that harnesses the flexibility necessary for researching the complex cultural economies of Bitcoin and other blockchains.

Chapter 3, "Tracing Political Histories" describes how cryptographic decentralisation emerged as a political counterweight of resistance to the encroachment of centralised governments within 'online spaces'. The decentralist worldview is shown to be rooted in the specific political geography of the West Coast of the United States that, during the latter half of the 20th century, became a crucible of counterculture and entrepreneurship. This monetarist desire to create fairer economies through algorithmic decentralisation gave rise to the advent of cryptocurrencies. The chapter then discusses the emergence of cryptocurrencies within a culture of programming where algorithmic decentralisation is imagined. The intersection, or dislocation, of this technologically deterministic imaginary (preaching a freedom from hierarchy and control) with geographies of material practice is developed throughout subsequent chapters.

Chapter 4, "The Money-Makers" outlines the community of developers who have contributed to Bitcoin's source code. Drawing from ethnographic data, the governance of the Bitcoin codebase is understood through obligatory passage points found among key individuals and groups who were/are involved in the creation of Bitcoin. The consensus model for making changes to the Bitcoin software shows how code is inescapably bound up with political tensions that arise through coordinating geographies of production and organisation. The tensions of governance between different stakeholders are exposed to show how a stagnation of decision-making in code development and the increased likeliness of the project 'forking' as it scales demands degrees of centralisation through space at the architectural level of cryptocurrency design in order for actions to be resolved and implemented.

The fifth chapter, "Grounding Cryptocurrencies", conducts a more specific and exploratory follow the thing research technique to uncover the digital-material architecture of Bitcoin. Treating the Bitcoin code as both a text and material, a singular bitcoin is followed *through* the decentralised protocol focusing on a transaction 'from' Australia 'to' the United States of America. By tracing the spatial relationships between miscellaneous paraphernalia from personal computers to Bitcoin mining rigs that facilitate the transaction, the chapter navigates the material culture of the Bitcoin blockchain. This involves opening up the cryptographic black boxes of algorithms to uncover the functional performativity of the network. The spatial lens reveals several material infrastructures such as undersea cables, data centres, pools of Bitcoin mines, active nodes, and third party wallet software, that assemble to form operational modes of centralisation.

Chapter 6, "Embedded Centralisation", draws predominantly from ethnographic research conducted within Bitcoin/blockchain meet-up groups and start-up companies in the San Francisco Bay Area. This chapter provides an account of embedded frictions amongst the varying stakeholders of Bitcoin in high technology culture. The clashing of libertarian anarchy and entrepreneurial profit-seeking are forced into a singular vision, reminiscent of the Californian Ideology, and contribute to the tensions of a splintering community: Bitcoin adherents are increasingly fragmenting as it becomes clear that the protocol cannot fulfil all of their ambitions. Equally, the desire to, quoting an interviewed venture capitalist, "change the world and make a lot of money doing it" is a driving force behind centralised start-ups forming around Bitcoin's distributed architecture. Bitcoin and blockchain technology are symptomatic of this polarising worldview. As 'radical' and 'disruptive' start-ups are absorbed into the embedded spatial ties of the surrounding economy, they become increasingly 'normalised' by their investors at the same time as scaling to enrol more users within their platforms. This has the effect of funnelling financial practices on 'the blockchain' through proprietary software controlled by a small number of technocrats situated in nation state jurisdictions. The entrepreneurial geographies of high technology agglomeration industries thereby act as another spatial limitation to algorithmic decentralisation.

The final chapter, "The Blockchain Turn", dives deeper into the territory of spin-off blockchains that are being offered as technological modes of organisation for decentralising a host of socioeconomic practices. Recent discussion of platform capitalism is used to critique claims that blockchains are an incorruptible mode of democratic governance. Instead, blockchain capitalism is offered as a more accurate transaction model where capital accumulation necessitates certain points of centralisation in blockchains. Through a close examination of blockchain typologies, the co-option of these architectures, by the very centralised banking firms that they were designed to bypass, is also explored. As financial giants design their own distributed ledger systems to increase the efficiency of their own business practices the innovation from the disruptive edges is once again absorbed into the centre by the corporate powers that be.

Algorithmic decentralisation itself is shown to be an inherent contradiction as spatial trajectories coalesce at different points around blockchain networks. This provides a starting point for understanding the economic geographies of distributed blockchain networks that on one hand, are open for all to see and, on the other, work out of view underneath the surface of cryptographically concealed code. Following Bitcoin into different aspects of its network reveals that money/code/space is not relegated to an autonomous machine world but is a complex web of humans and non-humans formed through cultural-economic practice. In doing so, the thesis debunks the libertarian and liberatory claims of cryptocurrencies by illuminating modes of uneven power. It is only by understanding these limitations that pathways can be taken to building less inequitable, or at least sensationalist, blockchain forms.

Chapter 1
Money/Code/Space

Introduction

The title of this thesis is taken from two important works in human geography. The first is *Money/Space: Geographies of Monetary Transformation* by Andrew Leyshon and Nigel Thrift who, in 1997, endeavoured to demonstrate that money circulates and is performed through dense social and spatial networks. As a collection and development of previously published works, the text reflects the multiple visions of money that manifest on different spatial scales. Twenty years later, in light of the exponential ubiquity of financial instruments, new payment technologies, the formation of the Euro, and the 2008 global financial crisis, this important work offers a framework for understanding more contemporary financial landscapes. The second key work is *Code/Space: Software and Everyday Life* by Rob Kitchin and Martin Dodge (2011), who examine how software increasingly shapes the modern world. Software, like money, is not only *in* space but *enacts* it. The key point made by Kitchin and Dodge is that software is now fundamental to spatial production so research must "produce detailed case studies of how software does work in the world, and to develop theoretical tools for describing how and explaining why, and the effects, of that work" (249).

Using *Money/Space* and *Code/Space* as a starting point, in this chapter I examine a threefold relationship between money, code, and space. By building an analytical framework that incorporates this three-body system, *Money/Code/Space* aims to open up the complexity of blockchains as sociotechnical objects. This is done through an interrogative lens designed to unpack the historical and modern manifestations of decentralisation. Michel Callon's (1986) term "obligatory passage points", from his famous work on the sociology of translation, is adapted here to frame modes of centralisation in 'decentralised' networks.

The chapter does five things. First, it places Bitcoin within geographical theorisations of money to better understand how monetary forms are spatially constituted/enacted.[1] Second, it critically deconstructs the term decentralisation amidst its plethoric connotations. Third, a geographic framework is devised for understanding (de)centralisation in relation to digital-material, cultural-economic networks. Fourth, drawing from actor-network theory, (de)centralisation is redefined under

[1] In doing so, this further contributes to busting some of the myths that surround Bitcoin and blockchain technology (de Jong et al., 2015).

the concept of obligatory passage points that highlight certain connectivities producing power in apparently distributed architectures. Fifth, blockchains are compared to traditional modes of monetary governance administered by central banks. Throughout money/space is conceptualised via modes of sociotechnical practice and, in its contemporary form, is shown to be tied intimately to code/space. This narrative works to present Bitcoin and other blockchain technologies as heterogeneous networks that can be examined—in terms of the digital code, material infrastructure, cultural-economic practice, and discourses of (de)centralisation held by different groups—to illuminate sites of 'centralisation' across their money/code/space(s).

Geographies of Money

Bitcoin does not fit neatly into the traditional definitions of money. It has consequently been classified as a number of different 'things' (see Table 1). In many ways, then, Bitcoin suffers an on-going identity crisis that feeds and perpetuates wider perceptions of cryptocurrencies as alien and ambiguous apparatuses. Yet a singular definition of money itself is hard to come by (Dodd, 2014). After William Stanley Jevons (1875), neoclassical economists maintain that money holds three functions: a medium of exchange; a unit of account, and; a store of value.[2] While these distinct functions are certainly useful, they can often oversimplify what is a complex cultural artefact teaming with social relations (Marx, 1867; Simmel, 1900; Zelizer, 1989; Ingham, 2004). Consequently, money-as-practice can be much sticker than such neat conceptualisations allow for. The neoclassical trinity of conditions provides a more idealised, abstracted, or, perhaps, 'perfect' model of money. However, no monetary example in history has ever held these properties without (sometimes radical) imperfections or, indeed, trade-offs between their functions.

So the threefold set of monetary functions are not static but move and shift interdependently with each other in a complex arrangement:

> The idea that modern money is general-purpose, fulfilling all the possible monetary functions, is simply incorrect. There exists no form of money which serves all such functions simultaneously. Legal-tender notes are rarely used to store value in practice… Cheques, credit cards and bank drafts serve only as means of payment. It is absurd to regard these monetary forms as general-purpose. (Dodd, 1994, xviii)

A convincing argument against Bitcoin being classified as money is its extreme volatility (Güring & Grigg, 2011; Forbes, 2013; Dowd, 2014; Harvey, 2014; Harvey & Tymoigne, 2015), which has led

[2] Jevons (1875) also included 'standard of deferred payment' to form four functions but this has, more often than not, been dropped by economists, in a belief that this characteristic is subsumed by the other functions.

Definition	Reference
Peer-to-peer electronic cash system	Nakamoto (2008)
Digital gold	Popper (2015)
Internet of money	Antonopoulos (2014, 2016)
Programmable money	Dalal (2014), Noyen et al. (2014), Worner et al., (2016)
Money-like informational commodity	Bergstra & Weijland (2014), Swanson (2014a)
Synthetic commodity money	Selgin (2015)
Technical informational money	Bergstra & de Leeuw (2013)
Censorship-resistant digital currency	Brito (2011)
Speculative commodity	Mittal (2012)
De facto fiat currency	de Jong et al. (2015)
Computer-generated commodity	Cusumano (2014)
Private money	McHugh (2013)
Public ledger currency platform	Evans (2014)
Ponzi scheme	Barok (2011), Grigg (2011), Richards (2014), O'Brien (2015)
Property	Australian Taxation Office (2014)
Asset	Yermack (2013), Glaser et al. (2014), Baur et al., (2015), Peetz & Mall (2018)
Commodity	Currie (Goldman Sachs) in Shieber (2014)
Virtual currency	IRS (2014)
Digital currency	HM Treasury (2015)
Payment system	Wikipedia (2018)

Table 1: Some existing definitions of Bitcoin

pundits from a range of fields to call it a speculative asset (Yermack, 2013; Glaser et al., 2014; Baur et al., 2015; Peetz & Mall, 2018). One reason for this is that only a small proportion of the entire amount of bitcoins (BTC) in existence are exchanged on a daily basis whereas the rest remain immobile under the surface like an iceberg.[3] Because the transaction data of the Bitcoin blockchain is public, statistical

[3] Bitcoin is capitalised when referring to the software protocol yet un-capitalised, or abbreviated to BTC, when referring to individual currency units. Certain journalists have claimed that both the network and the currency can be referred to as a capitalised "Bitcoin" but I maintain the distinction that better reflects the cultural norms of the Bitcoin community from which it originated. I also find it useful in this thesis to distinguish between the Bitcoin network itself and the currency that the network brings into being.

analysis can be used to demonstrate these flows: over different time periods around 70% of coins have been measured to be static (Ron & Shamir, 2013; Ratcliff, 2014; Swanson, 2014b). This has been attributed to hoarding which makes Bitcoin an investment vehicle for future returns as opposed to a medium of exchange or stable store of value. However, one need only look at the globalisation of currency markets and the cross-border flows of capital—here Bitcoin becomes another instrument that threatens to deterritorialise nation state money somewhat—to see how fiat is also used as an instrument of speculation (Strange, 1998; Gill, 1992, 1993; Walker, 1993).

The volatility argument against Bitcoin-as-money finds more traction when used to critique its inability of acting as a unit of account—that is, measuring the value of different commodities. This affect/effect of money gives almost everything in life a financial price (Marx, 1867; Simmel, 1900). One example where bitcoins have been used as a medium of exchange is the infamous black market website Silk Road branded the eBay of illegal drugs (Barratt, 2012; Ormsby, 2012). Its creator, Ross Ulbricht, helped facilitate the trading of illicit substances until he was arrested in a San Francisco library in 2013. The FBI shut down the site seizing 144,000 BTC (Greenberg, 2013; Ball et al., 2013) but many copycats have since sprung up in its place. The (pseudo)anonymity of Bitcoin transactions appealed to this underground market and quickly became branded by some as drug money (Broderick, 2011).[4] While products were priced with bitcoins their values were not static but pegged to fiat currencies and so fluctuated depending on the exchange rate of a bitcoin. This process, however, is in no way unique to Bitcoin but has historically manifested within different monetary networks around the world (see Appendix 1).

Money fills a "constellation of spaces" (Leyshon, 1997, 383). Bartley et al. (2002) provide an impressively broad yet concise account of monetary theorisations in human geography demonstrating there "are cultural nuanced geographies of money that are performed in different sites" (148). It is within, or rather through, these sites that money can be seen as socially, spatially, and temporally constituted. Neoclassical economic theory tends to overlook these subtleties by detaching theories of 'the economy' from space (Dicken & Lloyd, 1990; Hudson, 2005; Pike et al., 2006; Knox & Agnew, 2008).[5] Work in economic geography, especially since the cultural turn (Bartley et al., 2002), has enlivened the specific social complexity of money instead of treating humans as rational actors represented by highly abstract models (Gibson-Graham, 1996; Becker, 1997; Thrift, 2000). The

---

[4] Away from the negative press that surrounded Bitcoin's link to Silk Road, an article in the 'International Journal of Drug Policy' described how this system created a safer market with responsible vendors, intelligent consumers, high quality narcotics, and a transaction process with none of the dangers associated with face-to-face contact (van Hout & Bingham, 2014).

[5] David Graeber (2011) in *Debt: The First 5000 Years* explains how barter transactions were a rarity within historical communities but only existed in rare meetings between neighbouring communities. Instead forms of reciprocal debt were used as the primary mechanism for transferring goods. Despite there being no anthropological evidence to support it, economic textbooks continue preach money being introduced to solve the coincidence of wants in barter transactions.

reductionist misconception, however, is on some level understandable particularly when it comes to the peculiarity of money: to quote David Harvey (1989), money is apparently "everywhere but nowhere in particular" (167). The geography of money explicitly seeks out the particular. For example, Nigel Thrift (1994, 1996) and Andrew Leyshon (1997) have demonstrated how money is performed, circulated, and organised through dense financial centres such as the City of London. Their empirical work highlights the different spatial and institutional networks of money that reveal a deeply and tightly controlled spectacle. Money and finance are governed by different actors across disparate geographies so that there are a "wide variety of different economic worlds… [that are] unevenly distributed over space" (Leyshon, 1995, 534). It is with these works in mind that I set out with a spatial frame to test if blockchains can obliterate financial centres as they indeed claim to do.

It is useful to provide a brief taxonomy of some terms that will appear in this thesis to clarify their relationship. It may not be accurate to call Bitcoin the first cryptocurrency as there is a recent but rich historical relationship between cryptography and money (see Chapter 3), but it was certainly the first example of a blockchain architecture. It has subsequently inspired an array of alternative cryptocurrencies, blockchains, and distributed ledgers (Swanson, 2017a). All of these are transforming money/code/space in different ways. For example, denominations of a bitcoin can be split up into fractional pieces (up to 8 decimal points) so that minuscule and gargantuan amounts alike can be transferred across the network. What is more, these transactions (tend to) incur extremely low costs compared to pre-existing payment systems.[6] Consequently, it would be hard to deny that the Bitcoin protocol provides an extraordinary new mode for value exchange that could have enormous implications for the geographies of money and finance.

Contextualising Bitcoin

Centralised institutions have long and often been necessary to guarantee the value of money and create order in its production to generate trust (Thornton, 1802). In the United Kingdom, the role of the central bank evolved over time (see Appendix 2) into an intentionally dislocated arm of government adopting a 'non-bias' administrative role to the production and regulation of money (Goodhart, 1991; Elgie & Thompson, 1998). Different central banks enjoy different levels of independence but the world's oldest, the Bank of England, is positioned today so that it cannot be directly influenced by the economic whims of revolving governments in an effort to maintain longitudinal monetary stability. Despite the presence of such an entity in an overwhelming majority of nation states (Shah, 2008), boom and bust economic cycles have remained a reoccurring global phenomenon in the practical application of neoclassical economics played out by capitalism. Some see financial crises as a breach of

[6] Although current transaction fees have risen thanks to the recent spikes in Bitcoin's price. This will be addressed in Chapter 4.

responsibility and/or an inherent flaw in the current system governed by central banks. This comes down to central banks acting as a safety net for commercial banks—the lender of last resort (Goodfriend & King, 1988; Fischer, 1999; Goodhart, 2011; Flandreau & Ugolini, 2011). Few could argue against the postulation that the modern deregulated market that commercial banks operate in created an environment for the 2008 global financial crisis to occur, fostering a moral hazard with little rule or consequence. Bitcoin is a direct response to these conditions as a cumulative grassroots effort for reclaiming control over money.

It started, simply enough, on the 31st October 2008 when someone going by the name of Satoshi Nakamoto posted in a "low-noise moderated mailing list devoted to cryptographic technology and its political impact" (metzdowd.com, 2018).[7] [8] The post contained an abstract and link to a whitepaper hosted on the previously unheard of site bitcoin.com. This online paper barely ruffled any feathers. Few took notice and those that did entered into sporadic and speculative dialogue surrounding the merits and flaws of the conceptual apparatus it posited. The whitepaper was titled 'Bitcoin: A Peer-to-Peer Electronic Cash System' and it outlined a blueprint for a decentralised form of cryptographic currency for the Internet (Nakamoto, 2008). Cryptography was not only used here to cloak transactions but cryptographic hash functions were used as the very backbone of the protocol that would chain every transaction into a codified chronological ledger (the blockchain) to prove their validity (see Chapter 5).

The repercussions of the 2008 global financial crisis acted as the political petri dish in which Bitcoin was cultivated. Although the whitepaper itself made no mention of any agenda (published purely as a technical document) in other places it was resoundingly clear that Bitcoin was formed as an anarchical currency created in response to the government-corporate control of money. In fact, buried in the codified raw hex data of the first block (dubbed the genesis block) of the blockchain is the following text:

"The Times 03/Jan/2009 Chancellor on brink of second bailout for banks."

---

[7] As Satoshi Nakamoto is a pseudonym there is no way to know for sure whether they are male, female or a group of people. Various claims and educated guesses have been made as to who Nakamoto is yet there is no overriding evidence that can conclude this identification. Boellstorff (2008) argues that the "actual world" identities of people behind their online avatars are relatively unimportant to the virtual settings that they perform in. In this sense, it is not crucial to determine whom Satoshi Nakamoto is underneath the pseudonym/"avatar"/screen name but rather to take into account how this anonymity enacts the situations in which he/she/they contribute to. Satoshi Nakamoto, then, is taken to be an anonymous cultural actor without speculation over identity.

[8] Due to the nascency of Bitcoin and blockchain technology many of the resources in this thesis are online texts and do not have page numbers. Instead of citing "n.p." after each quotation, I state here that if no page number is shown then it can be taken to be a digital document.

This method for time-stamping the Bitcoin software proves it was initiated after the included date, with Nakamoto intentionally referencing the front page headline of an article from a UK Newspaper, *The Times*, that describes the British government using tax payers' money for saving banks (Elliott, 2009). It was with purpose that this politically charged "breadcrumb" (Frisby, 2014) was embedded in the codified structure that offered a radical alternative to existing distrusted monetary systems. It points to the manifestations of Lemon Socialism that emerged during the financial crisis: a term coined by Mark Green (1974) to describe the intervention of governments in the marketplace to prop up failing firms in order to prevent wider systematic collapse. This interposition contradicts the supposedly neoliberal form of world capitalism that preaches a 'free marketplace' because nation state governments systematically helped privatise the profits of big business while socialising the costs. The 'too big to fail' mentality that governments had proliferated when they saved the large oligopolistic banks from collapsing fuelled Nakamoto's political thesis.

A bottom-up 'hacker' resistance was launched as the given solution and computer code was the nominated tool of disruption. Satoshi Nakamoto offered Bitcoin as a means of emancipating people from the conventional means of monetary control, as stated on the networking website for peer-to-peer systems development, P2P Foundation:

> It's completely decentralized, with no central server or trusted parties, because everything is based on crypto proof instead of trust. The root problem with conventional currency is all the trust that's required to make it work. The central bank must be trusted not to debase the currency, but the history of fiat currencies is full of breaches of that trust. Banks must be trusted to hold our money and transfer it electronically, but they lend it out in waves of credit bubbles with barely a fraction in reserve. We have to trust them with our privacy, trust them not to let identity thieves drain our accounts. Their massive overhead costs make micropayments impossible… With e-currency based on cryptographic proof, without the need to trust a third party middleman, money can be secure and transactions effortless. (Nakamoto, 2009)

Bitcoin, then, was a direct monetarist response—a belief that economic performance is dictated by changes in monetary policy/supply—to the compulsory investment (and breaches) of trust systematically installed by centralised controls over money (so heavily influenced by the capitalist market and the liberal state). Decentralisation based on cryptography was offered as a means for escaping such ties, supposedly with the efficacy to formulate economic systems independent of any central authority or intermediate financial institution.

Deconstructing Decentralisation

There is a vast literature on decentralisation both as a governmental and financial process (see Appendix 3). Consequently, various typologies are laid out:

> Some are neighborhood-based, some focus on projects and some include the devolution of power to voluntary groups. Some approaches are purely managerial, others seek to widen public involvement in council decision-making. Those on the right even argue that the introduction of market mechanisms into public services is the ultimate form of decentralisation, on the grounds of power, in theory at least, is 'decentralised' to the individual service user who can exercise choice between competing service providers. (Burns et al., 1994, 5-6)

The World Bank (2013) distinguishes four types of decentralisation: political, administrative, fiscal, and market based. Political decentralisation looks to increase public participation with local electorates to bring decision-making closer to societies' interests. Administrative decentralisation redistributes authority from central state government to more local municipalities. Fiscal decentralisation defers revenue building/spending to lower levels of government. Finally, market (or economic) decentralisation adopts a neoliberal vision that opens public services up to the profit-seeking private sector, transferring government power to the market via deregulation. However, as processes of monopolisation play out, this can merely resemble a "shift of power and resources from one major, centralized power center to another" (Manor, 1999, 5).

Bitcoin offers a radically alternative blueprint for decentralisation. This framework originates from a bottom-up hacker mentality that focuses on individual control and responsibility over transaction management underlined by computer code. In this sense, *algorithmic decentralisation* provided by Bitcoin uses 'neutral', pre-programmed, administrative rules set in place by software to unleash the 'self-organising' and emancipatory power of the free market. For this reason, the Bitcoin blockchain is most strongly aligned with market decentralisation that embodies a faith in market mechanisms stemming from laissez-faire economics (Smith, 1776; Hayek, 1944). It is in this vein that decentralisation has become part of the lexicon for modern day libertarian ideologues that are skeptical of centralised state power (Loomis, 2005; Kauffman, 2008).[9] David Golumbia (2015, 2016b) thus labels the political economy of Bitcoin as "right-wing extremism" (see Chapter 3). From this point of view, blockchains become the algorithmic skeleton of Adam Smith's (1759, 1776) invisible hand of the market.

---

[9] The bailing out of banks after the 2008 global financial crisis and the scandal presented by the NSA PRISM data mining network has only fuelled this distrust in central government despite the role of corporations in both of these events.

Algorithmic decentralisation à la Bitcoin does not attempt to shift decision-making down the hierarchal tree but looks to de-centre previous structures completely by placing economic power in the hands of the individual. To early Bitcoin proponents political, administrative, and fiscal decentralisation were moribund because their processes still relied on a central core: the governments of nation states. In other words, the decision to 'decentralise' came from 'upon high' (central governments/World Bank/ International Monetary Fund) with a greater emphasis on increasing efficiency rather than dissolving power. Alternatively, the Bitcoin blockchain model bypassed state governments altogether—a political rift arising from questioning the given order of things and taking direct action (Rancière, 1998; Žižek, 1999; Swyngedouw, 2007, 2009, 2011). The individualisation of economic control offered by blockchain protocols, however, is often inhibited by a technical barrier to entry where users rely on entrepreneurial third parties to administrate transactions on their behalf—resembling a power shift to other centralised institutions (see Chapter 5 and Chapter 6).

Tracing Networks

Blockchains are infrastructures (the shape of material hardware) as much as they are algorithmic architectures (the shape of semiotic code). Brian Larkin (2013) describes infrastructures as "material forms that allow for the possibility of exchange over space" (327). In doing so, they materialise connective arrangements that generate different modes of organisation. Traditionally, these networked infrastructures have often been categorised into three distinct configurations: centralised, decentralised, and distributed. Such schemas are dependent on the patterns of connectivity between nodes in the network (see Figure 1). Paul Baran (1962) introduced these diagrams to demonstrate the vulnerability and resilience of infrastructural networks under the threat of nuclear attack during the Cold War. Centralised networks consist of "a single central power point (a host), from which are attached radial nodes" (Galloway, 2004, 11). These star-shaped networks are vulnerable because "[d]estruction of the central node destroys intercommunication between the end stations" (Baran, 1962, 3). A "*de*centralised network is a multiplication of the centralized network" (Galloway, 2004, 31) and is called such "because complete reliance upon a single point is not always required" (Baran 1962, 3). However, destroying a small number of nodes can still sabotage communications. This led Baran to "consider the properties, problems, and hopes for building communications networks that are as 'distributed' as possible" (ibid.). Mesh-shaped distributed networks "have no central hubs and no radial nodes. Instead each entity in the distributed network is an autonomous agent" (Galloway, 2004, 33). The Internet was originally designed to replicate this network form as a "solution to the vulnerability of the military's centralized system of command and control" generating resilience by being "precisely noncentralized, nondominating, and nonhostile" (Galloway, 2004, 29).

[Image removed for copyright purposes]

Figure 1: Centralised, decentralised, and distributed networks

Despite their theoretical differences, the terms decentralised and distributed are often taken to be synonymous—particularly in blockchain discourse where they are almost exclusively used interchangeably. This necessarily confuses what are distinct structural patterns. Usually when blockchain proponents champion "decentralised" architectures they invariably list all the characteristics of distribution. In response to this, an analytical framework is used here to address this disorientation and articulate an argument that takes the diversity of discourse and material conditions into account. It is useful to think of the two schemas, centralised and distributed, as two ends of an architectural and theoretical scale, or spectrum, for networks. This polarisation is mathematical: on one end of the scale all radial nodes must pass through a central node (centralised) and on the other all nodes must be able to connect with any other (distributed). Yet they are not a complete binary. The reality is that these two end points as network states are rarely (if ever) reached: "[i]n practice, a mixture of star and mesh components [are] used to make communications networks" (Baran, 1962, 3). Distinguishing between these "stars" and "meshes" can often prove to be a wild goose chase (Eggimann et al., 2015).

Algorithmic decentralisation is a process that relies on digital architectures to administrate transactions neutrally without the need of an overruling entity for authorisation—a quest for moving monetary systems from left to right in Figure 1. Bitcoin is supposed to do with value what early acolytes hoped the Internet would do with information: provide a network that eradicates or flattens power between actors. The Internet is widely regarded as the world's most distributed network thanks to its extensive connectivity that can relay information between nodes around the world via different communication networks. But, as Alexander Galloway (2004) states, the act of decentralisation itself *is* a political act: a theoretical premise akin to Lawrence Lessig's dictum "code is law" (1999). Even more pertinent to blockchain studies is how the Internet maintains and embodies centralised and hierarchal modes of organisation. The Internet's TCP/IP protocol, for example, must engage with hierarchal structures like the Domain Name System (DNS) to function (Galloway, 2004). Nicole Starosielski's (2015) ethnography of undersea network cables also helps shatter the popular illusion of a wireless world instead presenting the Internet as a latticework of wires and cables that traverse over land and submerge under oceans. It is at specific loci across this spatial infrastructure that particular actors can situate themselves to enable but also dominate network practices. Cultures and economies intersect with algorithmic architectures and material infrastructures in different ways but this relationship is always political. From this perspective, it is also important to remember that the network diagrams in Figure 1 are topological rather than topographical and so have limitations when imagining the precise spatial materiality of the Internet.

In its entirety, the Internet can be seen as a decentralised network where centralisation creeps back into its distribution in different places. For example, the "Great Firewall of China" shows how centralised governments can block connectivity to certain nodes in specific geographic areas (Clayton et al., 2006; Zhang, 2006). A similar pattern of restriction is also seen in corporate workplace Intranets (Bernard, 1998; Ferraiolo et al., 1999). Additionally, effects of platform capitalism coordinate and centre Internet activity through a small number of technology companies, like Google and Facebook, who collect enormous amounts of network data (Langly & Leyshon, 2016; Srnicek, 2017; see Chapter 7). The vast majority of this data, even that 'belonging' to other companies, exists in massive data centres, that are predominantly owned by a small number of companies (Rossiter, 2016). Meanwhile Internet service providers enforce monitoring and control over citizens at the consumer level. These processes have led commentators to claim that the Internet is now far less distributed than when it first appeared (Kopfstein, 2013).

These case studies suggest that there are limitations to using the term decentralisation when describing networked infrastructures:

> Perhaps it is time, then, for activists and political theorists of digital media cultures to take seriously the constitutive work of centralized systems of organization, and stop valorizing decentralized, distributed modes of communication and realize that these decentred modes are predicated on [some form of] centralization. (Rossiter, 2017)

By simply calling Bitcoin a decentralised system, without any further critical investigation that could pinpoint centrality, the varying modes of power in its network are ignored and blockchain networks are presented as systems that possess the mythological characteristic of network neutrality—something that has so far been proven to be a fantasy when lifted out of the abstract mathematics of pure code and contextualised within the complex network cultures in which software sits (Lovink, 2002; Rossiter, 2006). In fact, network neutrality is now more of a movement to push back against the closure/hierarchy of the Internet. The adjective 'decentralised', then, as an ambiguous term, should be handled with care and deconstructed to encapsulate the complexity of networks. As David Golumbia (2016a) aptly puts it "computerization always promotes centralization even as it promotes decentralization".[10]

Reconstructing Centralisation

The impotence of decentralisation to describe accurately technical, infrastructural, cultural, political, and economic systems demands a rethinking or reframing of its definitional parameters. I therefore pull back from a fetishisation of decentralisation—that goes hand in hand with a sweeping, radical, disruptive potentiality—to open up a more nuanced understanding of its contours. This is done by employing actor-network theory as a toolkit for thinking through coalescence in decentralised networks. Echoing tropes of Foucauldian discourse, actor-network theory became prevalent in the 1980's through the seminal work of Bruno Latour (1986), John Law (1986), and Michel Callon (1986). Actor-network theory outlined a "relational epistemological truth and ontological reality [that] are contingent and depend on the strength of heterogeneously assembled actor networks of human and non-human entities" (Demeritt, 2002, 775). In other words, it provided a material-semiotic framework for following or tracing objects and ideas as they are produced, discussed, maintained, and changed. Law (2007) explains how the

> …actor-network approach thus describes the enactment of materially and discursively heterogeneous relations that produce and reshuffle all kinds of actors including objects, subjects, human beings, machines, animals, 'nature', ideas, organisations, inequalities, scale and sizes, and geographical arrangements. (2)

---

[10] The same could also be said for free markets.

In this sense, reality does not precede mundane practices but is shaped within or through them (Mol, 1999; Thrift, 2007). By using actor-network theory as an analytical tool I seek to understand algorithmic decentralisation via blockchains by paying attention to the bits and pieces that hold them together.

Actor-network theory has been employed by Nigel Thrift (1994, 1996) to demonstrate how the heterogenous networks that perpetuate money are not abstract but embodied (Leyshon, 1997). With reference to Thrift's work, Bartley et al. (2002) explain how monetary networks are "produced and maintained by the conjoint action of actors, institutions and resources" (164). This is where value is formed as opposed to an inherent worth held by the isolated thing-as-money itself. As such, the human and non-human assemblages that support money are "inherently unstable, needing constant effort and attention" (163). Actors within these networks often strive to "improve their own representations of what money is, how it should be made, distributed and ordered" (Leyshon, 1997, 389). The networks of money, then, are essential to its becoming (Dodd, 1994, 2014): researching how cigarettes become a commodity money through practice in prisons, for example, one must pay close attention to the material, spatial, and temporal transduction of that thing into a particular form of currency. In this sense, "[m]oney, primitive or modern, can be understood only in its context" (Baker & Jimerson, 1992, 679).

This approach recognises the multiplicity and complexity of life and acknowledges that there is no unified narrative for anything (Mol, 2002).[11] There are, then, many Bitcoins or blockchains at work at any given time. My research explicitly seeks to illuminate parts of this multifariousness:

> [A]ctor-network theory is descriptive rather than foundational in explanatory terms… Instead it tells stories about 'how' relations assemble or don't. As a form, one of several, of material semiotics, it is better understood as a toolkit for telling interesting stories about, and interfering in, those relations. More profoundly, it is a sensibility to the messy practices of relationality and materiality of the world. Along with this sensibility comes a wariness of the large-scale claims common in social theory: these usually seem too simple. (Law, 2007, 2)[12]

---

[11] Another researcher could find alternative actor-networks that are just as important for blockchain culture, history, politics, economics, and geographies.

[12] A key objective here is to dissolve traditional Cartesian dualisms and unlock "more-than-human geographies" (Whatmore, 2006). This hybrid approach opens up "analytical space for nonhuman agency as an emergent relational property" (Lorimer, 2007, 913). In the case of this thesis, it explains how objects and (infra)structures take shape through networks of practice and provides a framework for understanding the material messiness of algorithmic architectures that are 'assembled' via a myriad of processes. This acknowledges the "living fabrics" of social life: "relational configurations spun between the capacities and effects of organic beings, technological devices and discursive codes" (Whatmore, 2000, 266). After all, the "mixtures and configurations of machines, animals, states, organisations, ecologies, [and] politics are continually made up of all manner of elements, which themselves are nothing if not hybrid forms" (Hinchliffe, 2007, 51).

Actor-network theory is used in this thesis to develop a new way of thinking about modes of (de)centralisation by reframing Michel Callon's (1986) term "obligatory passage points" and applying it to blockchain systems. Callon used this term to describe how control is afforded to those in networks that create points through which practices must be funnelled. Such bottlenecks become a suitable framework for understanding the cohesion of certain practices in what appear distributed networks where control is afforded to actors.[13] This raises certain actors into centralised positions of power as they control passage points through which other actors in a network are obliged to pass. Framing coalescence through obligatory passage points helps diffuse the centralisation-decentralisation binary and allows a plethora of material actors to become accountable in the empirical analysis of algorithmic (de)centralisation.

The relational mode of thought provided by actor-network theory has been championed for "complicating the distinctions between human and non-human, social and material' (Whatmore, 2002, 1). But this is a double-edged sword. While it gives objects a 'voice', it has also been accused of relegating *human* agency to the same potency as that of objects and ideas (Collins & Yearley, 1992). Critics claim that this flat ontology fails to attend to power structures in society such as classism, racism, or patriarchy by losing itself in an endless web of description (Amsterdamska, 1990; Whittle & Spicer, 2008). However, such postulations that actor-network theory is antithetical to structure are misguided. In fact, what actor-network theory claims is that hierarchy is not imposed from upon high by a preceding, external, all-powerful force such as 'the state' but rather the state, and other 'powers', are held within complex networks of material practice.

The Role of the Central Bank

Banking is often considered to be centralised because central banks act as the 'banker's bank' and control monetary policy: the connections by which a nation state's central bank interacts with commercial banks resemble the centralised network in Figure 1. However, citizens do not bank directly with the central bank but at commercial banks. Because there are many commercial banks, more spokes are formed off the central node to resemble a network closer to the decentralised configuration. Each international bank has its own centralised network tied to the central bank of its own nation state and are also connected together by other transaction networks such as SWIFT or, more recently, TransferWise. Banking as a whole, then, is not reliant on a singular centralised network but a multitude of networks. Global currency markets also integrate monetary systems as different state monies can be freely traded against each other. Because a vast array of centralised networks interact with each other in

[13] An example of an obligatory passage point in a decentralised network is the Panama Canal: an artificial channel of water that connects the Atlantic and Pacific oceans between the continents of North and South America. The control of this unique spatial conduit enables the Republic of Panama to become a powerful economic gateway in (apparently distributed) international maritime trade by permitting or omitting ships through a controlled point of convergence.

an interconnected manner to create the overall banking system, it is, from this perspective, decentralised despite a reliance on centralised institutions (especially central banks as the core of monetary policy). Bitcoin proponents, however, envision a global monetary network without any centres of control that can be corrupted or mismanaged (Appendix 4 provides an example of centralised control through the demonetisation of India in 2016).

Such widespread, collective faith in the global financial system demands trust in the "gatekeepers" of money including central banks, commercial banks, investment banks, and credit card companies (Vian & Michalski, 2011).[14] The three main roles of a central bank are balancing price fluctuations, maintaining financial stability, and supporting the state's funding in times of crisis (Goodhart, 2011). More specifically it sets the official interest rate to manage inflation and the currency exchange rate, controls the nation's money supply, regulates the banking industry, acts as the lender of last resort, and manages the country's foreign exchange, gold reserves, and government stock register. In contrast, Bitcoin represents an anti-centralised currency move—one that pushes against the nationalism of the financial system embedded in central banks. To enhance flow and decrease length, this chapter skips the deeper history of central banking but a better understanding of what Bitcoin seeks to oppose can be found in Appendix 2. Bitcoin proponents reject the premise of central banks who are afforded control over money, adhering more to the free banking system but with an algorithmically set monetary policy. It is with a degree of irony, however, that, as a response to the 2008 global financial crisis, Bitcoin aligns itself with the political processes of privatisation and deregulation to overcome any subsequent crises yet overlooks the role that both played in the spiralling collapse of *deregulated* derivatives issued by *private* banks (not to mention the centralising tendencies of the market towards monopolisation).

Blockchain: The Decentral Bank

In contrast to central banks, the Bitcoin blockchain exists as distributed and peer-to-peer software where every person running the protocol maintains a copy of the digital ledger (or blockchain) that designates currency units to particular accounts (or addresses). The shared maintenance of a ledger

---

[14] The central bank, for example, is afforded the power to make alterations in monetary policy. Money, under state rule, is currently created as debt through loans (Graf, 2013); central banks control monetary policy and determine the volume of 'base money'—a pool that commercial banks borrow from. By adjusting the interest rates of these loans and by changing the minimum deposit that commercial banks must keep with them, central banks maintain control over the total money supply. They manage and alter systematic components by tweaking the key lending rate. If central banks lend money to commercial banks with low interest and lower the minimum deposit requirement then banks like Barclays or Wells Fargo can lend 'cheap money' to the public less expensively. This has the overall effect of increasing the total money in circulation. If monetary supply increases without national economic growth then inflation sets in: because there is more money available, each unit of currency becomes less valuable and its buying power is reduced. This is reflected in the rising price of goods and services (hyperinflation is this process on steroids). Effectively, printing more money saps value from public deposits. To counter this, the central banks can raise the key lending rate and raise the minimum deposit requirement to decrease the money supply. In the case of the Eurozone, nation state central banks must also keep their own deposits with the European Central Bank who ultimately alter the interest rates for the entire euro.

[Image removed for copyright purposes]

Figure 2: A Bitcoin transaction where Alice sends 10 BTC to Bob by broadcasting it to every other node in the network that all update their ledgers simultaneously (Brikman, 2014)

removes the need to trust centralised third parties like commercial banks with keeping records. It also contributes towards the robustness of the protocol, as there is no single point of failure to attack or hack. The blockchain, then, is an active database and 'permanent' record of every Bitcoin transaction ever made. Transactions are sent to every node in the Bitcoin network at once and roughly every ten minutes these transactions are bundled into a block and added to the blockchain like new pages in a ledger (see Figure 2). Its architecture is such that every node in the global network updates the state of the blockchain 'simultaneously' so that a consensus is reached as to which addresses hold bitcoin. While transactions made with Bitcoin are transparent, addresses are pseudonymous in the sense that they are not tied to the identity of users.[15] This not only changes the transaction structure from traditional systems but is also designed to create a new inbuilt privacy model (see Figure 3). Here, identity is not a

[15] This is like watching people in a room wearing balaclavas passing fiat money around: it is clear where the money is moving and how much money each person is holding and/or passing yet it is not clear who the specific people exchanging the currency are. This analogy is, however, simplified as users can in fact have infinite addresses.

[Image removed for copyright purposes]

Figure 3: Traditional privacy model offered by financial institutions in comparison to the privacy model offered by Bitcoin (Nakamoto, 2008)

prerequisite for making a transaction and so personal information is no longer required for authorisation like it is with a centralised commercial bank. Instead, each user holds private keys to sign transactions from their addresses that hold bitcoin. This allows people to act as their own personal bank via the network. In this sense, control and security measures over monetary administration reside, not with a third party, but with all individual users.

Monetary policy, then, follows Lawrence Lessig's (1999) dictum "code is law" as it is defined and governed by the algorithmic structure of the blockchain. In regulation terms, operations can only be made within the codified parameters set by the protocol reflecting Alexander Galloway's (2004) argument that distributed protocols do not eradicate control; rather, power is defined by the rules of the system itself. Monetary production is also codified into the protocol so that bitcoin is released slowly over time in an exponentially declining manner until a maximum of 21,000,000 bitcoin will be produced by 2040.[16] Inflation, then, is steady, predictable, and declining until it stops entirely. This artificial cap makes Bitcoin analogous to a digital hyper-transferable precious metal that can be transacted through a computer or smartphone. Indeed, the practice of Bitcoin mining extends this metallic analogy (Maurer et al., 2013): chunks of bitcoin are randomly rewarded by the protocol to people (called miners) who 'donate' their computer power to administrate and secure the Bitcoin network simultaneously (see Chapter 5). The reward goes to the miner whose computing power finds a number called a nonce (which is extremely difficult to generate) and is then awarded the privilege of mining the next block (akin to writing the next page in the ledger). Blockchains, then, do not omit third parties as many proponents claim (Nakamoto, 2008), but rather randomise them across a distributed network. This randomisation, however, is important because it means no single miner can omit transactions from the blockchain and therefore restrict an actor from participating in the network: this is why Bitcoin is often referred to as 'permissionless' in terms of access.

[16] Each bitcoin is divisible to the increment of 0.00000001, named a satoshi after the pseudonym of its inventor(s).

Bitcoin mining is also the process in which the protocol distributes newly 'minted' coins that act as a game-theoretical economic incentive to miners. This system has since been labelled cryptoeconomics (see Chapter 4). Here, cryptography is used to prove the historical properties of the blockchain while the incentive of obtaining economic value in the form of cryptographic tokens defined by the system encourages those properties (and value) to hold into the future (Buterin, 2017). The combined computational power is used to bundle transactions into blocks thereby adding them to the blockchain. The Bitcoin blockchain, then, is like a digital tapestry of transactions woven by miners who hire out their computational power to maintain the ledger collectively (Scott, 2014b). Because bitcoins are internal to the protocol they (theoretically) cannot be created outside of what has already been predetermined by its codified parameters; this is unlike the process of fractional reserve lending practised by commercial banks or the 'printing' of money by central banks. Bitcoin, then, attempts to redistribute monetary trust into a codified architecture that decentralises the control of monetary policy.

Cash, Credit, or Crypto?

Value is categorically subjective. In fact, the subjectivity of value is the underlying foundation on top of which markets are built. Things are never inherently 'precious' on their own accord but are rather culturally defined and calculated/quantified as such. Markets function due to the temporal and spatial subjectivities of worth surrounding particular commodities: people are willing to pay different prices at different times in different places for different goods. This process of price negotiation (say for Google shares, gold contracts, oil derivatives, the British pound, Manhattan apartments, or a bitcoin) forms what is known as a market price, which is merely a consensus of the agreed-upon value for a specific commodity (Callon, 1998b, 1999). The globalisation of markets along with trading tickers has given the impression of a singular world price for certain commodities yet, in reality, the vast majority of trades are made at different amounts to that posted on global commodity or stock markets. Market value is a moving average of the 'going-rate' for goods derived from bundling their entire bid and ask prices together. This is fundamentally a social practice. To understand markets properly, researchers must "trace how the webs of heterogeneous material and social practices produce them. It is these that are performative, that generate realities" (Law, 2007, 12).

Often the intrinsic/use value of a thing-as-money is next to nothing: a coin or a bank note is inherently worthless independent of the value that networks of people ascribe to it.[17] But this simple fact does not make money any less powerful: if a million dollars were dropped from an urban rooftop people

---

[17] The example of the hyperinflationary German mark laid out in Appendix 1 suggest there is some use value to material currencies but this is not tied to its monetary value.

would still surely grab at the notes as they fell down onto the street. Peter Pels (1998) draws on literature that follows Karl Marx's (1897) idea of the fetish to explain this phenomenon; here, a "double attitude" (Freud, 1950), or "double consciousness" (Pietz, 1985), is at play. This form of fetishism is both 'false' and 'functional': "a form of misrecognition as well as recognition of reality" (Pels, 1998, 102). The value of money is false/fictional because of its inherent nothingness: the virtuality of value is somewhat detached from the medium itself so that to 'work' it needs institutions, beliefs, and trust. On the other hand, the value of money is functional/true because of what people can(not) do with(out) it. There are, so to speak, two sides of the coin.

The functionality of money is suspended by consensual networks of trust that propel things-as-money into the more-than-material. This is why money has historically been able to adopt many forms: none of the things-as-money hold monetary value outside of human interaction and their spatial or temporal settings. When the Bretton Woods agreement that tied the value of a number of fiat currencies to gold dissolved the term fiduciary money was used to describe the trust in money with no backing of precious metal. Yet this application of fiduciary to non-backed currency is a misnomer: all money is fiduciary and dependent on trust. Even gold, widely considered to be the holy grail or base of monetary value, can be seen as social meaning (value) attached to a certain arrangement of atomic particles that once worked as a monetary standard due to its rarity (Graf, 2013). But when the networks of trust disintegrate so does that thing's ability to act as money. Money is what money does, but not externally to its embedded social relations (see Appendix 5 for an account of the West African cowrie shell and Appendix 6 for the Swiss-printed Iraqi dinar).

Money, as the ultimate commodity (Harvey, 2010), has the ability to flatten other commodities into a relational and relative measurement of value (Marx, 1867; Simmel, 1900; Crump, 1978; Roberts, 1994; Maurer, 2006). It is "the great converter of everything into everything else" (Peel, 2000, 32). In this sense, money homogenises other commodities under a quantifiable scale. But money is deceptively fickle: it too (being a carrier of value) is the result of social consensus that is subject to the cultural constraints of time and space. Certain events demonstrate that such flattening is merely a consensus performed through networks. For example, in 2008 the foreshocks of the global financial crisis appeared when the British bank Northern Rock sought a liquidity support loan from the Bank of England, which instilled fear in their depositors leading to the first UK bank run in 150 years (Stuckler et al., 2008). For those queuing at Automated Teller Machines (ATMs) ready to swap their digital pounds in Northern Rock accounts for physical bank notes, fungibility between the two manifestations of British currency did not exist. This situation reveals the delicacy of money's networks of performance (for a demonstration of this delicacy within the board game of Monopoly see Appendix 7).

The spatial and temporal specificity to fiduciary trust has allowed money to 'materialise' in a plethora of forms. Historically, money's peculiar performativity has been reified in a bed of materialities such as cowrie shells, beer, salt, glass beads, gold, pepper corns, buckskins, yak excrement, tally sticks, grain, coinage, bank notes, cheques, and credit cards. As Laclau (1990) states, a "stone exists independently of any system of social relations but it is, for instance, either a projectile or an object of contemplation only within a specific discursive configuration" (101). If the materiality of money does indeed embody social relations then the spaces that it fills makes it culturally specific across disparate geographies. This character of money is described by Leyshon and Thrift (1997) as "information circulating in specific, separate but overlapping actor-networks, made up of actors, texts and machines, which think and practise money in separate but overlapping ways" (xiii). These networks culminate to create monetary value that is practised and brought into being through independent yet interlinked networks (the quotation can also be reused to become a fitting description of Bitcoin).

The idea of national sovereignty is often defined by currency control—hence debates surrounding the continuation of the British pound when the euro was first introduced. Here currencies are issued by central banks, informed by governments, administered by commercial banks, accepted by companies, and spent by citizens. All of these actors are essential to the successful performance of sovereign money. This production of money also becomes imperative to the articulation of borders (Dodd, 1995; Mezzadra & Neilson, 2013). The networks created not only propel fiat currencies into being but also perpetuate regional boundaries so that money is at once a result of predefined political parameters at the same time as contributing to the continued negotiation of national geographic spacing and constitutional territorial realities. This simultaneously and necessarily creates a monetary perimeter of inclusion and exclusion positioning actors inside or outside of state economies. It has even been argued that sovereign backing is *the* crucial factor for defining and enabling money (Knapp, 1924). However, state control is by no means a prerequisite of money and regionalised economies are more complex than the inside/outside of bordered national currencies (for example, Argentinians holding US dollars as a store of value; see Appendix 1).[18] Looking at states as bounded entities with a singular currency is far too much of a reductive approach as boundaries are always navigating a tightrope between the somewhat real and somewhat imagined (Terlouw, 2001; Van Houtum & Van Naerssen, 2005; Van Houtum et al., 2005; Walters, 2006). And, most importantly, nation states do not have a monopoly over money.

Bitcoin was by no means the first alternative currency in opposition to fiat-based money (Hileman, 2014). Non-state currencies have been used across varying geographies such as the localised Brixton Pound in South London (North & Longhurst, 2013; Taylor, 2014), Ithaca Hours in New York (Jacob et

---

[18] "Money does not map neatly onto territorial space; indeed, it often flows along the internees *between* spaces" (Dodd, 2014, 226).

al., 2004; Hermann, 2006), and the more wide-reaching M-PESA, a mobile telephone airtime credit that evolved after a predecessor was used for monetary transactions in Uganda, Ghana, and Botswana (McKemey et al., 2003). The network providers Safaricom and Vodacom (owned by Vodafone) later developed M-PESA: a company-backed credit that leapfrogged traditional banking systems and became widely used in Kenya (Hughes & Lonie, 2007; Mas & Morawczynski, 2009; Mas & Radcliffe, 2011; Omwansa & Sullivan, 2012; Maurer & Swartz, 2015; O'Dwyer, 2015).[19] It later penetrated (but to a lesser extent) Tanzania, South Africa, Afghanistan, India, Romania, and Albania (Taylor, 2014; 2015), whereas lobbying by banks stifled its success in Nigeria (International Finance Corporation, 2011; Scott, 2016). Mobile phones have saturated these national markets whereas banking facilities remain absent to the majority thereby providing fertile ground for M-PESA to thrive. Today it is used by tens of millions of people daily (World Bank, 2012) and is the "conduit for half of Kenya's GDP" (Lanchester, 2016). M-PESA was not thrust upon these populations as a currency; nor did it start as money in-and-of-itself. Rather it arose as such through dense cultural-economic networks.

Bitcoin, on the other hand, was conceptualised from the offset as an alternative currency. Unlike its predecessors, however, its designer(s) aspired to create a substitution for fiat currencies that is not limited to specific geographic areas: not a local but *global* alternative currency. Existing on distributed ledgers scattered across the material infrastructure of the Internet, cryptocurrencies therefore challenge the role of the central bank and claim to overcome patterns of financial exclusion (Castells, 1993; Lash & Urry, 1994; Leyshon & Thrift, 1994, 1995, 1996; Leyshon, 1995). Because banks profit more by catering for the rich, financial services and correlative wealth tend not to trickle down to poorer communities. Algorithmic decentralisation via cryptocurrencies is championed for bypassing financial institutions in developing countries so that citizens can become their own banks. Mobile phones themselves leapfrogged the landline telephone networks in African countries and the penetration of cellular devices within poor populations has presented an opportunity for cryptocurrency proponents and entrepreneurial start-up companies to design inclusive 'decentralised' banking models. These solutions and their success rate are dependent on the complex relationship between money, code, and space.

Bitcoin, as a form of non-institutionalised code-money, has played a role in challenging contemporary monetary assumptions: questioning concepts of value and offering a currency system that allegedly exists outside of networks controlled by centralised institutions. Words like 'decentralised', 'peer-to-peer', 'shared', 'distributed', 'dispersed', 'open source', 'digital', 'transparent', 'networked', and 'global' fill its articulatory toolkit. This vocabulary tends to suggest a border-transcending currency without any locus of control: rhetorically stripping away localities of power from its imaginary. Even the tagline given to Bitcoin by its proponents, "Vires in Numeris" (Strength in Numbers), promotes a trust in the

[19] In "M-PESA" the "M" stands for mobile whereas "Pesa" is Swahili for money.

reliability of mathematics (the algorithmic architecture of the blockchain) as opposed to the fickleness of people. Sequestering discourse to the realms of autonomous calculation, that defuses and diffuses governance in this manner, withdraws Bitcoin to the apolitical sidelines by removing it from human agency and hierarchal or geographical control. Indeed, that is its political intent: an "embrace of a libertarian ideology of non-governmental monetary policies and the promise of technology to free us from politics" (Karlstrøm, 2014, 2). These arguments are reminiscent of the promises and fallacies made by early Internet pioneers of network neutrality.

Bitcoin/Space

Today, only 3% of money in the United Kingdom exists as the 'physical' cash of bank notes and coins; the other 97% is in the form of digital balances controlled by commercial banks with similar figures for the global monetary supply (McLeay et al., 2014). The increasing digitisation of money has been described as another step in a growing abstraction as it has evolved through history (Weatherford, 1994) and used to reinforce Karl Marx's (1867) thesis that money is succumbing to dematerialisation: it is "no longer a commodity which is transported hither and thither. It no longer even consists of paper, in the main. Increasingly, money is a set of double entries briefly etched into computer memories" (Leyshon & Thrift, 1997, 22). While the codependence of money and code is important, its nebulous character should not be overstated lest rhetoric slips into an all-too-easy fetishisation of the digital, for example: the "movement of money in the global economy is based on code and much of the world's wealth exists as database entries rather than any material form" (Zook, 2012, 1106). By pulling the material out of debates of money/code, arguments step into a dangerous ontological territory because they often loose sight of the material-semiotic connections that bring both money and code into being.[20] Alternatively, I view the digitisation of money as a socio-spatial *re*materialisation. For example, state-based monies that are supported by code are not lost in an ethereal netherworld but are constituted by a host of materials including people, servers, computers, offices, mobile phones, ATMs, databases, cables, and wires. Understanding different instantiations of money/code in this way, acknowledges how they appear as distinct geographic assemblages that are constantly brought into being through relational, cultural-economic practice. This is what I refer to when I say money/code/space.

Adrian Pel (2015) describes how a resurgence of arguments that claim digital technology conquers space have arisen in relation to Bitcoin. Here, the 'decentralised' architectures of blockchains can supposedly detach money (and other things) from geography (Bergstra & Leeuq, 2013). It has become a cliché in the discipline of human geography to critique claims made in the 1990's that a promised

---

[20] This is excusable if discourse is intended as a metaphorical hyperbole but does not work ontologically.

digital revolution spelled a borderless world (Ohmae, 1990), the end of geography (O'Brien, 1992), and the death of distance (Caincrross, 1997). It is certainly true that digital infrastructures have harnessed tremendous globalising effects on the social, contributing to popular concepts such as time-space compression (Harvey, 1989) and a global sense of place (Massey, 1991). But this merely means that the complexities of space must be examined more closely (Sokol, 2011). Obituaries for space, then, are fallacious and it is the core precept of this thesis that algorithmic decentralisation via blockchains is fundamentally a spatial process. Geographical accounts of Bitcoin and blockchain technology, however, remain thin on the ground. For the most part, the word 'geography' only appears in a few technical papers (Bissessar, 2013; Baumann et al., 2014; Gervais et al., 2015; Donet et al., 2014; Lischke & Fabian, 2016; Tschorsch & Scheuermann, 2016). Yet a trickle of work has begun to map explicitly the spatial ontologies of Bitcoin (Gervais et al., 2014; Pel, 2015; Blankenship, 2017; Pilkington, 2017). It is with similar intentions that this thesis examines the geographies of algorithmic decentralisation as they relate to money. This undertaking demands a conceptualisation of space.

Human geographers have long been concerned with questions of space (Shields, 2013). It is Doreen Massey's (2005) conceptualisation that I adopt most strongly here: a relational and processual product of connected and disconnected trajectories that are always in a state of becoming (see Appendix 8). In this sense, space is not simply a container within which things happen; rather, "spaces are subtly evolving layers of context and practices that fold together people and things and actively shape social relations" (Kitchin & Dodge, 2011, 13). Bodies are not *in* space but *of* it (Merleau-Ponty, 1963). This means understanding space as a "product of *interrelations*" (Anderson, 2008, 228) or a relational flux that is constantly brought into being. Digital code is part of this process. Air travel, for example, "emerges through the interplay between people and software in diverse, complex, relational, embodied, and context-specific ways" (Kitchin & Dodge, 2011, 156). From this perspective, software is by no means a separate, inaccessible or lifeless representation of real space (Massumi, 2002; Rutter & Smith, 2005), but is an assiduous, lively, and forceful constituent of reality. So, "everything takes-part and in taking part takes-place: everything happens, everything acts" (Anderson & Harrison, 2010, 14). This ontology postulates an impossibility of holistic and utterly replicable spatiality in place of a more ephemeral and processual understanding of a constantly nuanced "throwntogetherness" (Massey, 2005). At the same time, 'spatial structures' can hold temporal stability and, although space-time is fleeting, practices, while never being entirely the same again, can follow particular patterns. This ontogenetic conceptualisation of space

> …does not deny the salience of structural or institutional expressions of power, variously labeled and analyzed within frameworks such as political economy, corporate capitalism, neoliberalism, or theocratic power, or the processes, practices, or systems of institutionally

> situated and enacted structures, such as the state and its delegates. (Kitchin & Dodge, 2011, 78)

Rather it recasts structures

> …as sets of ongoing, relational, contingent, discursive, and material practices, that are citational and transformative, and which coalesce and interact to produce a particular trajectory of interrelated processes. (Kitchin & Dodge, 2011, 78-79)

Understanding space in this manner has interesting implications for understanding how the Bitcoin blockchain is a constant meeting point for a myriad of sociotechnical trajectories that place money and code in a contemporary and dynamic relationship. The 'structures' of these spatial interconnections are deeply political. Such a perspective allows for temporal and geographic complexities, contextualisations, and contingencies to become apparent while softening the binary between centralisation and decentralisation by problematising algorithmic (de)centralisation as the coalescence of trajectories through obligatory points that form unique arrangements of money/code/space.

Conclusion

This chapter has problematised Bitcoin and blockchain technology and provided a framework for understanding their complex networks and geographical constitutions. Money and code can be seen as two things that are more or less centralised or distributed at different levels through space. This becomes an interesting point of interrogation for Bitcoin as its spatial trajectories stitch together new geographies of exchange. Framing obligatory passage points as loci of coalescence and control in algorithmically decentralised networks is a productive avenue for understanding the sociotechnical relationships that form blockchains. Because money (and value) is suspended through networks of practice, the Bitcoin blockchain becomes an 'object' that can be studied from an ethnographic perspective to uncover the material-semiotic processes that suspend it into being as a 'value carrier'. Such a methodology is appropriate for understanding algorithmic decentralisation as it helps trace certain practices as they coalesce in different spaces. In other words, money/code/space is a useful lens for examining the performativity of blockchains and uncovering the contours of their networked architectures, infrastructures, politics, cultures, and economies. A 'follow the thing' methodological avenue for researching Bitcoin and other blockchain technologies is the ambit of the next chapter.

Chapter 2
Follow the (Digital) Thing

"Down the Bitcoin Rabbit Hole"

A common phrase used within the Bitcoin community is "to go down the Bitcoin rabbit hole" (Moreno, 2013; Antonopoulos, 2015a; Mross, 2015; Smith, 2015; Lea, 2016; Bitcoin Project, 2017). This expression references the novel *Alice in Wonderland* and describes the shared experience of losing oneself down a twisting path into a surreal and unknown territory. The journey is one of self-education comprised of devouring every scrap of information pertaining to Bitcoin that one can get hold of: this often involves hours glued to a computer screen, reading, writing, coding, and learning as much as possible (Antonopoulos, 2014; Frisby, 2014). Down the rabbit hole is an obsessive and heterogeneous netherworld of programmers, speculators, entrepreneurs, political radicals, and libertarians whose practices contribute to a complex and compelling cultural economy. As it was for Alice in perplexing Wonderland, at times this intriguing adventure into the unchartered can feel lawless and nonsensical with scatty and fascinating figures of authority who provide reasons to question previously given or taken-for-granted realities. It is amongst this composite crowd that I situate my research to illuminate the tensions at play between the disparate actors spearheading a movement to disrupt 'dated' economic systems with software.

In this short chapter I build a 'follow the thing' methodology and apply it to the Bitcoin algorithmic protocol (the blockchain) with the aim of uncovering some of the human and non-human components that are bundled together in its becoming. Faced with researching a piece of cryptographic software that appears to work of its own accord, this technique was designed to be open to pursuing the unexpected connections that are uncovered in the process and which may not have at first been obvious during the research design. In other words, I sought to understand the material-semiotic relationships of Bitcoin's money/code/space, not by honing in on a singular aspect of my research topic, but by trying to view it from multiple angles.

As a multi-sited ethnography, the research process was undertaken in a variety of spaces including venture capitalist firms, FinTech accelerators, and Bitcoin/blockchain start-up companies and meet-up groups in the San Francisco Bay Area, New York City, London, and Sydney. I gathered qualitative data in the forms of participant observation and semi-structured interviews to understand better the roles that people play in producing the cultural economies of Bitcoin and blockchain technology, with particular attention paid to the obligatory passage points that are reinforced across their spatial networks.

Looking at these cultural-economic geographies through the phenomenological lens of actor-network theory, I was fully aware of my own role in the settings that I researched and allowed myself to become part of the cultural milieu as an "observant participant" (Thrift, 2000). This provided a rich empirical understanding of the ideological tropes and cultural practices that help weave together the material-semiotic/human-machine networks that permeate blockchains. At times this was utterly engrossing and it was not until after the six month research process that I realised I had, to some degree, 'gone native' by succumbing to technological 'solutionism'. On critical reflection, I was able to pull back and regain a form of objectivity but, in hind sight, my partial absorption into Bitcoin/blockchain culture was an extremely useful mode of self-reflection and (auto)ethnographic analysis (see Appendix 9).

This framework solves a number of research quandaries that arise when approaching a global algorithmic architecture that facilitates economic transactions concealed by cryptography. Bitcoin appears to be, by its very design, far-reaching, intangible, and untraceable; it exists digitally in a network that spans the globe and uses cryptographic code to conceal the identity of its users. How then, is a digital distributed software that grants a significant degree of (pseudo)anonymity via cryptographic practices to be approached/explored? The answer, for me, was made clear by using an ethnographic research method to trace the code and human relations (wherever possible) spun across Bitcoin's vast algorithmic fabric. This involved diving into the world of algorithmic code, dwelling in and engaging with online communities, attending Bitcoin and blockchain meet-up groups, working at Bitcoin and blockchain start-ups, and interviewing different people within its vast community to uncover (some of) the bits and pieces that propelled the Bitcoin phenomena into existence and continue to maintain it.

I initially gained access to the firms that I worked for and interviewed via a combination of cold emailing and face-to-face networking at Bitcoin meet-up groups. The second turned out to have a much higher success rate reflecting the deep social ties within the industry: meet-up groups were crucibles of interaction between venture capitalists, programmers, CEOs, enthusiasts, and lawyers, to name but a few. I was universally received with a warm reception and enthusiastic interest in my research that led to many referrals and further introductions. For example, at the San Francisco Bitcoin Devs meet-up I was invited to attend Blockchain University where I was later asked to join a blockchain company in Mountain View for two weeks. At the same developers meet-up I made friends with a company being incubated at Boost VC where I visited a number of times and which led to other event attendances like a hacker hotel book launch party. At the Sydney Bitcoin Meet-up I met a consultant who worked out of the Level 39 technology incubator in Canary Wharf, London, where I later worked myself following a visit where I was welcomed by its Head of Development. Table 2 outlines the key research activity undertaken—14 in-depth interviews were undertaken in addition to well over 100 ethnographic interviews opportunistically conducted in the field.

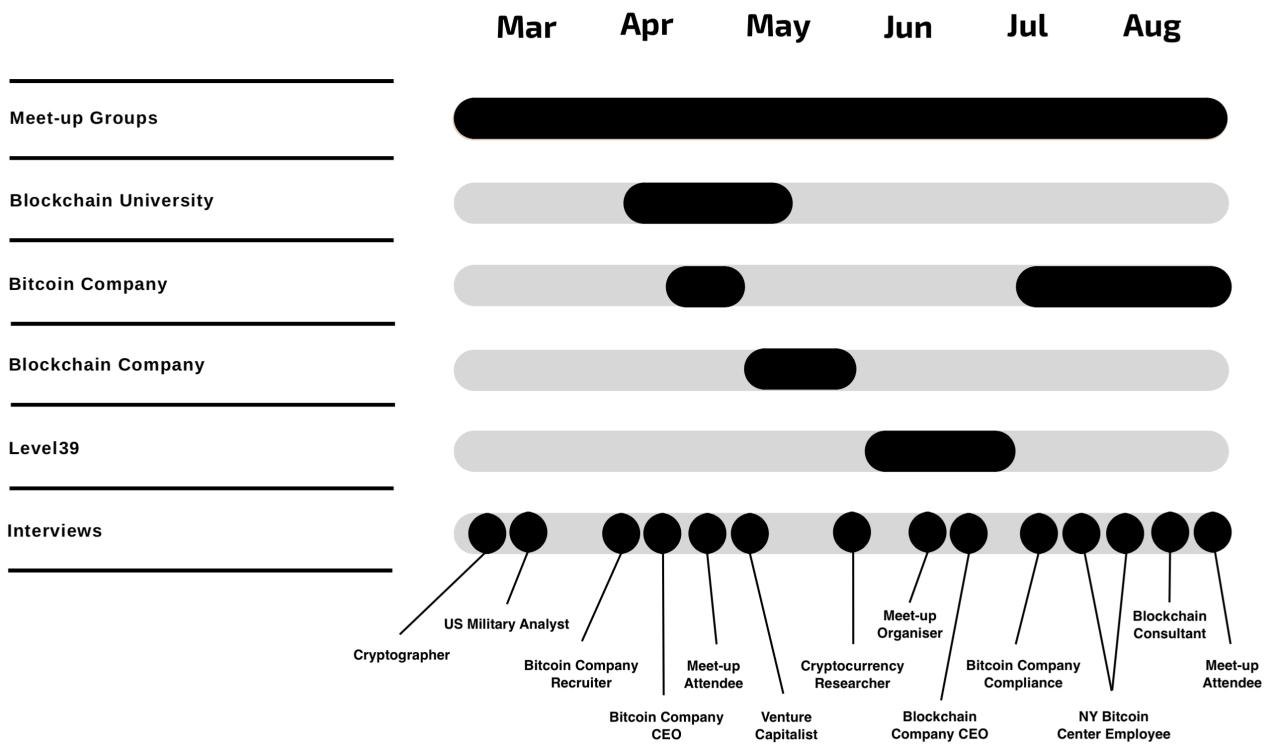

Table 2: Research field activity in 2015

Face-to-face data collection was complemented with an analysis of online forums, GitHub (where open source code is constructed), social media activity amongst Bitcoin and blockchain communities, and an experimental exploration of the Bitcoin code and hardware infrastructure. This helped develop an understanding of blockchain material geographies of practice and gather an empirical basis for outlining obligatory passage points in their networked economies. It is these bottlenecks that provide a template for centralisation within the material geographies of Bitcoin and other blockchains. From these datasets I construct a narrative on the broader factors influencing, (re)negotiating, and, arguably, revolutionising financial practices through the visions and materialities of decentralised algorithmic architectures.

Entering the Field

When Bitcoin was conceived in 2008 it largely evaded the pubic radar for the next three years outside of a small but blossoming online community. As such, debate was initially confined to niche online forums and the blogosphere but later found its way into journalism, law, and academia (mostly in that order). When I first started exploring Bitcoin in mid 2013, the nuts and bolts of my learning came

(Sub)Discipline	Reference
Computer Science	Androulaki et al. (2013), Bissessar (2013), Decker & Wattnhofer (2013), Meiklejohn et al. (2013), Courtois et al. (2013), Donet et al. (2014), Eyal & Sirer (2014), Kondor et al. (2014), Courtois & Bahak (2014), Gervais et al. (2014), Gervais et al., (2015), Miller et al. (2015), Nayak et al. (2016)
Economics and Finance	Güring & Grigg (2011), Becker et al. (2013), Kroll et al. (2013), Luther (2015), Weber (2014), Evans (2014), Hileman (2014), Dwyer (2014), Baumann et al. (2014), Böhme et al. (2015), Peters et al. (2015) Laszka et al. (2015), Selgin (2015), Bartos (2015)
Political Economy	Kostakis & Giotitsas (2014), Hendrickson et al. (2015)
Sociology	Karlstrøm, (2013), Dodd (2014, 2017), Garcia et al. (2014)
Anthropology	Maurer (2011, 2015), Maurer et al. (2013)
Legal Studies	Jeong (2013), Gruber (2013), de Filippi (2014), Michailaki (2014), Yee (2014), Hoegner (2015)
Network Culture	Lovink et al. (2015), Golumbia (2015, 2016b)
Game Theory	Johnson et al. (2013), Lewenberg et al. (2015)
Cultural Economy	Dallyn (2017)
Science and Technology Studies	Lustig & Nardi (2015), Worner et al. (2016)

Table 3: Bitcoin publications by (sub)discipline

largely from a collaborative online community that gathered on the Bitcoin Forum, Reddit, and GitHub to further the protocol's development (see Chapter 4). Supporting these resources was content generated by speculative news articles, enthusiasts' blogs, mailing lists, and other social media networks such as Twitter. As individual bitcoins began to trade at a higher and higher value, the phenomenon gained greater attention from a host of well-established newspapers and magazines such as *The Wall Street Journal*, *Bloomberg News*, *The Economist*, and *The Financial Times*. Bitcoin also featured heavily in more technology-centred mediums such as TechCrunch, Wired, Slashdot, TechRadar, and Hacker News, while emerging new media sources within the industry have played an extensive role in producing and disseminating knowledge, for example, CoinDesk, CryptoCoin News, Bitcoin Magazine, and News BTC.

In 2013, Bitcoin mainly appeared as the topic of technical cryptography documents (Reid & Harrigan, 2012; Androulaki et al., 2013; Decker & Wattenhofer, 2013), a handful of working papers (Grinberg, 2011; Barber et al., 2012; Kroll et al., 2013; Moore & Christin, 2013), and a few Masters theses (Šurda, 2012; Ortega, 2013; Fletcher, 2013). Brett Scott (2014a) describes the evolving state of Bitcoin scholarship as "almost no academic research" in 2008-2009, "only a trickle" in 2011, "a decent amount emerging" in 2012, the introduction of "big research" in 2013, and "peer-reviewed academic journal articles" in 2014. Bitcoin has since gathered a critical mass of attention in academia: a quick Google Scholar search of "Bitcoin" at the time of writing returns 32,400 results and, because Bitcoin intersects with so many strands of everyday life, disciplinary research has come from a plethora of knowledge bases (see Table 3). Consequently, Bitcoin, as a research subject, is inherently multidisciplinary. The most ethnographic accounts of Bitcoin to date do not come from academics but journalists who were first to the scene. A number of trade press books have emerged, such as *Bitcoin: The Future of Money?* (Frisby, 2014), *Digital Gold* (Popper, 2015a), and *The Age of Cryptocurrency: How Bitcoin and Digital Money are Challenging the Global Economic Order* (Vigna & Casey, 2015). These texts give important early accounts of the peculiarity of Bitcoin culture and provide compelling popular narratives of the vivid characters and the colourful culture of cryptocurrencies. While there is a degree of overlap regarding the places and people that appear in these books and my own work, and I sometimes draw from these rich descriptive anecdotes to support my own research, they rarely engage with theoretical concepts and academic scholarship. In contrast, I maintain a more critical stance by interrogating Bitcoin through an ethnographic lens to develop an analysis of how decentralisation manifests itself through blockchain architectures.

Navigating the Burrow

I speak from experience when I say that "going down the Bitcoin rabbit hole" can be a compelling campaign of discovery having been drawn down it myself in the summer of 2013. I first heard the word "Bitcoin" during the heated Orwellian debates over global security and privacy sparked by the public leaking of classified information via the US National Security Agency global surveillance programs instigated by Edward Snowden (Gellman & Poitras, 2013; Greenwald, 2013, 2014; Lind & Rankin, 2015). I had been speaking to a friend, a software engineer, at a barbecue in Shropshire, England, discussing the implications of the PRISM data-mining program used to extract public communications from highly reputable household tech companies such as Google and Yahoo. He mentioned that WikiLeaks, an (in)famous organisation that publishes before-secret information like the Snowden documents, had been able to bypass a banking blockade by accepting donations of a networked digital currency called Bitcoin (Matonis, 2012; see Chapter 4). It seemed to me, at the time, that money was being remade from the bottom-up by an ingenious group of cryptographers. Part of this remaking involved cloaking the identity of Bitcoin's users with cryptography while keeping important information about the transactions public. Bitcoin "was designed to be an oxymoron under close observation: regarding its actual technical functioning, it is transparent and public… The social aspects of its use are, however, on a nicely crafted dark side" (Velasco, 2016, 102).

Such opacity can present a problem for researchers. Pablo Velasco (2016) outlines how a number of computer scientists have embarked on different forms of network analysis to unravel some of the hidden characteristics provided by the Bitcoin protocol. Heuristic clustering techniques were used in 2013 to reveal that the majority of transactions flowed through third parties such as Silk Road and now defunct Bitcoin exchange Mt. Gox (Meiklejohn et al., 2013). Elsewhere, Biryukov et al. (2014) "unmasked Bitcoin users by linking pseudonyms (or wallet addresses) to the IP addresses of the origin of the transactions" (Velasco, 2016, 102). Velasco also explains how Kondor et al. (2014)

> …measured degree distribution, degree correlations, and clustering over time in the structure of the network… to identify two moments in the system, one before business accepted it as a form of payment and one after, and a correlation between accumulated wealth and number of transaction partners. (Velasco, 2016, 103)

Finally, Baumann et al. (2014) used descriptive techniques and network analysis to deanonymise certain entities or "hubs" using the protocol. Here, they demonstrated a "strong relationship of user activity within different time horizons and the exchange rate" (373). Such investigations show that even in crypto systems designed to conceal certain data metrics, information is always "from somewhere; about somewhere; it evolves and is transformed somewhere; it is mediated by networks, infrastructures, and technologies: all of which exist in physical, material places" (Graham et al., 2015). The work done by these researchers not only uncovered certain aspects of the Bitcoin network but also suggests that it experiences centralising tendencies at certain points: even in 2013 transactions were predominantly administrated by third parties (Meiklejohn et al., 2013). The research quandary arises: how to draw out different forms of centrality in distributed networks. While there are many ways this could be done I use an ethnographic methodology to tease out the sociotechnical assemblages that hold Bitcoin and other blockchains together. Here, I trace aspects of algorithmic architectures "through diverse contexts and phase circulation" (Foster, 2006, 285). As highlighted in the previous chapter, by uncovering obligatory passage points control in decentralised blockchains can be better understood.

Following Epistemologies

Anthropologist Arjun Appadurai coined the phrase "follow the thing" in 1986 in his book *The Social Life of Things* to explain a methodological strategy for approaching commodities: "exploring the conditions under which economic objects circulate in different *regimes of value* in space and time" (4). The very fact that things move around means that

> …we have to follow the things themselves, for their meanings are inscribed in their forms, their uses, their trajectories. It is only through the analysis of these trajectories that we can interpret the human transactions and calculations that enliven things. Thus, even though from a theoretical point of view human actors encode things with significance, from a methodological point of view it is the things-in-motion that illuminate their human and social context. (5)

Another anthropologist, George Marcus, extrapolated this methodology in his famous 1995 paper titled "Ethnography in/of the world system: The emergence of multi-sited ethnography" where he outlined a number of techniques of "observation and participation that cross-cut dichotomies such as the 'local' and the 'global', the 'lifeworld' and the 'system'" (95). This "allows the sense of system to emerge ethnographically and speculatively by following paths of circulation" (107). In this sense, follow the thing work is particularly well suited for animating the lives of things through their multiple social contexts (along with follow the people, follow the metaphor, follow the plot, follow the life, and follow the conflict). I reform and reapply this methodological technique of following to uncover some of the cultural economic geographies of Bitcoin and blockchain technology.

Follow the thing work has since been used in a plethora of ways, particularly in material culture literature. In his book *Stuff*, Daniel Miller's (2010) central argument is that "the best way to understand, convey and appreciate our humanity is through attention to our fundamental materiality" (4). This focus on materiality has led to a great deal of emphasis placed on 'tangible' things: physical objects that can, say, be picked up or broken. Ian Cook and Michelle Harrison (2007), for example, physically follow bottles of hot pepper sauce from their consumption point in North London to their production point of rural farmers in Jamaica presenting the evocative accounts of connected lives through the commodity while kicking up surprising and diverse connotations of capitalism and its uneven geographies. In doing so, they put the thing and its biography at the centre of the research and attempt to follow the social connections that are formed through it. Consequently, they stumble upon marketing consultants, bottling plants, container ships, and small-scale farmers all interconnected through the supply chain and all contributing towards bringing a bottle of hot pepper sauce into existence.

Follow the thing work unveils the politics of consumption by examining the lives of commodities: it has been used to reveal the apparently unassuming papaya fruit whose "body", upon closer examination, is dissected, polyfurcated, and globalised across multiple supply chains to form face-lift treatments, contact lens cleaning materials, indigestion remedies, canned meats, leather goods, shrink resistant woollen fabrics, and vegetarian cheese (Cook et al., 2004). Other followed things in academic literature include sugar (Mintz, 1985), sushi (Bestor, 2000), tomatoes (Barndt, 2002), cut flowers (Hughes, 2004, 2014), broccoli (Fischer & Benson, 2006), human organs (Scheper-Hughes, 2000, 2001 2002, 2003, 2004, 2007). Additionally, this methodology has blurred into popular forms of commodity activism that uncover the hidden production processes of everyday objects. Documentaries and non-academic books have followed coffee (Francis & Francis, 2006), corn (Cheney & Ellis, 2007), takeaway food (Christie-Miller, 2009), Mardi Gras beads (Redmon, 2005), hair extensions (Hughes, 2008), jeans (Paled, 2005; Snyder, 2008), second hand T-shirts (Bloemen, 2001), cheap Primark clothes (Simmonds, 2008), children's toys (Ekelund & Bjurling, 2004), batteries (Mak, 2008), oil (Kashi & Watts, 2008; Marriott & Minio-Paluello, 2012), mobile phones (Balmès, 2005), used electrical goods (Baichwal, 2006), and electronic components (McQueen, 2007).[1]

Much earlier, the literary works of 18th century it-narrative novels *Chrysal, or, Adventures of a Guinea* (Johnstone, 1760) and *The Adventures of a Bank-Note* (Bridges, 1772) beautifully captured the social life of money, as told from the perspective of these two (in)animate objects. In the case of the guinea, as it circulates through the story it simultaneously narrates, telling "tales from the gold mines of Peru, the streets of London, the canals of Amsterdam, the ports of the Caribbean, and the front lines of the Great War" (Piepenbring, 2016). In doing so, these anthropomorphised tales "offer a non-human autobiography that becomes… a bitingly satirical account of a society characterized by greed, ignorance and self-interest" (Lupton, 2006, 403). Mark Blackwell (2007) refers to this as an account of "human nature" being "overpowered, or banished, by the material world" (151)—a notion that is still prevalent today as people so easily "lose control of themselves through being swayed by the things their society has to offer" (Pels, 2010, 613). But there is something subtler here: a nuanced demonstration of material culture that depicts society moving with, forming through, and assembling around material things. Both books cleverly and explicitly play with this ontological perspective by self-revealing themselves as material and cultural objects: "speaking formulaically about their own constitution, appearance in print, handling as objects, and the movements of their readers through their pages" (Lupton, 2006, 402). Being "conscious engagements with their own materiality as print and paper" (404), they use this "materiality as an excursion into thought, rather than a stand against it" (417).

[1] Examples of this work are collated at followthethings.com—a subversive shopping website that I helped launch with Ian Cook, cataloguing "films, books, academic journal articles, art installations, newspaper articles and undergraduate research" (Cook, 2011).

Moving away from fictional (re)presentations of the material culture of money to a more methodological stance, follow the thing work has been offered as a means for illuminating its social (justice) life (Cristophers, 2011a, 2011b)—producing an empirical form of it-narrative. This kind of research is extremely apt for debunking commodity fetishism, a term first coined by Karl Marx (1867) in *Capital: Critique of Political Economy* to describe the peculiar force that "displaces social relations between people into material relations between things" (Harvey, 2010, 47). Marx (1970) referred to money as the God of commodities: an "estranged essence of man's work and man's existence, and this alien essence dominates him, and he worships it" (Marx, 1975, 172). In other words, throughout capitalist markets there is an acute focus on the materiality of commodities "rather than the social, political and economic relations that brought them into being" (Crang, 2005, 168). In 1990 David Harvey implored radical geographers to "deploy the Marxian concept of fetishism with its full force" and to "get behind the veil, the fetishism of the market and the commodity" (423). Whether money is in itself a commodity provokes rigorous academic debate (Gilbert, 2011) yet it is imbued with similar fetishistic qualities. What I mean by this is that money is undeniably teaming with social relations (Simmel, 1900)—or, rather, is itself social relation(s) (James, 2006)—but it is often taken at 'face value': a fetishised materiality that makes it appear objectively precious. Money, then, must be dethroned to uncover its deeper sociality (Nelson, 1999). Follow the thing methodologies, as a Latourian research process that can uncover contours of power, are therefore suitable for tracing out the then dense sociotechnical networks through which money and value are performed.

The form of "geographical detective work" (Hartwick, 2000, 1178) offered by thing following has already been carried out to track empirically the materiality of money back to its source(s), such as cotton in bank notes (Busk, 2009) and non-ferrous metals in coins (Black et al., 2010), to uncover the "the unseen others that produce the cash in our pockets" (Busk, 2009). Tracing physical cash is relatively straightforward but examining the digital balances controlled by commercial banks is a harder task. How then does one uncover the "fingerprints" (Harvey, 1990, 422) left on these fleeting digital etchings that have never apparently been touched by anyone?[2] The answer lies in the inescapable materiality of the digital and by moving past conceptions that portray cyberspace as some sort of otherly dimension. It is by following the spatial trajectories left (and indeed created) by blockchains in all their complexity that a "sense of system [can] emerge ethnographically and speculatively" (Marcus, 1995, 107). Yet Bitcoin's money/space is directly tied to its code/space. To start with, then, such a methodology must 'get behind' something else that has been called screen essentialism (Montfort, 2004; Kirschenbaum, 2008). Screen essentialism describes the focus on digital screens as a surface of interaction whose outputs "frame" information for their users (Knorr Cetina & Bruegger, 2002). These

[2] Tracing paper, or rather digital, trails is a process used by governments to track the movements of money used for illicit purposes but access to these accounts for researchers is much more difficult, not to mention questions of whether this would be ethical.

pixelated projections delight and distract people (Chun, 1999; Marino, 2006) from the "underlying software, hardware, storage devices, and even non-digital inputs and outputs that make the digital screen event possible in the first place" (Sample, 2011).

Screen essentialism is the fetishism of data through digital interfaces and thus it shares similarities with commodity fetishism: a concentration on material surfaces and a (blissful) ignorance of the sociotechnical relations that constitute the existence of (digital) things. To better understand the digital it is important to get behind the screen in the same way that researchers of commodities get behind the fetish (see Appendix 10). Researchers must not only think about the surfaces of engagement (of either screen or commodity) but also understand the deep networks that connect and perpetuate cultural practices. This is especially important when such insensitivity to the origination of data streams has seeped into digital research ontologies, epistemologies, and methodologies with output-focused approaches (Waldrip-Fruin, 2009). In an alternative push, I attempt to follow Bitcoin *through* its material economies/ecologies and tease out how its *thingness* is established through them. Follow the thing is one way of doing this by providing a framework for understanding the connection between different entities: the "constant process of folding together people and things in networks of activity means that action is distributed *between* people and things" (Jones & Boivin, 2010, 346, emphasis added).

My adaptation of this methodology seeks to enliven the materiality of code by examining its all-important infrastructures. So how does a researcher examine this greater spatial complexity? And in order to understand societal organisation "[s]hould we be following things, people or ideas?" (McNeill, 2017, 150). It is in answer to these two questions that my multi-sited ethnography takes a bit of a turn away from conventional follow the thing work that meticulously tracks a specific item through space and, instead, takes a more diverse approach in uncovering the social relations behind Bitcoin. In fact, this is absolutely necessary when approaching blockchains: diving into the cryptographic code that cloaks its users' activity, while certainly important, can only take one so far. It is for this reason that I try to follow different "paths of circulation" (Marcus, 1995) that circumscribe the development of blockchains. This is more attuned to the "following" used by Bruno Latour (1987) in *Science in Action: How to Follow Scientists and Engineers through Society*: a heuristic device for tracing connections between humans and things to illuminate their interoperability, codependence, and correlative power. As such, while the chapters are chronological they do not follow a linear, longitudinal narrative but rest at different obligatory passage points that were uncovered along the way. This is because my path constantly deviated as new avenues and opportunities were uncovered.

The inconsistencies of social-economic practice in different places present Bitcoin as a financial tool that encompasses varying utilities and visions. Thanks to its relative efficiency and low cost, Bitcoin is a growing avenue for migrant Filipino workers to send remittances home (Balea, 2014; Hynes, 2017):

"[B]itcoin powered remittances now account for 20% of the Asian remittance corridor between South Korea and the Philippines" (Parker, 2016). This is a significant emerging market regarding sovereignty given that remittances "are the country's largest source of foreign exchange income, insulating the domestic economy from external shocks by ensuring the steady supply of dollars into the system" (de Vera, 2017). Elsewhere, in China, the Bitcoin protocol has been used as a means for escaping the country's strict capital controls (Pal, 2013; de Filippi, 2014; Böhme et al., 2015). Swiss Federal Railways have also allowed users to purchase bitcoins with their terminals across the country (SBB, 2016; Higgins, 2016a) and the town of Zug—that is styling itself as "Crypto Valley" with an array of cryptography start-ups including Bitcoin and blockchain companies—accepts bitcoins as payments for public services (Higgins, 2016b). The Swiss municipality of Chiasso has followed Zug by letting its residents pay taxes with bitcoins (Meyer, 2017). While they all navigate the same protocol, this patchworked pattern of economic practice demands a cultural geography perspective of Bitcoin.

The anatomy of the Bitcoin blockchain is also constantly changed precisely because of the predominance and disparities of people conducting social-economic practices in different places. For example, the concentration of Bitcoin mining farms in China bends parts of the algorithmic network around this geography (see Chapter 5). I set out, then, to understand the relationship between culture and technical parameters. In a way, while Bitcoin remains the focal point, I am not just following but encircling it to interrogate and understand the sites where materials, people, and ideas come together *through* the codified organisations of blockchains. In this sense I am not always literally following the thing itself but going to different places, tracking certain trails, and examining the connections between material-semiotic networks that gather and organise around and through blockchains. Similarly, Hawkins et al. (2015) use thing-following more as a heuristic device than a methodology by interrogating a bottle of plastic water from multiple cultural angles in order to understand the (historical) politics of a taken-for-granted everyday object. This type of inquiry allows the researcher to "enter into a world that is, so to speak, continually on the boil" (Ingold, 2010, 8).

Mapping Methodology

The spatial arrangements of economic practices are, to a large degree, systematically concealed by blockchains. Luckily, however, not all of the components are enshrouded with cryptography like the identity of users in transactions. It is these 'gaps' that provide a route into the dense cultural economies of blockchains. The methodology for the research project was originally designed in 2014 yet a subsequent publication by Rob Kitchin (2017), "Thinking critically about and researching algorithms", works well to justify retrospectively some of the research avenues that I initially laid out. This section outlines six approaches for researching algorithms documented by Kitchin: examining pseudo-code/ source code; reflexively producing code; reverse engineering; interviewing designers or conducting an ethnography of a coding team; unpacking the full socio-technical assemblage of algorithms; examining how algorithms do work in the world (I use all of these to some degree except reverse engineering). First, though, it is pertinent to ask whether Bitcoin can be called an algorithm? The answer is both yes and no. Computational algorithms are a sequence of mathematical steps that transform an input into an output (Cormen, et al., 1990): they move, manipulate, reorganise, and (re)present information into different forms. Bitcoin is a protocol made up of algorithms. Some would certainly argue that this makes blockchains 'big' algorithms in and of themselves—merely composed of smaller ones. In fact, blockchains are software, algorithm, database, platform, and protocol all at once and while these descriptions are sometimes interchangeable I mostly refer to blockchains as *algorithmic protocols* for semantic cleanliness.

With this recognition in place, how can blockchains be followed? For me, the starting point was to examine the pseudo-code and source code that is readily available online (Kitchin, 2017); Bitcoin is an online collaboration of open source software so a swathe of historical and ongoing documentation and discussion is readily available on sites like GitHub, the Bitcoin Forum, Twitter, and Reddit. This process included "carefully sifting through documentation, code and programmer comments, tracing out how the algorithm works to process data and calculate outcomes, and decoding the translation process undertaken to construct the algorithm" (22). Additionally, I deconstructed how Bitcoin was "re-scripted in multiple instantiations" within the public code library GitHub (ibid.). In this sense "the question 'how does it work?' is also the question 'whom does it work for?' In short, the technical specs matter, ontologically and politically" (Thacker, 2004, xii). The algorithmic structure of blockchains is where trust in their mechanisms, and thus value, is derived. It is therefore particularly "necessary to have a technical as well as theoretical understanding" (Thacker, 2004, xiii). The codified architecture, then, is deeply *socio*technical. But because blockchains are contingent, primary research must differ depending on their specific variations.

Online 'spaces' are extremely important to the ongoing cultural conflicts surrounding blockchains and the governance structures for developing the Bitcoin protocol. This was my first step into the Bitcoin/ blockchain ecosystem. Chapter 3 looks at the cultural and political geographies of cryptography that gave rise to the invention of cryptocurrencies. Chapter 4 explicitly deals with these sites by examining the open source governance of an online community of practice and highlighting where hierarchal obligatory points of passage lie. From here, in Chapter 5, I move on from studying the code builders to an in depth interrogation of the Bitcoin code itself by following a transaction 'across borders'. The digital-material architecture provides an overview of spatial centralisation around different nodes in the decentralised network. When I began researching Bitcoin in 2013 it had already started shifting from a purely tight-knit (yet geographically dislocated) online project to an emergent economy that was carrying blockchain technology off in new directions. By examining online community activity and reading industry literature and news articles I pinpointed three key locations where the Bitcoin economy was firmly taking root: Silicon Valley, New York City, and London. In these places, that house globally renowned finance and technology economies, the density of Bitcoin and blockchain start-up companies and meet-up groups signalled important loci for understanding the sociotechnical bonds that were forming around this apparently 'decentralised' algorithmic protocol—Chapter 6 and 7 account for the process of algorithmic (de)centralisation in these different sites. From these geographic starting points, where I attended meet-ups and contacted start-ups, I followed a string of different connections through the Bitcoin and blockchain landscape for a period of six months.

Traditional follow the thing work encompasses a unique form of snowball sampling where the researcher lets connections across a thing's life or supply chain determine the people they come into contact with. While this is not necessarily extensive nor representative in the quantitative sense, it establishes a manageable and exploratory research technique (Babbie, 2008) where subjects recommend subsequent participants (England, 2003). This roadmap adopts the mantra that it is "not the sheer *number*, '*typicality*' or '*representativeness*' of people approached which matters, but the quality and positionality of the information that they can offer" (Cook & Crang, 1995, 12; Geiger, 1990; McCracken, 1988). Following the spatial traces between things, ideas, people, and practices gave me a platform from which to understand the complex cultural economy of blockchains and allowed me to (from the inside out) get an idea of their spatial organisations. From this position the geographies of decentralisation that surround blockchains could be more easily critiqued as I personally observed certain practices materialise and coalesce.

While examining source code gives "some insights into the workings of an algorithm… [it] provide[s] little more than conjecture as to the intent of the algorithm designers" (Kitchin, 2017, 24). One method for catechising software further is by interviewing or conducting an ethnography of a coding team to uncover "the story behind the production of an algorithm and to interrogate its purpose and assumptions" (ibid.). Both of these routes are difficult to do with Bitcoin itself (at least offline) given its dispersed set of open source programmers. Although I met a couple of Bitcoin Core programmers along the way I did not manage to explicitly interview them as a cohort—although their politics are often well versed through various mediums of social media like Twitter. Instead, my journey took me into the realms of proprietary software generated by start-up companies where I interviewed programmers, Chief Executive Officers (CEOs), recruiters, lawyers, risk managers, and venture capitalists. Throughout this process I adopted an ethnographic sensitivity by engaging in participant observation with different Bitcoin and blockchain start-ups, organisations, and meet-up groups while attending other important events.[3] Understandings of these spaces developed by "watching, observing and talking to [people] in order to discover their interpretations, social meanings and activities" (Brewer, 2000, 49). Sitting with programmers in their work environments, for example, provided "insight into the contingent, relational and contextual way in which algorithms and software are produced" (Kitchin, 2017, 25). This was not only true for new blockchains (some of which were not open source) but also for the software service economy that was beginning to gather around Bitcoin and other blockchains like Ethereum.

To some extent, ethnography is inevitably *auto*ethnographic. The point here is that "presence enacts itself as an embodied activity" (Taylor, 2002, 44) and so the body becomes an "instrument of research" (Crang, 2003, 499). It is in this vein that following different spatial connections also took me briefly into the realms of reflexively producing code myself (Kitchin, 2017). In a chance encounter at the San Francisco Bitcoin Developers meet-up I met the organiser of Blockchain University and started attending the weekend lectures of this hands-on learning/doing environment based in Mountain View, Silicon Valley (see Chapter 7)—this venue, in turn, became the meeting point for many other connections that I made within the Bitcoin/blockchain industry. It was in these classrooms that I learnt how to code and engage with different blockchains: using the Bitcoin Testnet (a copycat of the Bitcoin protocol designed for developer experimentation) attendees were taught how to run applications on top of blockchain architectures. With the skills learnt in lectures taught by industry specialists we built blockchain-based products that provided an intriguing insight into the practices, logics, and ideologies of code builders and also gave me the opportunity to experience reflexively (despite not having a software developer background) some of the problem solving that was occurring in blockchain code production. After all, the "basic purpose in using these [research] methods is to understand parts of the world as they are experienced and understood in the everyday lives of people who actually live them out" (Cook & Crang, 1995, 4).

The "ethnographer inhabits a kind of in-between world, simultaneously native and stranger" (Hine, 2000, 5). Creating blockchain projects and working for Bitcoin start-ups was extremely exciting and absorbing to the extent that I sometimes leant more towards a "native" than "stranger". This balancing act can sometimes be hard to navigate in such sites of emotion and expression (Davidson & Milligan, 2004). Such tendencies can become a limitation when the researcher encounters the "inherent subjectivities involved in doing auto-ethnography and the difficulties of detaching oneself and gaining

[3] I refer to this form of participant observation as having an "ethnographic sensitivity" because 'hardcore' anthropologists would most likely reject the term ethnography due to the duration of time that I spent in particular environments. For example, I would sometimes only stay with the same company for a few weeks whereas the term ethnography is usually reserved for participant observation that develops in the field for a year or more. With this in mind, to some degree ethnographies are becoming a dying art with the growing corporatisation of the neoliberal university where academics rarely ever have the chance to spend this amount of time in the field. In fact, increasingly it is usually doctorate students who only have the luxury to do so.

critical distance to be able to give clear insight into what it unfolding" (Kitchin, 2017, 23). What I mean by this is that I became caught up in a surrounding optimism that saw blockchains as an architecture at the forefront of an impending technological revolution (see Appendix 9). At the same time, however, as I tried to maintain a critical stance (particularly during post-fieldwork reflection) the 'auto' that inescapably exists in all ethnographic research was invaluable for understanding some of the ideologies that were (re)emerging with the development of Bitcoin and blockchain technology. I therefore echo that in "most qualitative research methods (such as interviewing and ethnography) embodied moments are crucial to intersubjectivity, interpretation and understanding" (Parr, 2003, 66). Researchers are unavoidably human and strengths of research come from recognising the impossibility of complete objectivity rather than pretending it can be accomplished.

The fluidity and flexibility provided by the form of following that I undertook created a multi-sited ethnographic method well equipped for penetrating the Bitcoin and blockchain cultural economy and, to paraphrase Kitchin, unpacking the full sociotechnical assemblage of algorithms. This takes on board an understanding that

> …algorithms do not work in isolation, but form part of a technological stack that includes infrastructure/hardware, code platforms, data and interfaces, and are framed and condition[ed] by forms of knowledge, legalities, governmentalities, institutions, marketplaces, finance and so on. (Kitchin, 2017, 25)

Kitchin offers discursive analysis as a method to "help reveal how algorithms are imagined and narrated, illuminate the discourse surrounding and promoting them, and how they are understood by those that create and promote them" (ibid.) This form of rationale certainly played a role in my research as I scanned online forums and noted the language used by different actors within the Bitcoin and blockchain ecosystem(s).

Chapter 3
Tracing Political Histories

Introduction

Algorithmic configurations have been referred to as both a language and an infrastructure because code "does what it says" (Galloway, 2004, 193); in other words, it self-executes what is written by the programmer(s). This can make software seem strangely alive or autonomous as its users do not see the work that is poured into it—Adrian MacKenzie (2006) calls this a "secondary agency". Code is also difficult to understand: it "often appears to be 'automagical' in nature in that it works in ways that are not clear and visible, and it produces complex outcomes that are not easily accounted for by people's everyday experience" (Kitchin & Dodge, 2011, 5). Yet code's independence is largely a mirage as people are constantly writing and reforming it.[1] As a product of humans, algorithms are *social* artefacts and can be infused with any number of political ideologies (Coleman, 2012). Software, then, is spatio-political in its becoming/maintenance and the Bitcoin blockchain is no different.

This short chapter dissects algorithmic decentralisation as a political movement to uncover its lineages and discrepancies of meaning. In doing so the chapter teases out decentralist ideologies that are, later in the thesis, compared to decentralisation in practice. All infrastructures have a complex history and to only examine them as they currently stand in a moment of time and space is to truncate existential understandings of their architectures. An analysis of Bitcoin's money/code/space must involve uncovering the ideological roots that precede and (in part) sustain the development of cryptocurrencies. It is here that I undertake my first form of following: tracing the actor-networks of semiotics/materialities that have brought about the spatial realities of blockchains. Following, then, does not have to be a physical movement but, as in this chapter, involves uncovering the empirical footprints and connections historically documented by books, journals, whitepapers, source code, policy documents, websites, forums, blogs, and documentaries. It is via these mediums that I first landed within the 'world of Bitcoin', or 'went down the Bitcoin rabbit hole', making it a suitable starting point to analyse the idealised and glorified concept of (algorithmic) decentralisation and unpack the contradictions that surround it. I also start to explore David Golumbia's (2016b) account of cryptocurrencies in *The Politics of Bitcoin: Software as Right-Wing Extremism*, which, at times, stands as a bitingly eloquent critique, but, at others, starts to wander down a path of reductivism. I echo Golumbia's argument that libertarianism and right-wing monetary policy is buried into the political

[1] The recent developments in artificial intelligence may begin to complicate this statement somewhat.

architecture of the Bitcoin code, but I also start to account for the emerging pluralism and contention throughout Bitcoin/blockchain communities that now encapsulate a myriad of stakeholders.

The chapter begins by outlining the growing practice of cryptography as it has transformed spatial relationships between people increasingly connected by digital networks. Following World War II, cryptographic practices became decoupled from their tight historical relationship with the state as techniques were further developed by countercultural 'anarchists' through digital means to protect themselves from the 'threat' of centralised 'big brother' government. As privacy, individualism, entrepreneurship, and counterculture grew out of the San Francisco Bay Area (Turner, 2006) and into other burgeoning 'copycat' tech hubs, the axiom of decentralisation was brandished as a form of moral organisation: unequivocally a positive and philanthropic advancement for human societies. I discuss Richard Barbrook and Andy Cameron's concept of the Californian Ideology and use it to develop understandings of ideological decentralisation as a form of technopolitics with deep ties to anti-statist, anarchic, and free-market mantras. I then develop an account of Bitcoin and blockchain technology that encompasses the diversity of their increasingly fragmented communities.

The Rise of Digital Cryptography

Cryptography is the "study of mathematical techniques related to aspects of information security such as confidentiality, data integrity, entity authentication, and data origin authentication" (Menezes et al., 1996, 4). Its etymology derives from the Greek *kryptos* meaning 'hidden' and *graphien* meaning 'to write' (Mollin, 2000). In other words, cryptography utilises "secret codes and ciphers to scramble information so that [it is] worthless to anyone but the intended recipients" (Levy, 2001). History is punctuated with cryptographic codes (Singh, 1999): from the Ancient Egyptians as far back as 4000 years ago (Khan, 1967) to the cracking of the German Enigma code during the Second World War by Alan Turing's team at Bletchley Park (Hodges, 1983; Hinsley & Stripp, 1993). The constant historical struggle between codemakers and codebreakers, described by Ralph Simpson (2016) as "crypto wars", has driven innovation behind cryptography, which has become a recognised academic doctrine. I briefly introduce the modern political history of cryptography and the protagonists that have championed it here before explaining the rise of cypherpunks and their dreams of electronic money.

The spaces that cryptographic codes transduce and actualise have changed dramatically over time. Initially, cryptography was developed to protect secrets and strategies practised by militaries, governments, and diplomatic services (Menezes et al., 1996).[2] Cryptography, in short, safeguarded

[2] For example, the Spartan scytale was a wooden staff with a specific diameter so that a strip of leather encoded with inscriptions could be wrapped around it in order to decipher an embedded code. In some accounts this cryptographic tool was used by Lysander of Sparta and his runners to convey messages in battle (Khan, 1967; Beutelspacher, 1994).

information in transit. Inscriptions moved through space in different forms where only those with the correct cryptographic keys could decipher their meaning. This remains true today but with revolutions in digital technology, information increasingly travels across nation state borders in the form of electrical currents through cables and wires:

> We interact and transact by directing flocks of digital packets towards each other through cyberspace, carrying love notes, digital cash, and secret corporate documents. Our personal and economic lives rely more and more on our ability to let such ethereal carrier pigeons mediate at a distance what we used to do with face-to-face meetings, paper documents, and a firm handshake. Unfortunately, the technical wizardry enabling remote collaborations is founded on broadcasting everything as sequences of zeros and ones… (Rivest cited in Menezes et al., 1996)

Those with the technical skills for eavesdropping can listen to pretty much everything online: "we think we're whispering, but we're really broadcasting" (Levy, 2001). This pattern of 'globalised' communication networks is making cryptography an ever more important component of the spatial make-up of everyday life (crypto/space).

The production of cheap digital hardware from the 1950s pulled cryptographic practices out of the narrow industry of mechanical computing and into people's homes (Diffie & Hellman, 1976). The ongoing development of digital computing since the 1960's, combined with the effects of Moore's law—an observation that the number of transistors found per square inch on integrated circuits doubles every two years—has lowered the costs of computing technology over time. These factors have provided the underlying platforms that make cryptocurrencies feasible. With the help of personal computers, university research, start-up companies, and stay-at-home enthusiasts, cryptography has been injected into platforms that continue to have wider and wider implementations. These include public-key infrastructures used in e-mail and Internet banking, transport layer security in web browsers, and file sharing software such as BitTorrent. All of the modern cryptographic innovations of blockchain technology rest upon this previous work.

Cryptographic techniques are now ubiquitous in commercial applications. This is increasingly the case following the NSA hacking scandal in 2013 that included the mass surveillance and storage of public online data in collusion with many reputable Internet companies (Gellman & Poitras, 2013; Greenwald, 2013).[3] Messenger service Whatsapp, for example, now provides end-to-end encryption by default largely in response to the public backlash sparked by this event. Elsewhere computer passwords,

---

[3] The security measures taken to preserve anonymity are an increasingly "useful strategy for contesting the pervasive surveillance apparatus of the state and large corporations within societies of control" (Taffel, 2015a, 2).

ATM's, satellite TV, mobile phones, urban transport travel cards (e.g. London Oyster and Sydney Opal), and online commerce are all actualised by cryptographic protocols that protect the passing of information between clients and servers in digital-material infrastructures. Spaces, then, are increasingly *crypto*spaces. The politics of algorithmic decentralisation that have been applied to these cryptospaces draws predominantly from the 'hacker' side of the cryptography ecosystem that came to fruition with the rise of the Internet.

Different methods have been invented for administering cryptographic systems: "[o]ne solution lay in equipping networks with centralized key distribution centers, 'trusted third parties' that could provide each pair of users with the required key pairs without the need for prior interaction" (Blanchette, 2012, 42). However, cryptographers like Whitfield Diffie, co-author of the landmark title *New Directions in Cryptography*, believed that users of systems should not have to trust others for securing communications because "any system that relied on centralized authority put the user at risk of having her personal information disclosed, even if that authority was well intentioned" (ibid.). This gave rise to the problem of sending secure communications over insecure digital channels without a mediating centralised institution (Merkle, 1978). To solve this, Diffie and Hellman (1976) designed one of the first public-key protocols that brandished a "decentralised view of authority" (Diffie cited in Levy, 2001).[4] Public-key encryption, and similar techniques, became the cypherpunk's cryptographic bread and butter: a practice heavily wrapped up in the political ideology that centralised power should be avoided at all costs.

The Cypherpunk Movement

Digital money had long been dreamt of by those associated with the libertarian-leaning cypherpunk movement of the late 1980s. Cypherpunks arose as an anarchist grassroots community who utilised the Internet for social cohesion and the proliferation of their ideologies that sought to harness technology as a means of liberation from what they saw as a growing technocratic Orwellian society (Ludlow, 2001; Levy, 2001; Farmer, 2003; Crofton, 2015). Their tool for disruption was computer code, more specifically cryptography, which they saw as a means of achieving societal and political change: the ultimate form of non-violent direct action (Assange et al., 2012).[5]

---

[4] In a fashion staying true to cryptography's statist history, this method had previously been theorised and modelled at the state level by the British Government Communications Headquarters (GCHQ) where it was referred to as "non-secret encryption" (Ellis, 1970). However, this work was not declassified until 1997 (Singh, 1999).

[5] Julian Assange is a cryptographer/cypherpunk known for the creation of WikiLeaks—another materialisation of decentralist/open politics— and is a vocal proponent of the mantra 'information should be free'. Assange's resistance against nation state control, especially military activity, has led to the issuance of an international warrant for his arrest. He has been granted asylum by the Embassy of Ecuador in London where he currently resides.

Although cryptography is now a respected academic discipline, for a time governments, such as the United States, regarded it as a dark art and even sanctioned against non-governmental cryptographic activity. In 1977 the United States National Security Agency targeted those participating in its development by threatening prospective attendees of a cryptography symposium, issuing them with letters explaining that their rituals could breach an Arms Regulation Law that classified cryptography a threat to national security equal in severity to handling munitions (Levy, 1993). Academics practising cryptography were therefore forced to do so in relative secrecy and publishing material became a risky venture (Corrigan-Gibbs, 2015):

> One particular software package, PGP (for Pretty Good Privacy), became the movement's cause célèbre, and its author, Phil Zimmerman, its first martyr, after becoming in 1993 the target of a three-year criminal investigation over possible breach of export laws. (Blanchette, 2012, 49)

The PGP encryption program was used for concealing/protecting civilian email (Zimmerman, 1995). Utilising a technical loophole in US legislation, PGP Corp started printing their source code into books before exporting them abroad so that the code would no longer be considered cryptographic 'software' under the law (Kantor, 2015). Others embedded programming code like the RSA algorithm into different material artefacts: condensing it down into "a mere three lines of the Perl programming language" and printing it on t-shirts or tattooing it on skin, "instantly turn[ing] the messenger into an international arms trafficker" (Blanchette, 2012, 49).[6] From these anarchic actions, the yet un-named cypherpunk movement formed as a bottom-up counterweight to the enclave-like enclosure of intellectual thought. The largely cyberlibertarian coders involved, rebelled against the warnings they were given by using cryptography to protect themselves, and wider publics, from Internet infrastructures that were beginning to eliminate privacy by architectural default. The power afforded to infrastructure is well documented in the humanities (Law, 1991; Star, 1999; Larkin, 2013; Easterling, 2014) and here cypherpunks used cryptography in digital-material networks as a political tool that bypassed the infrastructures of power imposed by governments thus generating their own vehicle for anti-authoritarian practices. Their political ideologies were deeply personified and solidified in the codified compositions they created: protecting free speech with cryptography and defining cryptography as free speech in the process.

Cryptography "exhibited the firm convictions that technology trumps regulation every time and that encryption as code could not be caged and—once released—would inevitably roam free, spreading security, freedom of speech, and democracy in its wake" (Blanchette, 2012, 61). By "the beginning of the 1990s, the cryptography community had seemingly turned on its head a centuries-old relationship

---

[6] RSA is an acronym devised from the surnames of its three creators: Ron Rivest, Add Shamir, and Leonard Adleman.

with the state, a relationship that had committed the field to obscurity, secrecy, and national security" (54). Blanchette continues:

> Most visibly, in the wake of the public-key revolution, it led to the emergence of an independent academic community, eager to distance itself from the 'Dark Side' of intelligence agencies and state controls over cryptographic research. Yet beyond the media-friendly image of cryptographers as defenders of electronic freedoms, multiple agendas operated simultaneously within the field. (60)

Here, "cryptography's emerging scientific program supported a broad range of positions on the social purposes of cryptographic research, many of a more conservative bent than crypto's well-publicized image suggested" (13). Amongst this plurality, the "explosion of the Internet propelled cryptography to the forefront of the cyberlibertarian movement" (5).

Most cypherpunks remained a rather secretive and tight-knit group hiding from the spotlights of governing bodies who opposed their practice. They were, on the whole, a loose coalition of academics, hobbyists, civil liberties organisations, and hackers (Narayanan, 2013). Many of them practised crypto anarchy to push back against digital infrastructural power (May, 1992; 1994; Crofton, 2015). Theoretically, the codified political action of crypto *anarchy* does not pertain to the popular conceptions of the term that resemble lawlessness, disorder, and chaos but represents the absence of government coercion in communications realised via cryptography. Rather than smashing shop windows, cypherpunks practise a different, but still profoundly political, action: providing tools for going unnoticed and bypassing the system altogether. As Assange et al. (2012) put it:

> The Universe believes in encryption. It is easier to encrypt information than it is to decrypt it. We saw we could use this strange property to create the laws of a new world. To abstract away our new platonic realm from its base underpinnings of satellites, undersea cables and their controllers. To fortify our space behind a cryptographic veil. To create new lands barred to those who control physical reality, because to follow us into them would require infinite resources.

This perceived process of cryptographic abstraction and dematerialisation away from controlled infrastructure is an important notion that will be explored in greater detail with regard to Bitcoin throughout Chapter 5.

Due to cryptography's initial legal uncertainty most cypherpunk communication was originally conducted online through the protected channels they carved out for themselves. However, the

[Image removed for copyright purposes]

Figure 4: Front cover of WIRED Magazine Volume 1, Issue 2, 1993

community aspect became more organised in 1992 when Eric Hughes, a Berkeley mathematician, invited a group of politically motivated programmers to his home in Oakland of the San Francisco Bay Area where they committed to an online revolution of sorts (Garfinkel, 1995; Manne, 2011). That same year Tim May (1992), who was also present at the gathering, had published "The crypto anarchist manifesto": a call to arms outlining the utilisation of personal computers with rapidly growing processing power in achieving privacy from centralised institutions. In doing so it sought to produce alternatives to the constraints of economic transactions controlled by oligarchic banks and governments: "just as the technology of printing altered and reduced the power of medieval guilds and the social power structure, so too will cryptologic methods fundamentally alter the nature of corporations and government interference in economic transactions" (May, 1992). It was under this philosophical banner that the group first rallied and it was here that the term cypherpunk—somewhat affectionately and in good humour—was first coined by Jude Milhon from the words "cipher" and "cyberpunk" (Manne, 2011).

Tim May and Eric Hughes can be seen alongside John Gilmore on the front cover of the second ever issue of *WIRED Magazine* for the story "Crypto Rebels" (see Figure 4).[7] Hughes later released "A cypherpunk's manifesto" (1993) that championed the protection of privacy and the re-empowerment of citizens envisioned in their brave new world of crypto/space. The cypherpunks set out to program political realities by infusing ideologies into their code; without their input, and consistent battling with higher powers, the codified spaces of modern computer systems would arguably look very different. It can be said with a reasonable degree of certainty, for example, that blockchains would not yet exist.

Technological Decentralism

Post-war computer technology was initially perceived as a cold, dehumanising form of mechanisation that limited human freedom (Turner, 2006). This impression was later turned on its head when hippie communalism melded with the Cold War technology of "computer networks in such a way that thirty years later, the internet could appear to many as an emblem of youthful revolution reborn" (Turner, 2006, 39). Running parallel to the cypherpunks was a broader cultural-political movement orchestrated by the cyberpunks who envisioned cyberspace as an anti-materialist digital frontier of the mind that could emancipate societies from the traditional-material constraints of power (Dyson, et al., 1994). The mantra of this (new)worldview was personified by John Perry Barlow's (1996) essay titled "The declaration of the independence of cyberspace":

> Governments of the Industrial World, you weary giants of flesh and steel, I come from Cyberspace, the new home of Mind. On behalf of the future, I ask you of the past to leave us alone. You are not welcome among us. You have no sovereignty where we gather... I declare the global social space we are building to be naturally independent of the tyrannies you seek to impose on us.

These tropes became known as cyberlibertarianism: "a collection of ideas that links ecstatic enthusiasm for electronically mediated forms of living with radical, right wing libertarian ideas about the proper definition of freedom, social life, economics, and politics" (Winner, 1997).

From the 1960s the counterculture of San Francisco—rebellious visionaries (Watson, 1995; Charters, 2001), hippies (Braunstein & Doyle, 2002), and gay rights activists (Boyd, 2011)—diffused into the

---

7 *WIRED* is a technology magazine and cheerleader for the Californian Ideology (Barbrook & Cameron, 1995), explained in the next section.

technological entrepreneurialism of Silicon Valley that was forming forty-five miles south, that quickly became home to the "densest concentration of electronics and semiconductor companies and highly skilled technological talent in the world" (Saxenian, 1983, 13). The geographic situation in which the majority of rallying cypherpunks gathered on the West Coast of the United States is extremely important for understanding the ideological undertow that brought about cryptocurrencies and the processes of algorithmic decentralisation. Here, cyberculture grew out of counterculture when computers started to be reimagined as tools for building alternative communities that harnessed communal connection and individual freedom (Turner, 2006).

Richard Barbrook and Andy Cameron (1996) would later call the product of this cross-fertilisation the Californian Ideology to capture the libertarian-entrepreneurial values that were beginning to saturate the technology industry. The countercultural New Left promoted by a "loose alliance of writers, hackers, capitalists and artists" (Barbrook & Cameron, 1996, 3) collided with the "entrepreneurial zeal of the New Right" (Barbrook, 2001, 50). What should have been a clash of polarised worldviews reconciled in a tantalising form: a "contradictory blend of conservative economics and hippie radicalism [that] reflects the history of the West Coast" (Barbrook & Cameron, 1996, 15). In other words, the Californian Ideology preached "an anti-statist gospel of cybernetic libertarianism: a bizarre mish-mash of hippie anarchism and economic liberalism beefed up with lots of technological determinism" (Barbrook & Cameron, 1996, 10). Such a peculiar cultural worldview emerged from a geographic anomaly:

> This new faith has emerged from a bizarre fusion of the cultural bohemianism of San Francisco with the hi-tech industries of Silicon Valley... [The] Californian Ideology promiscuously combines the free-wheeling spirit of the hippies and the entrepreneurial zeal of the yuppies. This amalgamation of opposites has been achieved through a profound faith in the emancipatory potential of the new information technologies. (Barbrook & Cameron, 1996, 1)

It is an overarching belief in technological determinism within this hybrid faith that fuses the two competing viewpoints together into a singular orthodoxy that believes "technology, efficiently deployed, will provide 'solutions' to 'problems' generated within the unfortunately messy sphere of human politics" (Hillis et al., 2013, 100). In other words, technological 'solutionists' saw the electronic frontier as tool for solving social problems.

The glorified egocentricism of Silicon Valley was taken, in part, from the philosophical writings of Ayn Rand. The Russian-American novelist promoted what she called "objectivism" where, free from authoritative control or restraint, people could become valiant figures by tuning into and following their own selfish desires (Rand et al., 1967; Rand, 1984; Peikoff, 1993; Weiss, 2012; Walker, 2012). She declared that "man" must empower "his" own rational self-interest because "his highest moral purpose is the achievement of his own happiness" (Rand, 1959). Indeed, "her portraits of heroic individuals struggling to realize their vision and creativity against the opposition of small minded bureaucrats and ignorant masses both foreshadow and inform the cyberlibertarian vision" (Winner, 1997). Individualism free from regulation was the Randian key to a truly free society. Machines, cyberlibertarians believed, could create stability where before there was volatility:

> Ever since the 1970s computer utopians in California believed that if human beings were linked by webs of computers then together they could create their own kind of order. It was a cybernetic dream, which said that the feedback of information between all the individuals connected as nodes in the network would work to create a self-stabilising system. The world would be stable yet everyone would be heroic Randian beings completely free to follow their desires. (Curtis, 2011)

This way of thinking drew heavily from right wing economics: "[c]rucial to cyberlibertarian ideology are concepts of supply-side, free market capitalism, the school of thought reformulated by Milton Friedman and the Chicago school of economics" (Winner, 1997). The economist Alan Greenspan was a regular and early acolyte of Ayn Rand's weekly meet-up, self-labeled "the collective". From her Manhattan apartment Rand would read new excerpts of her books that preached radical individualism and a mistrust in centralised forms of governmental force (Curtis, 2011).

From the late 1980s cyberlibertarians were seeing the Internet as a new territory from which to build virtual communities that would provide emancipation from traditional authoritative bonds (May, 1994; Borsook, 2000; 2001). Integrated circuits held the power for harnessing digital realms of production. Even critics of the New Economy began to be swayed by its tempting utopian dreams (Gordon, 2000). But then the dotcom bubble burst and Internet companies everywhere collapsed. As the dust settled a few companies like Google and Amazon appeared to have survived the wreckage and they went on to carve out business models 'within' the infrastructure of the Internet that became increasingly commercialised and privatised. As Barbrook and Cameron predicted (1996), the Internet evolved into a mixed economy with the creative and antagonistic hybrid of state intervention, capitalist-corporate entrepreneurship, and DIY culture initiatives. But the 2001 tech wreck was not the death of the Californian Ideology: the doctrine has only matured with the "colonisation of the Net by corporate behemoths and the exposure of their collaboration with the USA's spy agencies... [so that] its analysis has never been more relevant" (Barbrook, 2015, 8). Cyberlibertarianism has become an unhappy coalescence of fundamentally contradictory tenets with Bitcoin, blockchain technology, and algorithmic decentralisation the products and actions produced as part of the growing sophistication of cryptography. Unlike technology start-ups, who operated in the spotlight of the global stock markets, cypherpunks attempted to fulfil their cyberlibertarian dreams in the shadows. The genealogy of Bitcoin, as the first successful cryptocurrency, is therefore littered with motives to redistribute power through the medium of technology.

A Genealogy of Cryptocurrencies

By the 1990s the cypherpunk community had already made significant contributions to online privacy yet some had turned their attention to something they saw as more socioeconomically pressing and potentially emancipating: the concept of digital money. To them the digital economic infrastructures being proposed for the Internet looked like they would systematically reveal an "individual's life-style habits, whereabouts, and associations from data collected in ordinary consumer transactions" (Chaum, 1985). This gave cypherpunks like David Chaum "the chills" (Levy, 1993). Chaum was a strong advocate for privacy and a pioneer in the field of digital money in a time where few took him seriously (Levy, 1994). He first conceptualised ecash in 1983 with a whitepaper on untreatable payments (Chaum, 1983) and later realised it as the corporation DigiCash in 1990 that offered a cryptographic form of digital money harnessing public-key cryptography. However, these digital signatures were still signed by an individual firm (on servers held by Chaum's company) and the platform as a whole was dependent on its success.

By 1996 other forms of digital cash had sprung up—Cybercash, NetBill, First Virtual, and Mondex to name but a few (Kienzle & Perrig, 1996)—to challenge Chaum's leading position on what looked like the beginnings of a monetary revolution. He pitched his idea to government officials, central bankers, commercial bankers, technology leaders, and financial policy makers with the idea of selling licenses for the privilege of using his new monetary system that enhanced transaction privacy and reduced intermediary costs such as credit card fees (Vigna & Casey, 2015). Many were more than interested: the Dutch government signed a contract to use the system for toll-road payments; Deutsche Bank, Advance Bank of Australia, Credit Suisse, and Sumitomo took out licenses; Microsoft and Visa took an interest and began collaborating with Chaum; and Credit Suisse First Boston gave Chaum's team a lucrative space in its midtown-Manhattan offices (ibid.). The vision of 'hacker money' was being remoulded to fit the corporate world. Eventually though the interest subsided and the dreams of a new form of Internet money died away allowing the dated traditional payment infrastructures of credit cards, that had been designed in the 1950's, to be "bolted onto that of the Internet" (Vigna & Casey, 2015, 57).

The rest of the cypherpunk community were not wholly disappointed with the failure of DigiCash as most disapproved of the risk associated with trusting a central organisation (Chaum's company) to confirm every digital signature needed to authorise transactions. This was the very thing that public-key cryptography was designed to eliminate. The criticisms of centralisation proved valid when DigiCash, along with all its tokens, disappeared with the collapse and bankruptcy of Chaum's company in 1998 (Popper, 2015a). Elsewhere cypherpunks were already designing systems that did not rely on a central point of corruption or failure. In 1997 Adam Back, a British cryptographer, proposed a proof-of-work based digital currency called hashcash. This pioneering cryptographic currency was designed to make denial of service (DoS) attacks on Internet resources like email uneconomical by attaching a currency to outgoing emails that would make sending them incur a small cost (Back, 2002).[8] In doing so, Back solved an issue that had always haunted conceived modes of digital decentralised money: the double spend problem. Digital data not protected by centralised institutions possesses the quality of being infinitely copyable: a characteristic that would make currency valueless by disintegrating networks of trust and practice around it. With hashcash users would no longer be able to 'copy and paste' individual digital units of currency (spending them more than once) because there would be a cost to their production (ibid.). An adaptation of this cryptographic proof-of-work system, based on expending (electrical) energy on a hash function, is what the game-theoretical structure of Bitcoin mining uses today in order to secure the protocol, administrate transactions, negate double spending, and mint new coins (see Chapter 5).

Although hashcash eliminated the need for a central institution to authorise transactions, its tokens could only be spent once; to spend was to simultaneously destroy. But storing and re-spending currencies has long been a quality of money's long and intricate history (see Simmel, 1900; Davies, 1994; Chown, 1994; Weatherford, 1997; Leyshon & Thrift, 1997; Graeber, 2011). In 1998 Wei Dai, a computer engineer and cypherpunk, conceptualised b-money to counter this flaw: a digital currency that could be reused and controlled through a shared ledger to publicly broadcast transactions to the rest of the network—another architectural inspiration for Bitcoin. That same year Nick Szabo, a computer scientist and cryptographer at Berkeley, conceptualised bit gold: a digital currency that utilised unforgeable chains that contained public keys, timestamps, and digital signatures to form a function called 'proof of work' that could support the transfer of digital tokens (Szabo, 2008). The tokens, unlike hashcash, were also designed to hold value due to their programmed scarcity. Bit gold characteristics would later be reassembled to create the Bitcoin blockchain. Six years later, in 2004, Hal Finney, a cypherpunk who had worked with Phil Zimmermann on PGP Corp (and the first collaborator with Satoshi Nakamoto), developed a system called reusable proof-of-work (RPOW). This software administered digital tokens, combining many of the cryptographic developments above, allowing them to be owned and traded like money. "All of this—the good, the bad and the ugly of the

---

[8] Although the cost of sending one email is negligible in this system (fractions of a cent), sending thousands starts to become expensive and thus forces attackers to pay for this form of system abuse: an economical deterrent.

Cypherpunk's idea bank—would go into the intellectual soup from which bitcoin would emerge" (Vigna & Casey, 2015, 51).

The Politics of Bitcoin

The advent of cryptocurrencies has become an extension of the bottom-up narrative of re-empowering citizens. They are an attempt to democratise money through the programming of a fairer political economy: one based on the limited 'untouchable' supply of a digital currency controlled by a network playing by the rules of an algorithmic protocol as opposed to the centralised institutions of global finance. David Golumbia (2015, 2016b) accuses Bitcoin of being software symptomatic and systematic of political-economic right-wing extremism. From this perspective the ideologies that fuelled Bitcoin's development mean that by its very design—a fixed monetary supply, a decentralised consensus system for determining currency ownership, and a pseudoanonymous transaction ledger—reflects the assumptions of Milton Friedman (1962, 1993), as practised by the Chicago school of economic theory, that champions gold-backed currency, distrusts inflation, and blames central banks for crises sometimes to the point of conspiracy (Golumbia, 2016b). Golumbia claims that all people who use Bitcoin ultimately, and often unwittingly, propagate this politics. It is certainly true on an infrastructural-monetarist level that Bitcoin fosters right-wing ideologies (which it will possess from cradle to grave unless the Core developers conduct a radical system update supported by Bitcoin miners—see Chapter 4). However, this critique sometimes teeters into a monolithic and reductive account that explicitly omits the pluralistic and contestatory Bitcoin community that now encapsulates a myriad of stakeholders.

Golumbia is right that Bitcoin, on some level, will likely always reflect this form of right-wing politics (in terms of its fixed supply, for example) but it is dangerous territory to extrapolate early ideological intent into permanent, sweeping generalisations of future incantations of the protocol. It is fairly ironic when Golumbia (2016b), quite rightly, talks about hating the neologism "hacker" because it is too often used unambiguously, that he goes on to simplify elsewhere the politics of Bitcoin. He is half right. Bitcoin was certainly dreamed up by right-wing coders but infrastructures are not as static as they first appear (Bowker & Star, 1999; von Schnitzler, 2008; Anand, 2011; Larkin, 2013; Fisch, 2013; Antenucci & Pollio, 2017). Many Internet pioneers, for example, saw the TCP/IP protocol as a vehicle for bypassing centralised powers and fringe politics saturated its early developments. The Internet, however, has since become a radically different beast, being adopted by a multitude of users. The anthropological work of Daniel Miller and Don Slater (2000), that examines the Internet in Trinidad, demonstrates how cultural practice across architectures is contingent and contradictory in different, or indeed the same, place(s).[9] At times, then, Golumbia's critique fails to account for how infrastructural politics become wrapped up with a storm of other political intentions that can redirect the overall trajectory. As Nigel Dodd (2017) reflects, Bitcoin "can be many things politically" (6).[10] Additionally, blockchain architectures can be as much a vision for socialists, for example, as they can for right-wing extremists (Huckle & Wright, 2016; White, 2017).[11]

Concentrating purely on protocological control (Galloway, 2004), then, can become a narrowing limitation. There is more at work behind the scenes: power is not only exercised by the protocol itself but by actors that operate through it. Protocols evolve so that they never entirely settle in the forms that they were first envisioned on paper. Golumbia (2016b) is right, however, when he says that the ideologies that drive software's conception are extremely important. Here lie the deeper modes and politics of production. For example, the Internet protocol was originally designed to withstand attacks during the Cold War and developed as a communication platform between universities (Baran, 1962; Raymond, 1998; Galloway, 2004). What is interesting is how it still holds some of the characteristics it was originally designed to contain, for example an open flow of information, while, at the same time, has evolved to encapsulate polarising others, for example enclosed silos of information. Political infrastructures in this light become increasingly multifaceted (and often contradictory) with their maturation.[12] This is true for the often presupposed dualism of centralisation and decentralisation. For instance, in the 1990's Japanese rail networks largely replaced the Centralised Traffic Control (CTC) with the Autonomous Decentralised Transport Operation Control System (ATOS) that "combines advanced information technology and communications with the conventional commuter train apparatus to transform the commuter train network into a type of 'smart' infrastructure" (Fisch, 2013, 322). But this move

> …cannot be read simply as the story of a historical shift from a rigid centralized system to a flexible decentralized one. In reality, the complexity and density of traffic on main lines in

[9] The Internet did not bridge political divides, like its early acolytes promised, by facilitating the 'freedom of information' but, instead, different networks across its architecture seem to have created echo chambers that only polarise and reinforce the politics of individuals.

[10] In doing so Dodd (2017) quotes Bill Maurer et al. (2013): "[i]n the world of Bitcoin there are goldbugs, hippies, anarchists, cyberpunks, cryptographers, payment systems experts, currency activists, commodity traders, and the curious" (2).

[11] This is not in response to Golumbia (2016b) who does not claim the contrary by extending his critique to blockchains.

[12] As a response to the non-payment of water accounts in post-apartheid South African townships, for example, Johannesburg Water introduced pre-paid meters "with a quest to create a consumer-citizen who will, on the one hand, understand the fiscal responsibilities of citizenship, and on the other, learn how to budget and calculate consumption; calculativeness becomes an essential attribute and ethos of citizenship" (von Schnitzler, 2008, 916). Here, infrastructures "not only redefine and materialise the shape of the civil link with the state, but also, and more importantly, actively participate in the construction of particular subjectivities" (ibid.). Elsewhere, in Mumbai, connections to the water supply for particular slums is informally traded with officials for support in elections (Anand, 2011). Electrical networks have also been illegally tapped into on a more global scale by poorer populations (Smith, 2014).

> Tokyo prevented train operators from implementing an absolute centralized control under the CTC, whereas ATOS… allows for greater centralization of command than the centralized system ever did. In other words, the centralized system was in some ways very decentralized, while the decentralized system can be extremely centralized. (Fisch, 2013, 332)

Similarly, the developments of cryptocurrency, and blockchain technology as a whole, are expanding the reach of algorithmic decentralisation so that its geographies of practice are becoming many and varied.

Conclusion

This chapter has demonstrated the ideological forces that have led to the development of cryptocurrencies and blockchains but has also left room for the current and future splintering of divergent stakeholders. Computer scientists have now stepped up into positions of authority when it comes to building the narratives and architectures of money and finance. This chapter has started to unpack the cultural-political undertones that permeate online spaces of collaboration and their relationship with governance in terms of Bitcoin and wider notions of algorithmic decentralisation via blockchains. But while algorithmic decentralisation has strong roots, maintaining a cypherpunk/ libertarian bent, it has simultaneously become absorbed into a plethora of less radical political frameworks, almost as an a priori social 'good'. This is similar to other 'given' and 'desired' qualities discussed elsewhere, such as openness, transparency, ad-hocracy, participation, and collaboration (Tkacz, 2015). Following the 2008 global financial crisis (that many blame on the recklessness of centralised banking) this is perhaps unsurprising. Yet the ideologies that surround algorithmic decentralisation no longer follow a singular path—for example, the same banks and governments that have apparently abused their centralised positions of control are now co-opting blockchains for their own benefits (see Chapter 7).

Algorithmic architectures of decentralisation now stand to transform the relationship between money, code, and space. A look back at the maturation of the Internet gives fair warning not to succumb to sensationalist views of 'complete' or 'pure' decentralisation: networked culture of the TCP/IP protocol evolved into something quite different to what its builders first imagined—a fate that seems to be befalling Bitcoin and blockchain technology as a whole. The following chapters expand on the pluralism and the paradoxical nature of blockchains, paying close attention to different forms of (de)centralisation.

Chapter 4

The Money-Makers: Programming Political Realities

Introduction

Conceptualisations of money/space have indicated how the control and possession of different currencies is maintained within distinct networked geographies such as (global) cities (Sassen, 1991; Hirst & Thompson, 1992; Hall, 2007), financial institutions (Clark, 2000; Clark & Hebb, 2004; Clark & Wojcik, 2009; Hall & Appleyard, 2009), nation states (Strange, 1988; Leyshon, 1993, 1995; Wood, 1997), and the "developed world" (Castells, 1989; Corbridge, 1993). Relatively speaking, banking services exist for "social elites" compared to poorer geographic communities who are often underrepresented by the financial sector (Underhill, 1991: Davis, 1992; Lash & Urry, 1994; Leyshon & Tickell, 1994; Philo, 1995; Marshall, 2004; French et al., 2008). This is a capitalistic pattern: banks have divisions that cater for all markets where money can be made. As such, more financial services will stretch to poorer communities only when profit seems viable—for example, the aggregation of cheap mortgages that brought about the global financial crisis. On a global scale, however, contemporary financial services exist mainly for citizens in wealthier countries (Mitchell, 1990; Christopherson, 1993; Leyshon & Thrift, 1995). Consequently, wealth tends to stay concentrated in particular spaces, or, as Gordon Clark (2005) aptly puts it, "money flows like mercury": it "runs together at speed" but pools in a way that is "never ever randomly distributed" (104). Particular actors in monetary networks perpetuate the unequal distribution of financial wealth across different spatial scales.

Satoshi Nakamoto (2008) created the Bitcoin protocol as a monetarist mechanism for dissolving the financial/monetary power held by both commercial and central banks by offering a codified, non-hierarchal architecture that bypasses these centralised institutions altogether. In the same move, algorithmic decentralisation can supposedly deterritorialise money by obliterating the financial borders of nation states with the unrestricted online movement of value (Carmona, 2015; Bashir et al., 2016; Goodman, 2017; Yates, 2017). Blockchain decentralists assert that this is precisely achievable because the money/space of cryptocurrencies relies on their code/space and vice versa. This chapter is reserved for understanding the non-provincial mode of governance that Bitcoin offers in place of the monetary policy of central banks: the codified rules created under an open source software model. In doing so, it further unpacks Bitcoin's money/code/space by examining its geographies of production and (re)introduces discussions of centrality and control into the debate.

Bitcoin is upheld as a distributed protocol cultivated and sustained through open source software practices that supposedly flatten and distribute power between contributors. The open source model itself is widely seen as an egalitarian, decentralised, and non-hierarchal mode of organisation (Ducheneaut, 2005). Bitcoin's production and maintenance mechanisms are therefore said to be transparent and democratic as anyone, in theory, can contribute to the development of its code (van Wirdrum, 2014; Zerlan, 2014; Metz, 2015; Jeftovic, 2017). Digital environments like the Bitcoin Forum and GitHub, that are governed by moderators and those with commit access respectively, assemble to form a system of code assembly where communities of practice attempt to fulfil their political ideologies. Following Bitcoin into the online spaces where its code development is orchestrated starts to unpick the argument that centralised control is systematically eradicated from its production process (van Valkenburgh, 2017; Gatecoin, 2017).

In doing so, this investigation asks: where does power to influence or govern Bitcoin lie? Methodologically, answering this question involved tracing connections between actors within the online communities that facilitate Bitcoin's modes of open source governance. Unlike earlier follow the thing work, such as Cook and Harrison's (2007) account of hot pepper sauce, I could 'teleport' straight to its production site precisely because it is constructed at the online code repository website GitHub. Further discourse takes place within sites like the Bitcoin Forum.[1] Examining how code is built and modified in these spaces can form a better understanding of its "contours of governance" (Tkacz, 2015, 124).

Following on from the political history of cryptocurrencies in the previous chapter, I begin by outlining how the Bitcoin community came into existence. The chapter then moves into a description of the production model in which Bitcoin rests: open source software development. Empirical observations and case studies such as the block size debate are used to demonstrate how centralisation manifests in this mode of open source code development and how cultural-political practices affect the technical parameters of the Bitcoin blockchain. Subsequently, the chapter focuses on the governance model of GitHub and more specifically the Bitcoin code repository. Different forms of forking are discussed as political strategies for branching away from these closed, centralised, organisational structures to create competing centralised decision-making vehicles. The overall political framework for making changes to the Bitcoin code is described as senatorial governance.

---

[1] In these particular spaces I adopt more of a participant observer role than an observant participant as I do not develop the Bitcoin source code myself.

Cultivating a Community

Software increasingly "mediates, saturates and sustains contemporary capitalist societies" (Graham, 2005, 562). The "modern city exists as a haze of software instructions [so that n]early every urban practice is becoming mediated by code" (Amin & Thrift, 2002, 125): it admits people into buildings, makes telephone calls, navigates cars, calls elevators, monitors heart rates, and purchases stocks. Adam Greenfield (2006) describes this ubiquitous dependence on underlying digital systems as a state of "everyware". This has the effect of rendering code as a mysterious and spectral substance working away in the shadows. However, while code might appear to be '*every*ware' it always comes from, and acts, '*some*ware'.

The geographies of Bitcoin's inception are extremely hazy thanks to the anonymity of its creator Satoshi Nakamoto—incidentally this glorified incognito adds to the 'anarchist' and 'hacker' mythology that surrounds cryptocurrencies. Following the publication of Nakamoto's whitepaper in 2008, Bitcoin remained a concept circling amongst a specialised set of cryptographers with discussion concerning its feasibility continuing in dribs and drabs on the cryptography mailing list for a little over two months. It appears, however, that Satoshi Nakamoto (whoever he, she, or they might be) had been developing the Bitcoin code for quite some time before this. Their theory was put into practice at 18:15:05 GMT on the 3rd January 2009 when the codebase that Nakamoto had been building was initiated on a couple of unknown machines somewhere in the world. In doing so they became the only nodes on the Bitcoin 'network'.

Nakamoto continued a closed model of development with some advisory help from other cryptographers like Hal Finney who were recruited from the cryptography mailing list. Later the software was made available for download on sourceforge.com—version 0.1.0 was written in the computer language C++ and had 12,222 lines of code (remotemass, 2013).[2] It was not until the Bitcoin source code was uploaded to GitHub on the 30th August 2009, however, that a community of voluntary programmers, called Core developers, began to help Satoshi Nakamoto, then Lead Developer, advance the protocol. Since then the Bitcoin source code has been consistently revised, maintained, and modified by voluntary programmers from a variety of different countries. This makes the geographies of Bitcoin's code production quite complex and relatively obscure because some contributors remain (pseudo)anonymous whereas others maintain a high profile on social media. Yet, while its open source software model "weaves together a surprising range of places, objects and people" (Kelty, 2008, 2), having contributors from a multitude of countries is not the same as having distributed governance. This is an important distinction that this chapter will go on to demonstrate.

---

2 Disregarding comments, spaces, and line breaks, and suppressing sha.cpp and she.h (adding up to a total of 12,759 lines when including these two files).

The early political-economic discourse surrounding Bitcoin heightened when a second year computer scientist at Helsinki University of Technology called Martti Malmi (screen name serius-m) began cooperating with Satoshi. Malmi renovated the bitcoin.org website, helped Satoshi design the Bitcoin logo/symbol, and became the first person given permission to contribute directly to the Bitcoin source code (Popper, 2015a). In the process he intentionally politicised the Bitcoin vocabulary to appeal to groups of various (radical) political persuasions (such as anti-state.com) in an effort to encourage broad(er) adoption of the software (ibid.).[3] Perhaps Malmi's most significant contribution to Bitcoin, however, was the advent of the Bitcoin Forum in the autumn of 2009 that provided an online environment for proponents and critics to discuss the protocol. The forum attracted a diverse set of cryptographers and other programmers who began analysing the conceptual apparatus of Bitcoin: dissecting, critiquing, constructing, disassembling, reassembling, shaping, reshaping, and affirming the theoretical (pseudo-code) and practical (source code) architecture. It was also in these cultural-political online environments that terms like 'cryptocurrency' (Bitcoin Mailing List) and Bitcoin's tagline 'Vires in Numeris' (Bitcoin Forum) were first used.[4]

Through the Bitcoin Forum an online community of practice began to emerge (Wenger, 1998; Wenger et al., 2002, 2009; Bryant et al., 2005; Dubé et al., 2005; Murillo, 2008). Here members collaborated to discuss the philosophical and technical apparatus of Bitcoin. Programmers from all over the world (although the majority from the United States) began gathering online to innovate the conceptual, and increasingly practical, apparatus of Bitcoin through its adolescent stages sharing levels of mutually reinforcing interaction around a common goal: an object-orientated online interaction that connects people widely separated by diverse geographies (Johnson & Squire, 2000; Johnson, 2001).[5] The open-source software became a technological vehicle for delivering political visions: an experimental sandbox and a political space created by a "grass-roots collaboration of enthusiasts" (Taylor, 2013, 1). This development ensued on the code repository GitHub where some contributors became key figures and later on social media sites such as Reddit and Twitter.

On the 4th December 2010 WikiLeaks, a "journalistic non-profit organisation dedicated to publishing selected secret and classified information provided by anonymous sources" (Champagne, 2014), fell

[3] In these online spaces Bitcoin began resonating strongly with libertarians, cryptoanarchists, and cypherpunks who revelled in the idea of a monetary alternative to fiat currencies that claimed to obliterate trust in banks and governments (see Chapter 3).

[4] The term cryptocurrency was first conceived by a user on the Bitcoin mailing list—a discussion-based list on sourceforge.net that accompanied the Bitcoin software download—in reference to the cryptographic functions that allow it to run (Popper, 2015a). Nakamoto and Malmi approved of the terminology and began using it themselves.

[5] While technically anyone can contribute to Bitcoin's development from anywhere in the world, its contributors are not as varied as this might imply—see section titled "The Bitcoin Project".

under a financial blockade from Paypal, Bank of America, Visa, Mastercard, and later Western Union. The US government had applied pressure on these financial institutions, following the public disclosure of Iraqi and Afghan War documents by the organisation, to cut the economic lifeline on which WikiLeaks survived: monetary donations. For the largely libertarian Bitcoin community this blockade personified the ultimate form of corruption by state powers and demonstrated the control enjoyed by an oligopoly of financial companies. Collusion had isolated WikiLeaks from the entire global economic structure. To the majority of the Bitcoin community this seemed to be an act of self-preserving malfeasance by the US government, especially considering organisations like the Ku Klux Klan could still accept donations facilitated through MasterCard, Visa, and PayPal (Mross, 2015). Additionally, a significant proportion of Bitcoiners were politically aligned with the idea of WikiLeaks that stands for transparency, the freedom of information, and the accountability of justice—largely against the 'wrongdoings' of the centralised state.

The blockade of Wikileaks also provided the fledgling Bitcoin community with an opportunity to test Bitcoin as an alternative financial channel for sending donations to WikiLeaks where no centralised institution could be intimidated to withdraw their services. The Bitcoin Forum was rife with comments that supported this political intervention but not everyone shared such optimism. Satoshi Nakamoto opposed this excitation writing "No, don't 'bring it on'. The project needs to grow gradually so the software can be strengthened along the way" (Nakamoto, 2010a). But then an article in *PC World Magazine* conjectured the Bitcoin-WikiLeaks solution to a wider audience (Thomas, 2010). Nakamoto responded with a final post on the Bitcoin Forum: "It would have been nice to get this attention in any other context. WikiLeaks has kicked the hornet's nest, and the swarm is headed towards us" (Nakamoto, 2010b).

Nineteen hours later Nakamoto put out Version 0.3.19 of Bitcoin and then disappeared from the public eye. Gavin Andresan, a software developer from Massachusetts who had become Satoshi's 'right hand man', accepted an invitation to talk at the CIA where he hoped to persuade them Bitcoin did not pose a threat to government institutions (Mross, 2015). Whether this was the reason for Nakamoto's departure from the project or not, the creator of Bitcoin became a ghost soon after and Andresen took up the role of Lead Developer. Contributors came and went but the Bitcoin code continued to be built.

The international pool of Bitcoin Core developers is often distracting for commentators who claim that open source software is distributed because its contributors are geographically dispersed. This is a common misconception. In fact, the title of Lead Developer is an important indicator that modes of organisation in open source software development are fundamentally hierarchal. It was Satoshi Nakamoto who first provided access to Bitcoin for Martti Malmi, created the GitHub repository, and later passed on the role of Lead Developer to Gavin Andresan following the (unwanted) attention received from the WikiLeaks blockade. In other words, the Lead Developer is enrolled into a position of power within the network of Bitcoin's code production. If Bitcoin's code/space and money/space are inextricably linked, the maintenance, or alterations, of monetary policy prescribed by the codified rules of the protocol are also subject to hierarchy despite the repeated claim that open source models are a from of decentralisation governance.

The Hunt for Satoshi Nakamoto

Debates over who (and where) Satoshi Nakamoto is/was have circumscribed Bitcoin throughout its short history. Some reports, diving into the forensics of linguistic and coding grammar (as well as political ideologies and skill sets) of possible candidates, have pointed to, amongst others, Nick Szabo (Frisby, 2013; Hajdarbegovic, 2014), Michael Clear (Davis, 2011), Neal King, Vladimir Oksman and Charles Bry (Penenberg, 2011), Hal Finney (Greenberg, 2014), Michael Weber (Walker & Wile, 2014), Donal O'Mahony and Michael Peirce (CoinDesk, 2016a), and Shinichi Mochizuki (Nelson, 2013; Oates, 2013). Such speculation is so embedded in Bitcoin culture that it even forms the basis for the narrative surrounding a fan fiction comic book called "Bitcoin: The Hunt For Satoshi Nakamoto" (Preukschat et al., 2014; see Figure 5). Incidentally, I was once sitting on a table with Bitcoin Core developer Gregory Maxwell at the Silicon Valley Bitcoin Meet-up where this comic was being passed around before a presentation started. Inside, it overtly presents the political ideologies of the cypherpunk anarchist subculture that originally formed around cryptocurrencies (see Chapter 3). Mirroring the powerful early rhetoric found on the Bitcoin Forum, the comic glorifies Nakamoto almost to the point of deity.

This mystification of Satoshi Nakmoto's identity ties into a case study that represents the centrality of Bitcoin's mode of software governance. In 2016, Craig Wright, an Australian computer scientist and businessman, publicly 'revealed' himself as Satoshi Nakamoto (Bustillos, 2015) after two previous proposals made in *WIRED Magazine* (Greenberg & Branwen, 2015) and Gizmondo (Biddle & Cush, 2015) highlighted him as the probable creator of Bitcoin. Wright later 'proved' this to the BBC, *The Economist*, and *GQ Magazine* by cryptographically signing a mined block on the Bitcoin blockchain that 'only Nakamoto' would have the private key for (BBC, 2016; The Economist, 2016; GQ Magazine, 2016). Cryptographers in the Bitcoin community immediately debunked his claim via channels such as Twitter and Reddit (see Figure 6). The block that Wright signed was found to have been publicly done so by Nakamoto years earlier and his refusal to sign the genesis block—which cryptographers attest is the only fool-hardy way someone could prove themselves to be Nakamoto—suggested a fraudulent

[Image removed for copyright purposes]

Figure 5: Front cover of a crowd-sourced Bitcoin comic book

declaration.[6] Andrew O'Hagan (2016), who spent six months with Wright during the ordeal, later concluded in *The London Review of Books* that his assertions were inconclusive and unlikely.[7]

When Wright made his claim many turned to the Core developers, and other industry leaders respected by the wider Bitcoin community, for confirmation. During the incident Gavin Andresen, who by then had passed on his Lead Developer role to Wladimir van der Laan, but remained a contributor to the project, flew to London as a 'trusted' and 'revered' certifier of the 'proof' that Wright was providing. When Andresen publicly supported Wright's claims on a personal blog post the Core developers

[6] Once Satoshi Nakamoto initiated the Bitcoin code it was out in the open and so theoretically anyone could have mined a block thereafter.

[35] The BBC article was originally titled "Bitcoin creator reveals his identity" and changed to "Australian Craig Wright claims to be Bitcoin creator". The text was also rewritten to recognise that there was still doubt about Craig Wright's claim.

[Image removed for copyright purposes]

Figure 6: Humorous tweet alluding to Craig Wright's lack of cryptographic proof for his claim of being Satoshi Nakamoto

worried about the authenticity of Andresen's declaration. In the fear that his online accounts, through which he accredited Wright, may have been hacked or compromised, the Core developers chose to revoke Andresen's commit control (his ability to make changes to the source code) on GitHub as a precautionary measure having themselves concluded that Wright's 'evidence' was not sufficient to prove that he was Satoshi. As the project owner/maintainer, Wladimir van der Laan was the one to temporarily pull the plug on Andresen. This clearly demonstrates that a singular authority and centre of power exists within communities of open source GitHub developers. While anyone can voice their opinion through consensual dialogue, it is the Lead Developer who has overruling control both over code changes and the administrative/commit/permission privileges of other developers.

There have been three Lead Developers in the historical advancement of Bitcoin's code on GitHub: Satoshi Nakamoto (location unknown), Gavin Andresen (United States), and, currently, Wladimir van der Laan (Netherlands). Each has had the position passed on to them by the last—Andresen stepping down on the 8th April 2014. Wladimir van der Laan adopts a philosophy that mirrors that of blockchain models in that he leads via 'consensus': requiring a certain level of agreement between the Bitcoin Core developers before he makes/confirms changes to the source code. However, this mantra has fallen under criticism—for example, by ex-Bitcoin Core Developer Mike Hearn—for being profoundly hollow in practice. Before this claim is unpacked, open source software is further problematised as a mechanism for distributed code governance.

Organising Open Source Software

Like all software Bitcoin is a product of labour. The organisation of this open source work, while being by no means unique, differs from the traditional assembly of privately designed proprietary software produced at companies such as Microsoft or Apple.[8] Open source software is publicly available to copy, modify, and distribute as others see fit (Deek & McHugh, 2008). This means that programmers on a global scale can contribute to the development of a project (Shrestha et al., 2013). The popular imagery of open source software is therefore of an "egalitarian network of developers free of hierarchal organization and centralization of control" (Ducheneaut, 2005, 324). In other words, open source embodies a bazaar model (Raymond, 2001), which is purposefully designed to increase the robustness of code through an outsourcing of brains (DiBona et al., 1999).

Bitcoin's programmers claim that the open source software model they utilise dispels structural hierarchy, promotes transparency, and decentralises processes of governance. Nathanial Tkacz (2015), examining open organisational structures in *Wikipedia and the Politics of Openness*, explains that hierarchies of control are usually presented as a rhetorical antithesis to open models. Openness comes across as attractive and ambiguous in equal measure so that "it appears seemingly without tension, without need of clarification or qualification" (13). Yet, contradictory to this imaginary, closed and ordered systems stay prevalent in their organisational structures. While Wikipedia champions a benevolent guise of openness aligned with the buzzwords of collaboration, decentralisation, participation, transparency, and spontaneity, its governance actually operates under precise structures: decisions are closed and voices are excluded through hierarchies that follow predetermined political and philosophical frames set out by policies and guidelines. In other words, patulous governance demands a degree of hierarchy for organising disparate actors and channelling decision-making. I continue down this line of thinking by demonstrating how points of power positioned between the builders of the Bitcoin blockchain are rendered through hierarchal bottlenecks heavily wrapped up in forms of organisational centrality. As such, Bitcoin is caught uncomfortably between a growing and fractured community that is beginning to tear the algorithmic-political protocol at the seams.

---

[8] Although the lines already blur as both of these companies now utilise a version of open source to benefit from code creation outside of their employee base through mechanisms such as app stores.

As Tkacz (2015) tested the claims of openness amongst the builders of Wikipedia, I here test the claims of decentralisation amongst the builders of Bitcoin.[9] While the intentions of open source software are clear (see Appendix 11), its politics does not stop at ideological motivations but extend into, and are manifested by, its practices and governance structures. I now, to repurpose a phrase from Tkacz, attempt to capture the organisational politics of Bitcoin and "rub these up against the language of openness[/distribution], revealing [their] tensions, contradictions, subjugations, invisibilities, and lines of force" (13). In other words, I ask: if Bitcoin is supposed to change the plumbing of finance then who are the plumbers and how do they operate? This mode of investigation continues to articulate Bitcoin's money/code/space and shed light on its production processes as a 'decentral bank'.

The Block Size Debate

Scalability has been a concern for Bitcoin proponents from very early on in its development. The Bitcoin network was built to (theoretically) handle 7 transactions per second, whereas Visa on average processes 1677 per second with a maximum capability of 56,000 (Vermeulen, 2017). Many Bitcoiners have made propositions to solve this problem by altering the technical parameters of the Bitcoin blockchain: expand the block sizes to increase the transaction rate by fitting more transactions into every block. But this has also come with considerable backlash from other members of the community for a number of reasons: one of these is that big blocks discourage network decentralisation because they require more system resources (such as bandwidth) to mine, making it harder for lower scale miners to operate a full node (peoplma, 2015). These disagreements between core developers started to bring about stagnation in Bitcoin development (Hearn, 2016a). An employee of the New York Bitcoin Center, that for a time was located on Broad Street next to the New York Stock Exchange and could be seen from Wall Street, exemplified this to me in 2016: "Bitcoin has become really boring. It's like a civil war of Core developers, and none of those killer apps we were promised in 2014 are coming out".

Wladimir van der Laan has been blamed by some in the community for failing to make important and necessary interventions that could resolve development issues. But for Mike Hearn (2015) the block size deadlock cuts deeper: it not only represents a failure of dispute-settling within Bitcoin Core but also personifies, with resounding clarity, the (coercive) centralisation of Bitcoin code maintenance. He stated in 2015 that "when you boil away all the noise, there are only 5 people in the world who can make changes to the Bitcoin Core source code". These were, at the time, Gavin Andresen, Jeff Garzick, Wladimir van der Laan, Gregory Maxwell, and Pieter Wuille. From his own personal

[9] In fact, throughout Tkacz's book the words open/openness could be replaced with decentralised/decentralisation and the words closed/closure with centralised/centralisation to make sense in the context of Bitcoin production. For example: "[centralisation] remains an inherent part of the [decentralised]; it is what [decentralisation] must continually respond to and work against—a continual threat amongst the ranks" (36).

experience as an active member of Bitcoin Core, Hearn explains that the "illogical" whims of van der Laan ultimately stifled resolution over issues like the block size debate. He notes that Gavin Andresen was "a solid and experienced leader who [could] see the big picture" but never, in actual fact, wanted to be Lead Developer:

> So the first thing Gavin did was grant four other developers access to the code as well. These developers were chosen quickly in order to ensure the project could easily continue if anything happened to him. They were, essentially, whoever was around and making themselves useful at the time. (Hearn, 2016a)

This demonstrates the closed system of governance from within which the code of a global distributed currency ledger is written showing that commit access is passed around within a tight clique of programmers with one central leader who has ultimate control. Such centrality of decision-making later became clear via the block size debate as van der Laan's activity on the bitcoin-dev mailing list showed him to be mostly siding against raising block sizes (van der Laan, 2015). In an interview with CoinJournal he stated:

> I mostly have a problem with proposals that bake in expected exponential bandwidth growth. I don't think it's realistic. If we've learned anything from the 2008 subprime bubble crisis it should be that nothing ever keeps growing exponentially, and assuming so can be hazardous. It reduces a complex geographical issue, the distribution of internet connectivity over the planet for a long time to come, to a simple function. (cited in Demartino, 2015)

Mike Hearn (2015) saw this argument as "illogical in the extreme: computer speeds have nothing to do with subprime lending practices. The financial crisis wasn't caused by exponential growth". Aside from the tenuous nature of van der Laan's claims, it is Hearn's view that open source projects need a benevolent dictator as opposed to a passive one (Demartino, 2015). He states that "there cannot be any code added to a Core release without Wladimir being satisfied with it. And he believes that *any change to the block size at all* simply can't happen 'any time soon'" (Hearn, 2015). These tensions start to show how the closed model of Bitcoin development cannot harmoniously cater for a multitude of outlooks. This lack of resolution is heavily wrapped up with the (socio)technical parameters of GitHub.

GitHub Governance: The Role of Version Control Systems

Version control systems "are a category of software tools that help a software team manage changes to source code over time" (Atlassian, 2017). They store information for every file as well as the general project structure in what is called a repository where "several parallel lines of development, normally called branches, may exist" (Ruparelia, 2010, 5). This model "keeps track of every modification of the code in a special kind of database. If a mistake is made, developers can turn back the clock and compare earlier versions of the code to help fix the mistake while minimising disruption to all team members" (Atlassian, 2017). Previous architectures, such as Concurrent Version Systems (CVS) and Subversion (SVN), relied on a client-server model so that each developer worked on their own local copy of the source code. Once programmers had edited their version they would have to push/commit their changes direct to the central repository without a chance for any other team members to see their changes. Because each developer would make changes to copies of the original files, as opposed to direct changes to the central source code itself, updating the many conflicting versions was a manual-based process that made editing laborious, confusing, inefficient, time-consuming, and prone to error. To resolve these problems *distributed* version control was introduced bringing concurrency into software production. This is akin to all programmers having access to the central repository and the full history of the code allowing team members to work offline with full functionality. No changes can be seen, however, until the individual developer connects to the network and pushes their code to the other repositories. Such distributed systems allow everyone to work on the same source code at once. Ultimately, this environment of collaboration "protects source code from both catastrophe and the casual degradation of human error and unintended consequences" (ibid.). As such, distributed version control systems have become an integral element of everyday practice for software development teams.

Git is now the most widely adopted form of version control for both closed and open source software development. It is a "particularly powerful, flexible, and low overhead version control… [originally] invented by Linus Torvald to support the development of the Linux kernel" (Loeliger & McCullough, 2012, 1). It was designed to facilitate distributed development, scale to handle thousands of developers, perform quickly and efficiently, maintain integrity and trust, enforce accountability, create immutability, sustain atomic transactions, support and encourage branched development, provide complete repositories, foster a clean and integral design, and harness freedom (Loeliger & McCullough, 2012). Like Bitcoin, Git is secured with a cryptographic hashing algorithm, in this case SHA1, that "protects the code and change history against both accidental and malicious change and ensures that the history is fully traceable" (Atlassian, 2017). This is like having constant and authentic backups of every alteration made by every developer. Additionally, and again like Bitcoin, the distributed structure ensures there is no single point of failure. Gits, then, share some functionalities with blockchains in that the entire chronological history of the database is shared across different nodes and updates 'simultaneously' with the rest of the network. However, blockchain architectures promote a 'write only' philosophy as, theoretically, *historical* data is irrevocably sedimented into the blockchain whereas *new* data can only be added via newly mined blocks (although there have been times when this has not been the case—see Chapter 7).

Eric Raymond (1998), a key pioneer of the open source software movement, once stated that the revelations of open source projects are not technical but sociological. While from an actor-network perspective this is not entirely true—open source systems are *sociotechnical* architectures—his sentiment of paying attention to the sociality of code production holds weight. The company GitHub has become a flagship for open source development and the world's largest host of source code (Gousios et al., 2014), with 24 million users and 67 million repositories (GitHub, 2017a), attracting a diverse mix of novice and professional programmers (Vasilescu et al., 2013). The website "provides services for individuals and teams to manage public and private repositories via Git" (Begel, 2013, 52). It is, quite literally then, a hub for Gits.

With the tagline 'social coding', GitHub creates a "developer-friendly environment integrating many functionalities, including wiki, issue tracking, and code review" (Thung et al., 2013, 323). It is this blend of code repository and social networking that has become so compelling for developers (Begel, 2013). While Gits are not unique to open source software, GitHub actively promotes openness via its carefully crafted revenue stream. The company provides free hosting for all projects with open access while their economic model is such that paid subscribers, who develop code on the website privately, cover the costs of everyone else. This business strategy is, in part, political and has helped the open source software community to grow exponentially. It also makes GitHub relatively unique because it is a "platform where [other] platforms are assembled and configured" (Mackenzie, 2018, 37). This turns the social act of coding collaboration into (future) revenue streams in a process known as platform capitalisation, which, more widely, looks to transform on-boarded networked practise into financial assets (Mackenzie, 2018; see Chapter 7). This mechanism also allows GitHub to "function as an element in a wider platform configuration" (Mackenzie, 2018, 48), or, as this chapter will go on to show, a centre in apparently distributed software development.

The monetary policy of Bitcoin is subject to the open source governance mechanisms present in GitHub that maintain the codified parameters of the Bitcoin blockchain. Because the Bitcoin repository relies on an open source distributed Git, its code production practices have become married to the idea of a distributed, non-hierarchal organisational structure—what Tkacz (2015), after Toffler (1970), refers to as an "ad-hocracy". This represents a shift towards promoting equitable contributors in lateral, as opposed to vertical and bureaucratic, networks: all the way harnessing a "narrative of liberation" (Tkacz, 2015, 92). But Tkacz goes on to show how, in the governance structure of Wikipedia, the "most contradictory forces can be mobilized—dictatorship, democracy, rough consensus, and, indeed, bureaucracy—as long as they can be legitimated by higher principles of ad-hocracy" (Tkacz, 2015, 94). If openness, decentralisation, and ad-hocracy are vocalised within organisational structures, power can operate unnoticed:

> Ad-hocracies rise and fall with the currents of change, but the bureaucracy remains in the background as a constant, albeit in a radically reformed and reduced state. Ad-hocratic forms are flexible, flat, in flux, and transient, and while the forces of history (i.e. change) are pushing organizations toward this ad-hocratic form, some elements of bureaucracy must remain. (Tkacz, 2015, 95)

Ad-hocracy/bureaucracy, openness/closure, and decentralisation/centralisation are not repelling binaries that separate like oil and water but rather swirl together through organisational practice in a hybrid and co-dependant capacity. It is in the analytical framing of heterogeneous networks that these complex states can be better illuminated and understood.

The Bitcoin Project

In this section I hope to shatter the illusion that GitHub is a distributed mode of governance through an examination of the Bitcoin repository. On a purely user basis, different studies have shown how the developers using GitHub are "highly clustered and concentrated primarily in North America and Western and Northern Europe, though a substantial minority is present in other regions" (Takhteyev & Hills, 2010, 1). This pattern of cultural and spatial aggregation is similar for the Bitcoin GitHub repository resulting in the majority of its contributors being white males. So although the openness of Bitcoin's source code allows people from all corners of the globe to participate, in practice the governors of its code are predominantly men situated in Western countries.[10] While the Bitcoin whitepaper has been translated into other languages the maintenance of the Bitcoin source code is mainly done in English. There are, then, limiting cultural and social factors to the distributed geography of Bitcoin's code builders.

What I concentrate on more strongly, however, are the mechanisms of governance internal to GitHub. Here, not all contributors are equal:

> Actions on code or associated with code include committing, forking and submitting a pull request. Project owners can make *commits*, i.e. changes to the code, by directly modifying the contents of code files. Developers without commit-rights to a project must fork a project, creating a personal copy of the code that they can change freely. They can then submit some or all of the changes to the original project by issuing a pull request. The project owner or another member with commit rights can then merge in their changes. Developers

[10] From time to time, I would bump into famous (in the Bitcoin world) Core developers in the San Francisco Bay Area during my fieldwork.

> can also communicate around code-related actions by submitting a comment on a commit, an issue, or a pull request. (Dabbish et al., 2012, 1279)

The Bitcoin code repository, or Bitcoin Core, exists on GitHub under an 'organisation' account that acts as a shared space for code collaboration. However, in this environment "[o]wners and administrators can manage member access to the organization's data and projects with sophisticated security and administrative features" (GitHub, 2017b). As of the 23rd March 2017, there were 24 Bitcoin Core developers listed on GitHub and a total of 522 contributors in its history (see Figure 7). All of these can technically be considered Bitcoin Core developers although there are significant levels of contribution: at the time of writing Bitcoin had 15,648 commits but the 10 top contributors accounted for 6079 of them. The majority of contributing programmers, however, do not have 'commit access'. At the time of writing, such a right is reserved for only three team members: Marco Falke, Jonas Schnelli, and the 'owner' (Bitcoin Core Lead Developer) of the project Wladimir van der Laan.

[Image removed for copyright purposes]

Figure 7: Homepage of the Bitcoin repository on GitHub on the 23rd March 2018

Contributors download their own copies of the Bitcoin source code from GitHub onto their computers, which are said to be 'downstream' from the main, shared repository. These clones are called forks and allow contributors to make their own edits on the code independently to other developers who may also be working on the code simultaneously. Contributors' local copies update, or pull, the authorised changes that are constantly being made to the shared repository. A contributor may make a bug fix, for example, on their personal fork and then push their local changes to the rest of the network; this is called submitting a 'pull request' because from GitHub's perspective the modifications are pulled 'upstream' to GitHub's servers. These changes must then be authorised by an administrator with commit access. In Bitcon's case, this is one of the three authorised people—although a quick glance through GitHub will show that Wladimir van der Laan does the lion's share of this work. If two contributors have made edits to the same piece of code this 'conflict' must be resolved by an administrator. Once resolved, the two (or more) forks will be merged together into the upstream shared master repository by 'committing' the changes to the source code. The administrator can then cryptographically prove that they made/authorised the commit by signing it with a GPG key.[11] The pull request will thereafter be labelled 'verified'.

The Bitcoin Foundation: Institutional Conflicts

The voluntary aspect of Bitcoin's open source code contribution is called into question when examining the dynamics between Bitcoin Core programmers and other institutions. The first time this became apparent was with the forming of the Bitcoin Foundation in Seattle of September 2012. The Foundation came about as a self-(s)elected organisation of prominent figures within the Bitcoin community including Lead Core Developer Gavin Andresen, BitInstant CEO Charlie Shrem, Mt. Gox CEO Mark Karpelès, and the first Bitcoin company venture capitalist, Roger Ver. In true open source fashion, the Bitcoin Foundation bylaws were posted on GitHub to open them up to scrutiny and suggestions from the Bitcoin community. It states, "the purposes of the Corporation include, but are not limited to, promotion, protection, and standardization of distributed-digital currency and transactions systems including the Bitcoin system as well as similar and related technologies" (Bitcoin Foundation, 2012). In a more political tone it continues, "[t]he Corporation shall promote and protect both the decentralized, distributed and private nature of the Bitcoin distributed-digital currency and transaction system as well as individual choice, participation and financial privacy when using such systems" (ibid.). A significant role of the Foundation was to give nation state regulators a body to approach in order to deal with issues relating to the emerging technology. With Bitcoin's links to Silk

[11] GPG stands for GNU Privacy Guard and is a hybrid-encryption software program. GNU is itself a recursive acronym that stands for "GNU's Not Unix", an operating system that was developed by an open source software model as opposed to Unix's proprietary model.

Road, this would allow the community to "separate itself from the virtual currency's controversial past" (Popper, 2015a, 138).[12] Yet, the existence of the Bitcoin Foundation has not been without its own controversy: Charlie Shrem was imprisoned for aiding money laundering through his exchange (Hern, 2014) and Mark Karpelès was arrested for suspected embezzlement following the collapse of Mt. Gox (Soble, 2015). The Foundation has also faced insolvency and been repeatedly accused of mismanagement (Parker, 2015).

After conducting a number of surveys amongst the Bitcoin community the Foundation eventually turned its attention to supporting the development of the Bitcoin software as opposed to its outreach programs (Higgins, 2014). Supported by donations from companies and other members these funds were redirected to pay Bitcoin Core developers who could then spend more time working on the code. Important contributors, already a tight-knit group, therefore, became financially rewarded by an external centralised institution that could potentially influence the direction of Bitcoin's code development. While this does not, in itself, prove any form of coercion, it does provide a framework for the centrality of decision-making to exist amongst different technocrats that act on behalf of the wider community. The Bitcoin Foundation has always been clear about their political motives: "[w]e believe that money supply should not be used as an instrument of monetary policy as inflation that destroys value & encourages unsustainable consumption" (Bitcoin Foundation, 2012). Further, "[w]e believe that centralization of the money supply leads to corruption & exploitation" (ibid.).

The Bitcoin Foundation came close to bankruptcy in 2015 and retracted its role as financier for Bitcoin Core (Parker, 2015; Wong, 2015). Wladimir van der Laan is now paid by the MIT Digital Currency Initiative: a research group focusing on cryptocurrency and its underlying technologies. Like the Bitcoin Foundation it raised money from companies like BitFury, Bitmain, Chain, Circle, and Nasdaq, and individuals like Jim Breyer, Jim Pallotta, Jeff Tarrant, Reid Hoffman, and Fred Wilson, to form a $900,000 USD Bitcoin developer fund (Forde, 2016). Bitcoin Core have also opened up a "sponsorship programme" to enable public donations (van Wirdum, 2016). Many Bitcoin Core developers, however, work for a variety of Bitcoin and blockchain companies as their main occupation. This is where Mike Hearn's (2015, 2016) critique of Bitcoin Core becomes a little more insidious as their relationships with companies create conflicts of interest. At the time, eight Core developers were working for, and part-owned, a company called Blockstream that develops protocols like the Lightning Network, Elements, and Liquid, designed to rest on top of blockchains to increase their efficiency and interoperability. In short, the company software is designed to better blockchains. Hearn's argument is: "the developers the Bitcoin community are trusting to shepherd the block chain (sic.) are *strongly* incentivised to ensure it

---

[12] Bitcoin has also been linked to a number of hacks where computers have been frozen and locked with encryption software only to be unlocked by the perpetrators when the victims pay a bitcoin ransom (PBS, 2015). Additionally, the hacker(s) that leaked nude photos of over 100 celebrities on the website 4chan in 2014, after infiltrating their cloud storage, asked for donations of bitcoin for their trouble (Arthur & Topping, 2014).

works poorly and never improves. So it's unsurprising that Blockstream's official position is that the block chain (sic.) should hardly change, even for simple, obvious upgrades like bigger block sizes" (Hearn, 2015).

Cryptoeconomics

There is a mechanism in the Bitcoin governance structure that, on some level, takes power away from Bitcoin Core and their possible affiliations: as changes are made to the GitHub repository, via the organisational structure outlined above, the Bitcoin Core Lead Developer will periodically release a new version of the software, reflecting the decisions made, as an update available for download. It is then up to Bitcoin miners to decide whether they wish to start running the new code: *version* forking onto the latest software or not. Such a practice means the miners can vote on implementations made by Bitcoin Core with their mining power. This section introduces the governance mechanism of forking through the lens of cryptoeconomics.

In the few months between Satoshi Nakamoto releasing the Bitcoin whitepaper and running the Bitcoin protocol, a few tweaks were made to the conceptual apparatus. One of these was the introduction of block rewards for successful miners as incentive for securing the network. This built-in system for 'minting' new coins resonates strongly with the dictums 'code is law' (Lessig, 1999) and 'protocol is power' (Galloway, 2004) because those that participate inevitably abide by the codified parameters set in place by its programmers. But, as I have begun to show through the governance structures for altering the Bitcoin code, these rules are somewhat malleable under the GitHub practices for making change. In this sense, trust in money supply is not eradicated via Bitcoin but rather redistributed into an alternative framework that remains, to some degree, centralised on an organisational level of maintenance.

A programmer at the Silicon Valley Ethereum Meet-up Group once told me that "the blockchain is truth". This, he explained, was the very point of its existence. A co-founder of a blockchain company in the same three-way conversation expanded on this point by saying that "blockchains are a thermodynamic commitment to a point of view of history". What he meant by this is that the proof-of-work mechanism utilised by blockchains expends energy (mining) to create a trusted record that people in a distributed system can reach consensus on. Before Bitcoin this was an unresolved issue in computer science known as the Byzantine Generals' Problem (Lamport et al., 1982): a dilemma that seeks an algorithm (computational or otherwise) to communicate a common agreement between multiple parties when one or more of them has the potential to be dishonest. The blockchain solves this by being a chronological cryptographic chain of transactions that form a shared ledger secured by proof-of-work mathematical mechanics thereby generating a coherent global view of the system state.

In this sense, there is "supposed to be a single blockchain, the idea being that the ledger's sequentially arranged hash-based linkages create an unbroken, monolithic record of all confirmed transactions" (Vigna & Casey, 2015, 149). There are times, however, when two miners can find the correct nonce for a new block within a few seconds of each other and both broadcast their block of transactions (nigh on) simultaneously to the network. This causes a split where miners go 'rushing off' to mine on top of two competing valid blocks. Because this form of divergence is endemic to the blockchain's mechanics I call this a *systematic* fork; this split should be quickly resolved by network mechanisms.

In the Bitcoin blockchain, systematic forks are recognised and accounted for by the protocol so that their presence is fleeting: they are temporary glitches to be resolved by the network (Waldman, 2015). The idea is that the rest of the miners on the network will begin working on the block that was broadcast to them first while keeping an eye on the other chain. Once a new block is found the miners on the shorter chain will switch their power to mining the longest chain discarding, or 'orphaning', the block they were before working on. Any transactions that were in blocks of the shorter chain will go back into the mempool (memory pool)—a list of queued transactions that have not yet been confirmed into a block. This effect occurs because miners will always trust the longest chain as it contains the most proof-of-work and is thus more difficult to undo.[13] To change the state of the network a miner would have to overtake the longest chain, which is extremely difficult because they would be competing against the accumulated power of the rest of the miners. Since the miner should be (selfishly) looking to obtain the block reward (and transaction fees) it would be more economically viable for them to find the nonce on the longest chain rather than expend power (and costs) on an impossible catch-up game while all other miners are ignoring, and thus making irrelevant, the state of the network that they are 'preaching'. This game-theoretical component of the blockchain mining process is also what protects the network because it should not be in the miner's economic interest to cheat the system:

> If a greedy attacker is able to assemble more CPU power than all the honest nodes, he would have to choose between using it to defraud people by stealing back his payments, or using it to generate new coins. He ought to find it more profitable to play by the rules, such rules that favour him with more new coins than everyone else combined, than to undermine the system and the validity of his own wealth. (Nakamoto, 2008)

Thus, Nakamoto designed a system where self-interest aligns itself with the best interest of the network: a process that has since been called cryptoeconomics (see Chapter 5). This is why when a

---

[13] Technically it is the chain with the most work that is always trusted as opposed to the longest chain due to the fact that longer chains could theoretically be made with less work done upon them. This was not taken into account by Satoshi Nakamoto's whitepaper but has since been incorporated by the Bitcoin Core developers.

transaction is made, subsequent blocks built on top of the block containing that transaction are known as confirmations; as the work to undo the chain becomes exponentially harder that transaction becomes more likely to be cemented (thus confirmed) in the 'historical record' with time. Thereby consensus is not an end product but is ever-more-closely reached with each subsequent block built on the chain. When a coffee is purchased with bitcoin a merchant may accept the transaction entering the mempool as standing whereas a car salesman selling a Ferrari may wait for six or more confirmations to be sure that the network has reached a consensus on that transaction and the coins now 'officially' belong to the garage. The mathematics of the system ensure that the probability of an attacker catching up to the rest of the network (without collusion) and changing the ledger state, thus being able to 'double spend' their bitcoins, becomes increasingly infinitesimal through time. Therefore the Bitcoin *consensus* model materialises as a codified mathematical process built into the protocol and reached via the longest chain.[14] But version forks can be much 'stickier' than systematic forks as the next section will discuss.

Version Forking: Splitting Reality

On the 12th March 2013, as the Bitcoin exchange rate reached $48.40 USD, version 0.8 of the Bitcoin Core was released. Shortly after, there was discrepancy between miners over what the latest block number was: some miners were mining on top of block 225,450 and others were mining on top of block 225,451. On this occasion the shortest chain was not being eliminated and both sides of this version fork continued to grow. In other words, there were two blockchain 'truths' about the state of the network and so consensus was not being reached amongst miners. This situation can lead to a disagreement over who owns any coins sent after the fork because different transactions will be mined into the competing blockchains. If a hard fork of this nature were not fixed then "there would essentially be two conflicting Bitcoin networks, which would be likely to result in no one trusting either of them, or Bitcoin itself" (Popper, 2015a, 193).

The Core developers got wind of this event and a race to solve the problem began. Bitcoin's Lead Developer at the time, Gavin Andresen, quickly consulted Pieter Wullie, Jeff Garzick, and Gregory Maxwell (Vigna & Casey, 2015). It became clear that the reconstituted database of version 0.8 was not reconciling with the database records of version 0.7 (ibid.). As such, version 0.8 was accepting blocks that "were not considered legitimate by the old software and the computers still running it" (Popper, 2015a, 193). If both versions had been compatible then miners using each could have continued to work somewhat harmoniously: when a miner running version 0.8, for example, mined a block and

---

14 Block rewards can only be spent by miners after 100 confirmations have been made on top of their block to account for forks and further incentivise the mining of longest chains –- dishonest nodes would not be able to spend their block rewards on shorter chains.

[Image removed for copyright purposes]

Figure 8: Soft Fork and Hard Fork by Investopedia (2018a, 2018b)

broadcast it to the network the version 0.7 nodes would have accepted it as legitimate, whereas the 0.8 nodes would ignore any blocks created by the 0.7 miners. This form of version forking is described as *soft* because the new rules implemented by the upgraded software is backward-compatible (follows old and new rules) with the previous version—0.7 miners can come slowly over to the new software without causing a permanent split in the network or the majority of miners can decide to stick with the old rules by staying on 0.7. The miners can quite literally vote on soft forks with their power by upgrading to the new software or not. The majority of hashing power is supposed to decide which version wins out. In this circumstance, however, the 0.7 nodes began rejecting the blocks from the miners who had switched over to the 0.8 version because they were not playing by the original codified rules (the new software was not backward-compatible). This is known as a *hard* fork because the split 'sticks' and two competing blockchains are formed (see Figure 8).

It was decided by the Core developers first to the scene that one of the versions must be accepted as the true blockchain and that all miners must be convinced to move to that chain. The largest mining pools (see Chapter 5) had been the first to switch to the new software and they agreed to revert back to the 0.7 version giving up any coins they had mined for themselves as block rewards for the version 0.8 side of the fork. However, because the Bitcoin exchange rate floats on the market its value is derived from trust in the protocol (demand based on buy and sell orders) so the losses would have been "much greater if the entire Bitcoin network lost the confidence of users" (Popper, 2015a, 194). This game-theoretical market mechanism is what keeps all stakeholders interested in perpetuating the blockchain's functional existence to the benefit of everyone involved. Yet, this event proves that the orchestration and coordination of certain practices, particularly in a crisis, must be channelled through a centralised group of programmers in order for important decisions to be made—a very similar process to solving problems and settling disputes in the apparently decentralised Wikipedia (Tkacz, 2015).

The response to, and successful resolution of, this fork is extremely telling of the centralised modes of maintenance for Bitcoin, as eloquently recognised by Ethan Buchman of Eris Industries during the Blockchain Global Impact conference at Stanford University in March 2015. Buchman's sobering synopsis stood out amongst panels that largely championed Bitcoin and blockchain technology as the ultimate decentralising phenomena:

> I refuse to take a consistent stance on anything in the space because it is still too young. Bitcoin is not just a protocol—a lot of people think it's this holy grail of decentralisation and maybe it is in theory. And maybe it was back in 2010 when there were only a dozen users. But now it's different. It's a set of computers running a suite of ever evolving implementations of a relatively stable, but kind of buggy, specification (i.e. the Bitcoin protocol). This protocol makes no accommodation of what is actually true in the real world; it doesn't care about any reality of history. It only cares about who's wasting the most electricity. And the source code for the most widely used implementation is updated via a voting procedure, which is participated in by a very small number of individuals and is secured by a reputation based security model made by a successor of a second successor of the protocols inventor, Satoshi. It's essentially controlled by three dudes, which is kind of scary but kind of important because when Bitcoin forked in 2013 thank God there were few enough of them to get on Skype and sort it out. If it was truly a decentralised protocol then it would have been harder to fix. So Bitcoin is centralised.

This excerpt explains how the technical functions of the Bitcoin network (and therefore monetary policy) are not set in stone but are constantly evolving thanks to a structured methodology for proposing (Core programmers) and voting on (miners) change. Version forking, therefore, demonstrates a senate-like structure of Bitcoin governance: everyday users of the protocol have no say, contributors suggest changes, the Bitcoin Lead Developer (and those with commit access that the Lead Developer can revoke) authorises changes, and miners vote on those decisions (see Table 4). In this sense decision-making in Bitcoin Core is not distributed amongst users but rather runs through a structured hierarchy with clearly defined parameters where the Bitcoin Core Lead Developer stands out as an obligatory passage point. Once code changes have been filtered through this bottleneck,

Group	Senate Equivalent	Level of Power
Bitcoin Lead Developer (and those given commit access)	Consuls	Initiate change
Bitcoin miners	Senators	Vote on change
Bitcoin Core developers	The assembly	Suggest/call for change
Everyday users	Plebeians	No say

Table 4: A representation of the power structure of decision making for implementing changes to the Bitcoin protocol

decentralisation is achieved on the other side through a new form of democracy where miners vote on whether to implement them or not—although even miners are being redirected into their own centralisation funnels (see Chapter 5).

As it stands the process of decision-making is not a realisation of decentralist ideologies, rather it perpetuates an uneven distribution of power in the network.[15] As Vitalik Buterin (2013a), inventor of Ethereum, said at the time:

> Bitcoin is clearly not at all the direct democracy that many of its early adherents imagined, and, some worry, if a centralized core of the Bitcoin community is powerful enough to successfully undertake these emergency measures to set right the Bitcoin blockchain, what else is it powerful enough to do? Force double spends to reverse million-dollar thefts? Block or even redirect transactions known to originate from Silk Road? Perhaps even modify Bitcoin's sacred 21 million currency supply limit?[16]

But here, a degree of centralisation seems imperative for making (important) decisions. So this suggests that completely distributed governance is a practical impossibility and would theoretically be a liability subject to failure at times of crisis.

Copycat Cryptocurrencies

The success of Bitcoin has led to a cascade of copycat cryptocurrencies called altcoins (alternative coins). Because Bitcoin development follows an open source model, its source code is readily available

---

[15] To adapt a phrase taken from George Orwell's *Animal Farm*: All developers are equal, but some are more equal than others.

[16] Ironically, Buterin later did "[f]orce double spends to reverse million-dollar thefts" as the Lead Developer of Ethereum (see Chapter 7).

online and can quite literally be copy-and-pasted onto different machines to form new cryptocurrencies. Dissent, then, comes by another type of forking away from these funnelled forms of decision-making allowing disenfranchised members of the community to break away taking the open and unowned intellectual property with them to create new competing organisations. I refer to this as *organisational* forking because part of the community breaks away to cultivate a different project. Such a process, as discussed by Tkacz (2015), is the bedrock of open source politics: anyone can take the source code to start their own ventures.[17] Organisational forking is therefore the reason that altcoins often carry different characteristics to Bitcoin. For example, Litecoin (often referred to as the silver to Bitcoin's gold) has a lower block rate of around 2.5 minutes (as opposed to Bitcoin's 10 minutes) allowing it to facilitate more transactions in a given amount of time. Litecoin was also designed to improve upon Bitcoin by running on a different hashing algorithm called scrypt that technically makes mining less energy intensive by favouring high-speed RAM for hash generation as opposed to raw CPU power. This *theoretically* changes the cryptoeconomic framework of the cryptocurrency because daisy-chaining application-specific integrated circuit (ASIC) mining chips together (Taylor, 2013), in order to boost CPU power and scale up the productivity of mining rewards, becomes a fruitless technique (see Chapter 5).

In essence, this makes Litecoin a greener cryptocurrency: a common critique of Bitcoin is the amount of electricity that is by default needed, or as critics say, 'wasted', in order for it to function (Buterin, 2012a; Limer, 2013; Malmo, 2017; Hern, 2018). Requiring high-powered forms of RAM technically makes the mining process more akin to one CPU per vote (originally outlined in Satoshi Nakamoto's whitepaper) and gives less room for a Litecoin mining arms race thereby reducing the amount of energy needed to secure the network.[18] Elsewhere, developers have used different proof mechanisms such as proof-of-stake (NXT and Peercoin) and proof-of-space/capacity (SpaceMint and Burstcoin) to secure cryptocurrencies in order to bypass the energy-intensive limitations that they see in Bitcoin's proof-of-work system. Such a multiplicity of political, technical, and economic discrepancies between cryptocurrencies has led to the generation of over 1200 different altcoins to date. Each has their own vision on how the parameters of digital currencies/ledgers should be programmed and so blockchains are being (re)designed to cater for a plethora of worldviews (see Chapter 7). This practice shows how any disgruntlement in Bitcoin's open source development can ultimately be overcome via organisational forking as a last resort (Tkacz, 2015). However, unlike the governance contours of Wikipedia that Tkacz lays out, blockchains also allow for a more internal break from the rules as the last section will discuss.

---

[17] In fact, one-third of projects on GitHub are copies (Mackenzie, 2018).

[18] However, companies like Alpha Technology have since designed ASICs for scrypt hashing so that a similar pattern of scaling is reproduced for Litecoin mining (Southurst, 2014a).

Bitcoin Cash

The senatorial governance of code production outlined above is internal to the Bitcoin Core client built on GitHub. However, other clients can be constructed to connect to the Bitcoin network: as long as they are compatible with the clients of other nodes they will not fork and can mine the same blockchain.[19] Different clients are usually used for technical reasons. For example, bitcoind is the second Bitcoin client in the network's history and provides a command line-based daemon that replaces a graphical user interface (GUI) with JSON-RPC: its application programming interface (API) is useful for integrating with third party software and payment systems.[20] Since bitcoind was built as part of Bitcoin Core, it has since been bundled in with later versions. MultiBit, and other 'thin' clients, have been designed so that users can interact with the network without having to download the whole blockchain (174.74 GB at time of writing). However, new clients can also be used as a political tool providing a platform for generating an intentional hard version fork: 'hijacking' part of the network from Bitcoin Core and redirecting it onto a new chain that follows new rules. This subverts the singular obligatory passage point of the Bitcoin Core Lead Developer by creating alternative bottlenecks of code production. Although power is still funnelled through the permitters of organisational practice in these other open source software channels, it allows different groups of programmers to compete for 'the same' protocol: a multitude of senates.

This was personified by a recent culmination (but by no means conclusion) of the Bitcoin block size debate when a user activated hard fork was instigated by the group Bitcoin ABC (Adjustable Blocksize Cap) creating the 'altcoin' Bitcoin Cash—this group's code development is also managed via a senatorial governance structure on GitHub. The block size debate had ensued for a number of years and the two camps were coming to a breaking point. It had been made clear by the Core developers for some time that they saw Bitcoin as a settlement layer (Torpey, 2016). By 2017 the amount of transactions being processed on the Bitcoin network had far surpassed its capability resulting in transaction queues in the mempool (some transactions would take up to 10 hours). This gave rise to a bidding war over miner fees because users were willing to pay more to have their transactions included in a block more quickly. In conjunction with the rising price of bitcoins, the cost for sending units rose to around $3 USD per transaction. The constricted codified parameters (or monetary policy) effected the way in which bitcoin transactions were imagined and practised: low block sizes favoured those who saw Bitcoin as a digital investment as opposed to a transactional currency because high costs meant it

---

[19] Bitcoin Core is what Ethan Buchman was referring to in the quotation above when he said "the source code for *the most widely used implementation* is updated via a voting procedure" (my emphasis). This section shows that other implementations can be introduced to connect to the network for different technical and political reasons.

[20] "Beyond the reference client (bitcoind), other clients and libraries can be used to interact with the bitcoin network and data structures. These are implemented in a variety of programming languages, offering programmers native interfaces in their own language" (Antonopoulos, 2014, 56).

could no longer be used to buy everyday items (Popper, 2017; Wong, 2017b). The Bitcoin Core programmers stayed reluctant to increase the block size and instead offered a consensus layer called segregated witness (SegWit) that would split up transaction data and store segments of it in a separate structure to reduce the size of each transaction. The implementation of this change was to be facilitated by a soft fork.

This 'solution', however, did not satisfy those who wanted a higher block limit like libertarian and ex-member of the Bitcoin Foundation, Roger Ver. As an extremely vocal early Bitcoin proponent, Ver has been nicknamed 'Bitcoin Jesus'. His view is made clear by a post on Twitter in 2017: "[s]ince Bitcoin Core is no longer usable as a currency, we should no longer consider it to be a crypto currency". It was this line of thinking that has given rise to competing clients built by programmers who look to wrench control away from Bitcoin Core. These groups include Bitcoin XT, Bitcoin Classic, and Bitcoin Unlimited. The most successful of these ventures has been Bitcoin ABC revealed by Lead Developer Amaury Sechét at the Future of Bitcoin conference in June-July 2017. The client had started being developed earlier that year as an experimental platform and Sechét was later approached by Chinese mining company Bitmain who proposed implementing a 'user activated hard fork' which they would support with their mining power (van Wirdrum, 2017). This meant that Bitcoin ABC would set in place new rules for the Bitcoin blockchain—calling the fork Bitcoin Cash—raising the block size from 1 MB to 8 MB and Bitmain would start mining by the client's new rules accepting those blocks as valid. The plan was initiated on the 1st August 2017 splitting the blockchain in two—block 478588 being the last common block between the two chains. Because both chains share a common history, those who had already possessed an amount of bitcoin found themselves the owners of an equal amount of bitcoin cash after the hard fork. As miners joined the Bitcoin Cash chain to support the political bifurcation the chain 'stuck' in place and a 'permanent' schism was made.[21]

Other forks have since followed such as Bitcoin Gold, Bitcoin Diamond, UnitedBitcoin, BitcoinX, and Super Bitcoin. This resembles more of a blocktree than a blockchain with different programmers governing the software of each branch. In this model blockchains become discretionary as opposed to anti-discretionary where version forks, or branches, are not temporary glitches but a vehicle for disagreement and the fragmentation of communities that may never realign (Waldman, 2015). This is akin to the historical partings of communities like the Catholic and Orthodox churches (ibid.). In this sense, the politics of Bitcoin is not necessarily set in stone, as suggested by David Golumbia (2015, 2016b) in the previous chapter, but certain technical parameters can be changed to fit an evolving culture/economy. Additionally, there can be multiple governing bodies, and obligatory passage points of code development on different branches of a blockchain/tree.

---

21 At the time of writing miners often swap between Bitcoin and Bitcoin Cash depending on which is more profitable at the time.

Conclusion

Bitcoin is supposed to condense all of the centralised bits and pieces of global monetary systems into a distributed algorithm. The aim is to democratise the control of money and flatten its spatial unevenness in terms of services and wealth concentration. Yet, at the start of this chapter I asked the question: where does power to influence or govern Bitcoin lie? I have since traced out, through an ethnographic account of online environments and a number of case studies, the governors of the Bitcoin software and the contours of power that materialise within their networks. This has teased out the underlying nuanced politics present in Bitcoin's geographies of production. The changing culture of the programmers that weave Bitcoin's vast algorithmic fabric together affect the technical parameters of its infrastructure. Ultimately, this illuminates emerging online spatial centres in Bitcoin's networked geography 'from' and 'around' which certain aspects of its architecture are organised—no matter where the contributors of the project are situated in terms of topographical co-ordinates. This acts as a starting point for critiquing decentralisation that, like its terminological cousin openness, can often be "bereft of content" (Tkacz, 2015, 35). I have shown how there are limits to algorithmic decentralisation for the simple reason that algorithms must be made and maintained by people through space and therefore coordination must take place between its builders. This clearly demonstrates that while geographies of production for Bitcoin may be spatially dispersed, upon closer inspection, its connections run through specific channels.

The Bitcoin Core Lead Developer is enrolled into a network as an obligatory passage point for developing code (Callon, 1986). The version control architecture of GitHub, supported by a heterogeneous network of servers, employers, and code—all with their own hierarchal bottlenecks—is such that it places Wladimir van der Laan in a significant role of power. Edits proposed by contributors must go through a screening process conducted by an elite set of programmers who are closest to the Lead Developer but only the person in this role, and a select few who have been granted commit access, can authorise changes to the Bitcoin code directly. Far from a decentralised consensus mechanism, GitHub senatorial governance, personified by the block size debate, resembles a technocratic meritocracy where decision-making is currently repressed by conflict and only one central figure has the ultimate power over resolution and change-making. While the open source model certainly differs from that of closed proprietary software, organisational practices ensure that code production is a tightly controlled spectacle.

If space is the concoction of connected and disconnected trajectories that are constantly in a state of becoming (Massey, 2005), then Bitcoin can be said to be spatially (de)centralised where centralisation represents the 'connected' enrolment of trajectories through controlled funnels and distribution represents those that do not have to pass through a singular point. Following the connections within the Bitcoin governance structure illuminates that political action must be taken via another centralised decision model (i.e. Bitcoin Cash) when voices are not heard by a client's Lead Developer. Tracing these networks is extremely important for disrupting imaginations of ad-hocracy in open modes of code development. GitHub acts like a spatial cable tie that gathers and coordinates loose ends. Through the bottlenecks of code repository certain actors are enrolled as obligatory passage points through which decisions must pass. This works to critique algorithmic decentralisation as labour must be coordinated and operationally centralised in order to build code. Of course, this is necessary for the same reason that there are centralised moderators in the 'open' and 'decentralised' model of Wikipedia governance to stop people changing content without review. In the case of Bitcoin, centralisation prevents programmers (miscreants or collaborators) altering the Bitcoin source code whenever they want to. The imaginary of Bitcoin as a tool for breaking down centralised modes of governance for monetary creation/regulation therefore falls short in practice.

The money/code/space of Bitcoin's production shows that no matter how distributed its network is, (in terms of the layout and number of nodes) its governance is highly centralised. This centralised governance also effects the networked architecture of the protocol itself so that competing cultural groups can influence the technical parameters of Bitcoin. For example, decisions to increase the block size make the scaling of mining operations easier, which allows for an increased oligopoly of large mining firms as opposed to dispersed small scale participants. In turn, this gives certain (larger) miners more power on voting for decisions. While the ideology of decentralisation is to promote systems that cannot be coerced, the necessity for decisions to be coordinated through centralised channels limits this effect. In the case of Bitcoin, the power structure of the Bitcoin GitHub community acts as a knowledge funnel that allows ideas from programmers to be channelled into discourse that can then be actioned into the code by the Core Developers. My intent is not to paint open source software models as completely impotent: they remain incredibly productive environments for solving problems in code development. And with a multiplication of senatorial bodies (clients) Bitcoin governance is certainly (de)centralised, particularly in comparison to the monetary policy of nation states. But centralisation does not disappear. While open source allows for the absorption of many, dispersed brains into the project, voices are heard or ignored by those enrolled at 'the top' of its power structure: to make change contributors are obligated to pass through a passage point or make their own.

Senatorial governance is a key driving force behind Bitcoin's money/code/space as it is the underlying framework for change. Instead of one central bank, the open network allows anyone to build a client with code and plug in to it. To influence its technical parameters (monetary policy), however, this new client must reflect the updated rules in its code (achieved through centralised version control politics) that must be adopted by the networks miners. The next chapter follows the material infrastructures that run the Bitcoin code, to examine how algorithmic decentralisation is further predicated on centralised components.

Chapter 5
Grounding Cryptocurrencies: The Digital-Material Architecture of Bitcoin

Introduction

Bitcoin strives to achieve decentralisation via a carefully crafted algorithmic architecture that works to reach a singular network consensus maintained by a ledger that remains distributed through space. Such a reliance on digital networks can conjure up the fetishised semblance that Bitcoin (and other blockchains) exist in an intangible and ethereal dimension, similar to the imaginary of 'cyberspace' in the 1990s. This chapter is dedicated to dismantling that illusion. Here, I ground the Bitcoin code within its material architecture, that is computer hardware and telecommunications infrastructure (as well as the humans and institutions that manage them), to understand how its protocological transactions facilitate new geographies of value exchange that 'move' across space in a neoteric fashion. This is done by following a singular unit of bitcoin in a 'cross-border' transaction 'from' Australia 'to' the United States. More than anywhere else in this thesis it is important to remember here that Bitcoin (as a software protocol) is one thing and *a* bitcoin (as a unit of 'currency') is another. This is why Bitcoin is often described as both a payment network and a form of money: the Bitcoin software is a system that allows the spending of bitcoin currency units within its parameters/protocol. At the same time, Bitcoin and bitcoins are inextricable; the functionality of one depends on the functionality of the other. Currency units rely on the protocol to administrate them and the protocol relies on the currency units through the codified economic incentive of cryptoeconomics to keep the payment system running (see Chapter 4).

Cryptography obscures the identity of those involved by a Bitcoin transaction and so I decided to follow a bitcoin sent from one of my own Bitcoin wallets to another one in my control to make clearer the coin's 'movement'.[1] This involved following information (a bitcoin) through a relatively fluid algorithmic architecture (Bitcoin software) across a relatively static infrastructure made up of computers, wires, cables, sockets, wifi routers, servers, relaying stations, electricity, and mining chips scattered across the world (the Internet). In doing so, the money/code/space of the Bitcoin software-hardware/architecture-infrastructure is partially (and materially) mapped out, thereby illuminating many

---

[1] An alternative metaphor that could be used is shining light down two ends of a tunnel to see what lies in the middle.

of the human and non-human actors that enrolled to support the network. Throughout, the ways in which material hardware connects through centralised points forms a basis for critiquing Bitcoin's algorithmic decentralisation: while the 'abstract' logic of the Bitcoin code certainly emanates distribution, its execution must always operate physically through mediating infrastructures such as circuitry and fibre optic cables that intersect to form unique spatial patterns in actor-networks.[2] This is because information is always formed, first and foremost, through material 'carriers' (Blanchette, 2011), and so points of centralisation necessarily appear where infrastructures are concentrated and coalesce. In other words data is material-semiotic and is often channeled through centralised infrastructural bottlenecks for efficiency. These points are often controlled by private companies who are enrolled as gatekeepers to obligatory passage points.

To "study a technological project, one must constantly move from signs to things, and vice versa" (Latour, 1996, 80). This is particularly true for software that must be closely read as both material and text (Mackenzie, 2006): it "is a tangle, a knot, which ties together the physical and the ephemeral, the material and the ethereal, into a multi-linear ensemble that can be controlled and directed" (Berry, 2011, 3). It is to untangle the knot that I delve into the active code of the network to unpack Bitcoin's materiality. This is to understand code as having a double function: it simultaneously executes a mechanical process and relays the mechanical process in a readable format to the human reader-writer (Mateas & Montfort, 2005). Software, then, is always mechanical *and* symbolic, material *and* semiotic. Paying closer attention to the material backbone that stitches infrastructures together as well as the code structure of software, this critical analysis of Bitcoin navigates, deconstructs, and reflects on its underpinning structures: linking immaterial flows back to geographies, jurisdictions, nationhood, and material objects (Herregraven, 2014; Kubrak, 2015). In doing so, the material enactment of code is used to critique spatial limitations of algorithmic decentralisation.[3]

I begin by outlining how the conceptual, material, and spatial grounds from which I attempt to trace out the digital cryptographic system of Bitcoin. Pursuing the network geography of a bitcoin, I first highlight difficulties and tensions that arise when approaching the "socio-spatial materialities" of software (Ash et al., 2016, 14). This leads into a more concrete explanation of Bitcoin—how it exists in digital wallets and how these wallets are, in turn, supported by nodes composed of material components inside computers. The distributed architecture through which these computers communicate is then articulated before the centralised company that executes my Bitcoin transaction is explored. The way in which information travels from my laptop through the material infrastructure of

---

2 This is not to say that logic itself is not (re)crafted through material processes that must involve brains, diagrams, paper, computation, etc.

3 Recognising the functional materiality of (digital) infrastructural networks in this way has elsewhere been described as understanding the muscle of the global economy (Herregraven, 2014).

the Internet is described with the help of third party software and a knowledge of technical systems. This detail provides a basis for understanding how a Bitcoin node, operating code, initiates and broadcasts a transaction to the rest of the network, releasing my coin from the address to which it is encumbered. Cryptographic hashes are dissected and I demonstrate how they, as mathematical scripts performed by machines, allow my coin to become mined into a block of the Bitcoin blockchain thus becoming a permanent entry in an algorithmic ledger across a network of computers. The modes of centralisation that are illuminated by following the Bitcoin code through its material network are then elaborated upon to show how the functionality of the protocol is modulated into different segments that can, to a degree, be controlled. These segments, or obligatory passage points, demonstrate material limits to algorithmic decentralisation.

Tracing Crypto/Space

Following software is a difficult proposition because it appears to exist 'behind' screens. It is, then, with a degree of experimentation that new methodologies can be fashioned in order to explore the darker spaces of infrastructure: Brett Neilson (2016a) calls such innovations methodological, analytical, and political necessities. Ash et al. (2016) "encourage geographers to adopt and embrace an epistemological, ontological, and methodological openness in their engagements with the digital" (14). This recognises there is ample room to "invent some new methods that can address the distinctive qualities of digital cultural production: its mutability, its multimediality, its massiveness and in particular the uneven spatial dynamics of its interfacial, frictional networking" (Rose 2016, 346). With this in mind I embark on following a bitcoin across space (a parallel to this endeavour is drawn in Appendix 12, where I describe the workings of a more traditional cross-border payment from Sydney to San Francisco).[4]

In following a digital thing I immediately and inevitably encountered a problem: what is it exactly that I was attempting to follow? A bitcoin, after all, cannot be picked up, dropped, or broken. How, then, can I observe the trajectory of something that appears to have no real form of matter that would make it susceptible to touch or visible to the eye? The answer relies on navigating the digital-material architecture of the protocol (Galloway, 2004). In this way, what Bitcoin (software) and a bitcoin (currency unit) actually are, existentially, becomes clearer the deeper I dive.

The "material architecture which underpins the digital revolution is commonly referred to in terms which postulate only the most tenuous of connections to the hardware layer of contemporary digital ecosystems" (Taffel, 2016, 122). Information communication technology succumbs to a fetishisation of

---

[4] In many ways this chapter most resembles traditional follow the thing work to date as it involves 'literally' following a specific 'thing' through part of its life—although it is fairly safe to say that 'traversing through' a digital, decentralised, and cryptographic network most likely makes it the most obscure in comparison to existing examples of such research.

the information over the technology, the media over the medium. As many scholars have pointed out (see Chapter 3), this, more often than not, creates a fallacious ontological disjuncture that reinforces Cartesian dualisms allowing for the separation of opposing realms such as body/mind, physical/digital, material/immaterial, hardware/software, medium/media, real/abstract, actual/virtual, and spatial/aspatial (Graham, 1998; Kinsley, 2013a, 2013b; Ash et al., 2016).

I maintain the stickiness of binaries should never be overlooked as there is a tendency for humans to define things through opposition and differing (Derrida, 1967)—even those that are dedicated to obliterating dualisms seem to do so in their polarising yet persistent terms (for example, centralisation and decentralisation). However, there is much more entanglement and tension at stake in binaries than Cartesian thought allows for: a connection and an interplay at the same time as separation and distance.[5] Ontological schisms between alternate spheres neglect to acknowledge how humans are always already caught up in the fabric of the world (Merleau-Ponty, 1963). It is for this reason Tim Ingold (2000) calls the Cartesian framework "the single underlying fault upon which the entire edifice of Western thought and science has been built" (1). Developing a more complex, hybridised, and material account of society has been a key driving force behind academic scholarship over the last forty years (Latour & Woolgar, 1979; Haraway, 1991; Latour, 1987, 1993, 1999; Thrift, 2008; Anderson & Harrison, 2010). What has often come across is how polarising binaries previously presented as existing in detached environments are actually "enlaced and intertwined, in a 'being-in-the-world' that precedes and preconditions rationality and objectivity" (Wylie, 2007, 3). It is along similar lines that scholars have battled against vacuous representations of the digital and pushed to generate a more spatial and material lexicon (Graham, 1998; Bontems et al., 2008; Aoyama et al., 2004; Knoespel & Zhu, 2008; Blanchette, 2011).

To study a 'thing', in this case a bitcoin, is always to examine "an infinite regress of relationships" (Bateson, 1972, 249). Digital information (whether a news article, video game, tweet, database, bitcoin, or otherwise) is no different: "computer code creates relationships among multiple symbolic systems, those necessary to move the cogs of the machine, and those necessary for those operations of the machine to be situated within language, and thus, social order" (Blanchette, 2011, 1045). The order and stability of digital things, then, is achieved heterogeneously. It is the task of this thesis, understanding centralisation as the enrolment of networked practices through specific spaces/entities, to trace out the limits of algorithmic decentralisation in multifarious arrangements. Sy Taffel (2012, 2015b) has used the idea of digital materiality to follow the life cycle of the components that make up computers to uncover the environmental costs of their production. I use the material as an analytical technique to dive into the functional processes of those components to understand how they

[5] This concept of tension between binaries—a nearness of the fictional and functional, falsity and truth, virtual and actual, immaterial and material, without them fusing completely—is drawn from John Wylie's (2007, 2010) work on landscapes.

support the existence of Bitcoin/bitcoins. In following a bitcoin "backstage" (Goffman, 1959) into the infrastructural messiness of cryptospaces I uncover where certain trajectories congeal. In doing so, "questions are asked around the complexity, and indeterminacy, of matter and about how qualities of liveliness are internal to, rather than in supplement or opposition to, the taking place of matter and materiality" (Anderson & Wiley, 2009, 319).[6]

The enormity of the network geography and material infrastructures that underpin Bitcoin means I cannot form a literal, physical presence among all its pieces; yet the same logic of association and connection of *following* defines my ethnographic enquiry (Marcus, 1995). The protocol itself leaves digital breadcrumbs that can be traced via its blockchain (an open database) whereas third party software can be used to monitor in more detail this network activity. I used these breadcrumbs to follow my transaction as it became solidified in a block that was propagated across the network. Downloading Bitcoin Core allowed me to become a fully fledged participant in the algorithmic fabric of Bitcoin by filling up nearly 180 GB (at the time of writing) of my hard drive with the very 'substance' of the blockchain. Doing so allowed the blockchain downloaded onto my hard drive to become a research tool that could be excavated.

Inside Bitcoin Wallets

To follow a bitcoin, I needed some to transact. So how does one store a digital unit of cryptocurrency? First, I needed a 'wallet' for bitcoin to be assigned to and, in the absence of mining or trading goods or services, I needed to pay someone fiat currency in exchange for it. A Bitcoin wallet is composed of a cryptographically linked public and private key—two unique strings of letters and numbers—the first is used as a receiver for incoming bitcoin transactions and the second acts as a signature for authorising the spending of money from that address. So a Bitcoin wallet is not synonymous to a public key but rather contains a public key. In other words, the wallet is the entire structure that contains a private key, public key, and address—the address being the unique identifier for the whole wallet:

> A bitcoin wallet contains a collection of key pairs, each consisting of a private key and a public key. The private key (k) is a number, usually picked at random. From the private key, we use elliptic curve multiplication, a one-way cryptographic function, to generate a public key (K). From the public key (K), we use a one-way cryptographic hash function to generate a bitcoin address (A)…The relationship between private key, public key and bitcoin address is shown [in Figure 9]. (Antonopoulos, 2014, 63)

[6] "Recent work has disclosed an excess of different materialities: ghosts, dance therapies, footpaths, pained bodies, pain, trance music, reindeers, plants, boredom, fat, anxieties, vampires, cars, enchantment, nanotechnologies, water voles, GM Foods, landscapes, drugs, money, racialised bodies, political demonstrations" (Anderson et al., 2006, 13).

[Image removed for copyright purposes]

Figure 9: The cryptographic relationship between private key, public key, and Bitcoin address in a Bitcoin wallet (Antonopoulos, 2014)

The private key should only be known by the owner(s) of the wallet so only they can sign off on the release, and thereby spending, of funds. Managing cryptographic keys requires specific coding expertise and so third party wallet providers have created business models based on administrating wallets on their customer's behalf, handling the technical part of the process. In other words customers trust these companies with their funds to overcome the technical barriers to entering the Bitcoin market (possessing and transacting bitcoin).

I began using Bitcoin as a personal means for making global monetary transactions following an international banking fiasco that occurred when I first landed in San Francisco to undertake my ethnographic research (see Appendix 12). As such, Bitcoin wallet services became a trusted channel for sending money 'overseas'. One such wallet service provider is the joint wallet and exchange company Coinjar who accept Bpay deposits from Australian bank accounts. Coinjar acts as the gateway between my bitcoin and Australian dollar transactions thanks to its built-in exchange that allows me to trade one for the other on demand as opposed to selling and buying bitcoin with individuals on open market exchanges such as Bitstamp. Using the my bank's application on my smartphone I sent Coinjar $400 AUD using the Australian Bpay system and waited for the transaction to be confirmed (see Figure 10).[7] Once Coinjar had authorised the transaction I was attributed a credit of $400 AUD in my Cash Account in a similar manner that a bank would display a balance of fiat currency (see Figure 11). I then exchanged this Australian dollar balance for bitcoin at a rate of 1 BTC for $354.66 AUD and the value appeared on my Everyday Bitcoin balance. This meant that Coinjar had given me access to a certain amount of bitcoin that they control in the same way my bank gives me access to an amount of Australian dollars they control as reflected by my bank account balance—both institutions show me a balance and authorise the movement of funds when I give (or, rather, ask for their) permission to do so. It is for this reason that many in the Bitcoin community refer to wallet services as "Bitcoin banks".

[7] This transaction alone is a function heavily reliant on a plethora of sociotechnical actors and material architectures required to facilitate the transfer of funds. One only has to imagine the office floors, administrators, Internet service providers, computers, servers, cables, papers, office chairs, and the components of other third party companies for the Bpay transaction to be conducted.

[Image removed for copyright purposes]

Figure 10: My Bpay transaction to Coinjar and a pending deposit message

[Image removed for copyright purposes]

Figure 11: Authorisation of 400 AUD deposit credited to my Coinjar account

[Image removed for copyright purposes]

Figure 12: Reviewing an outgoing Bitcoin transaction from my Coinjar account

[Image removed for copyright purposes]

Figure 13: Incoming transaction from my Coinbase account

With $400 AUD worth of bitcoin (1.12783914 BTC) now under my, or more accurately Coinjar's, control, I was able to send it to other wallets. I also established another account with a Bitcoin wallet service called Coinbase who are based in the United States. Coinbase allows me to sell bitcoin for US dollars that will be deposited in my Wells Fargo bank account. This provides a fluid way of transferring money across borders because my Coinjar wallet is connected to my Australian bank account whereas my Coinbase wallet is connected to my American bank account. I can therefore send bitcoin from my Coinjar wallet to my Coinbase wallet and sell it for US dollars on the 'other side'.[8] To facilitate this transaction I signed into the Coinjar website, clicked on the payments tab, selected the account that I

[8] I could, of course, sell this bitcoin for cash on the street but these third party wallets with built-in exchanges provide me with a streamlined system for such a process and the vast majority of transactions conducted on the Bitcoin network use centralised institutions like this.

wanted to send money from (my Coinjar Bitcoin wallet), typed in the recipient Bitcoin address (the Coinbase Bitcoin wallet 13oqZGuUNkGqY6tquFBVghgFcPi3JjPJG), and disclosed the amount of bitcoins to send. I then reviewed this transaction and clicked the 'Pay now' button (see Figure 12). The bitcoin value was 'debited' from my Coinjar wallet and 'credited' to my Coinbase wallet (see Figure 13).[9] In this case I sent 1 BTC but I could have sent fractions of this if I so wanted (provided there was enough for a mining transaction fee).

On the surface this seems like a simple mathematical subtraction from my Coinjar address and an addition to my Coinbase address of 1 BTC: an uncomplicated change of numbers between accounts. This simple sum relies on a host of sociotechnical actors and assemblages that bring the transaction into being as a financial reality. Backstage, all out of view yet in concert, untold actors are swimming beneath the surface and a multitude of hybrid strings are being pulled to weave together the complex spatial fabric of this single bitcoin transaction. But where does the bitcoin in my Coinjar wallet actually exist? Where is the balance in the wallet 13oqZGuUNkGqY6tquFBVghgFcPi3JjPJG actually being stored? The short answer is on the Bitcoin blockchain, but this simple fact encompasses a "skein" of material-semiotic complexity (Latour, 1993).

Into Black Boxes

Every value of bitcoin exists on each copy (or node) of the blockchain, cryptographically locked in place waiting for its owner to spend that amount with their private key by creating a script (a program that executes a task). The script unlocks these values from their public key and locks them to another public key in the process. Every node will then update periodically and 'simultaneously' to reflect any alterations made to balances on a global scale.[10] So, how does the blockchain exist on one of these nodes? My own copy of the Bitcoin blockchain 'lives' on my laptop in the location MacOS: ~/Library/

[Image removed for copyright purposes]

Figure 14: The Bitcoin-Qt client software on my Mac dashboard

[9] At this point the transaction had 0 confirmation because subsequent blocks in the blockchain had not yet been built on top of it.

[10] It is actually more of a ripple effect than a simultaneous update, which will become clear as the chapter develops.

ApplicationSupport/Bitcoin/blocks (see Figure 14). This node is an active participant in the maintenance of the Bitcoin ledger, propagating transactions and updating its state to maintain a publicly distributed consensus.

More specifically, all this activity is being conducted on silicon chips where digital information is stored as electrical impulses. So what 'breaths life' into the apparently 'deadened' materials of my computer? The answer is the arrangement of tiny channels that are etched into integrated circuits that organise electricity in a manner that can represent (and perform) data. This is poetically put in *The Pattern on the Stone*, a book written by microchip designer W. Daniel Hillis (1998):

> I etch a pattern of geometric shapes onto a stone. To the uninitiated, the shapes look mysterious and complex, but I know that when arranged correctly they will give the stone a special power, enabling it to respond to incantations in a language no human being has ever spoken. I will ask the stone questions in this language, and it will answer by showing me a vision: a world created by my spell, a world imagined by the pattern on the stone. (Hillis, 19998, VII)

Despite its intentional allusions to fantasy, this is a strangely accurate description of the performative operations of silicon chips inside computers. My MacBook Air contains four Toshiba 128 GB Solid-State Drive (SSD) silicon chips, which is where my version of the blockchain is stored and enacted (see Figure 15). Each chip is composed of thousands upon thousands of minute silicon 'wires' that interconnect in certain arrangements to create minute logic gates (see Figure 16). Each gate acts like an electronic valve that allows or disallows electricity to flow depending on the inputs of electricity it receives.

Computer scientists abstract these signals into an 'on' or an 'off' which are represented as 1s and 0s respectively so that they can be mathematically manipulated through computation. This binary code, however, only really ever represents the presence or absence of electricity on a wire: these signals and non-signals are referred to in computer science as 'bits' that are "both logical and material entities" (Blanchette, 2011, 1042). Bits "move up from their grounding as signals in some physical media (fiber optic, magnetic drive, electrical wires) to binary information organized according to units defined by each layer (file, datagram, etc.)" (Blanchette, 2011, 1046). This is done via a process called functional abstraction: the geometric patterns formed by grouping logic gates together can be cumulatively built upon to represent data with the flows of electrons that run around electrical circuits. Eventually, through the 'software stack', electronic impulses can be functionally abstracted to form computer programming languages (code). Alexander Galloway (2006) describes the relationship

[Image removed for copyright purposes]

Figure 15: Toshiba 128 GB SSD Chip Found in my MacBook Air (iFixit, 2012)

[Image removed for copyright purposes]

Figure 16: Silicon wires in an electronic chip under a microscope (NISENet, 2014)

between code as material and language by explaining the transfer of information down the software stack:

> When basic logic gate functionality is abstracted and strung together into machine commands, translated into assembly op-codes, and then later articulated in a higher-level computer language such as C, the argument from Kittler is that one should never understand this 'higher' symbolic machine as anything empirically different from the 'lower' symbolic interactions of voltages through logic gates. They are complex aggregates yes, but it is foolish to think that writing an 'if/then' control structure in eight lines of assembly code is any more or less machinic than doing it in one line of C, just as the same quadratic equation may swell with any number of multipliers and still remain balanced. The relationship between the two is *technical.* (319)

Symbolic code and the mechanics by which it runs cannot be pragmatically separated: signs are directly related to voltage differences as signifiers (Chun, 2006). It is functional abstraction that allows computer scientists to pass, like this, from the world of engineering into the world of mathematics (Hillis, 1998):

> Once we figure out how to accomplish a given function, we can put the mechanism inside a 'black box,' or a 'building block' and stop thinking about it. The function embodied by the building block can be used over and over, without reference to the details of what's inside. (Hillis, 1998, 19)

In science and technology studies the term black box is used when technical work achieves some form of stability making the inner workings invisible so that only the inputs and outputs are acknowledged (Winner, 1993; Hinchliffe, 1996, Latour, 1999). Similarly in computing, the lids are put on these boxes deliberately so that the function of what that box is doing can be concentrated on rather than the complex mechanics, or electrical pathways, that bring that function into being. Software, then, is enacted by the whizzing circuitry of computers: not in, but *as*, machines. The Bitcoin blockchain, therefore, is not floating around in a fourth dimension somewhere unmoored from materiality, but rather exists as a relational spatial entity: not just embedded *in* but performed *by* the processes of silicon chips.

From such a materialist vantage point, hardware and software are by "no means separate or discrete elements of computation" (Marino, 2006).[11] As Friedrich Kittler (1995) explains in his provocatively titled paper "There is No Software", "code operations, despite their metaphoric faculties… come down to absolutely local string manipulations and that is… to signifiers of voltage differences" (4). Software, then, is merely hardware-at-work: the "material substrate of code, which must always exist as an amalgam of electrical signals and logical operations in silicon, however large or small, demonstrates that code exists first and foremost as commands issued to a machine" (Galloway, 2006, 326). In short, digital culture is always, first and foremost, material culture.

While the micro geographies of code are important, my machine is not running the Bitcoin protocol alone; it is constantly interacting with other nodes at a greater algorithmic macro geography that forms a peer-to-peer network. Because these other nodes are also maintaining the Bitcoin blockchain across the world my claim on Coinjar's store of bitcoin exists on every machine in the network. When bitcoins are sent (or spent) no physical movement or tangible exchange of an item takes place. Instead, there is a

[11] Hardware and software can only ever be ideologically separated, never physically (Chun, 2006).

transfer of ownership via the abstract logging system of a shared ledger that exists as a peer-to-peer algorithmic protocol—one, like all ledgers, categorically manifested by material, *technical* means.

Stitching Algorithmic Fabrics Together

Third party software exits to track certain aspects of the Bitcoin blockchain. A monitoring system called BitNodes, supported by mining start-up 21 Inc, crawls the Bitcoin network in order to retrieve geographic data based on IP addresses that indicate where nodes are located worldwide. This global distribution at the time of my transaction is shown by Figure 17. With 5728 nodes scattered around the world it is evident that peer-to-peer algorithms are by no means spaceless entities. In fact, their geographic complexity and dynamic spatiality are what characterise and enhance resilience. It is not that Bitcoin becomes formless through digitisation but rather its unique spatial configuration grants it a certain amount of stability. Its design paradoxically uses (the dislocation of) space to overcome previously spatial limitations (such as the transfer of value across borders) via simultaneous separation and connection. Bitcoin's relational and systematic operation, with all of the bits and pieces that interconnect to suspend it, carves out new linkages and trajectories. In doing so it becomes durable: if

[Image removed for copyright purposes]

Figure 17: A web-based visualisation of nodes in the Bitcoin network by BitNodes

one node collapses the others maintain the ledger as if it had never existed. In this way, Bitcoin, while by no means static, maintains a particular form—building sturdiness from a spatial elasticity. It would be ignorant, then, to render Bitcoin a circumventor of space when its neoteric geography (the way its various actors align to compose it) is what propels it into existence as functioning, distributed software. Digital peer-to-peer architectures do not nullify geography but emerge as new spatial compositions.

The map in Figure 17 tells more about the nature of the Bitcoin protocol: the nodes, where the software materially exists on silicon chips, are globally distributed but heavily clustered in Western countries (epitomised by the concentration of dots in North America and Europe). While this does not say anything about its individual users, it demonstrates that bitcoin's 'record keepers' tend to come from affluent countries. Bitcoin nodes are, as would be expected given the digital divide (Norris, 2001; Warschauer, 2004; Selwyn, 2004), unevenly distributed across the globe making, on some level, the maintenance of the ledger culturally, politically, economically, and spatially specific. It is also important to remember that the map is a snapshot of a dynamic network where nodes are constantly joining and leaving: the protocol does not hold a static, bounded algorithmic geography but embodies a continually evolving spatial connection. Additionally, nodes are not disconnected islands of software but rather interact through signals manifested by a plethora of hardware—running on the rails of the Internet's global, labyrinthine material infrastructure (owned and operated by a multitude of nation states, companies, and other institutions).

Bitcoin Banks

I now come back to the Coinjar website from where I sent my bitcoin; I had just asked Coinjar to send 1 BTC to a new address by clicking the 'Pay now' button. To understand what happens beneath the click I now dive through a number of architectural layers. Coinjar controls Bitcoin addresses on the behalf of their account holders and administrate transactions and manage security in return for in-built fees. These companies are therefore important spaces of control within the Bitcoin ecosystem as they administrate layers of software/bureaucracy between users and the blockchain. Although they streamline the Bitcoin experience, allowing more people to participate, these companies also centralise aspects of the Bitcoin economy through tightly controlled channels accountable to more fixed spatial loci such as tech hubs like Silicon Valley (see Chapter 6). In this way, these 'Bitcoin banks' materialise as trusted third parties—the very thing that Bitcoin was designed to negate. A point I return to later.

My ethnographic work led me to Coinjar's London office situated in Europe's largest financial technology accelerator called Level39, named after its floor position within One Canada Square, Canary

Wharf.[12] Coinjar was originally founded in Melbourne by Asher Tan and Ryan Zhou in February of 2013 but, after the Australian Tax Office defined Bitcoin as an asset, thereby subjecting it to Goods and Services Tax (Australian Tax Office, 2014; Han, 2014), the company headquarters was moved to London (Heber, 2014; Swan, 2014; Southurst, 2014). More progressive legislation in the UK meant (re)registering Coinjar as a British company allowed it to escape the 10% tax on buying and selling bitcoin. The move also gave the company greater access to a global market (Spencer, 2014; Carmody, 2014; Coinjar, 2015). The majority of their team, however, stayed in Melbourne.

Sitting with the General Manager of Coinjar in their London office for a couple of weeks, I learnt more about the technical nature of the company's operations. I found that Coinjar manages a series of 'hot wallets' (public keys that have their private keys stored online so that they can be extracted on demand) held on their servers. When a user signs into the website they are authorising themselves to Coinjar via their password and a code sent to a device such as a mobile phone (this is done through SMS or an application such as Authy or Google Authenticator). Multi-signature procedures like this increase the likelihood of the person logging in being legitimate as an imposter would need to know the password and be in possession of the account user's mobile phone. Once access is granted, the website provides a streamlined and user-friendly experience for managing their Bitcoin funds via a graphical interface. The website is supported by software designed, maintained, and monitored by Coinjar running on servers rented from third parties. The information that I type in signals to the software churning away on Coinjar's servers that a value of 1 BTC must be taken from their hot wallets and sent to the address that I indicated (154FhxVKSgL1LHqdazwHHQVB9bhoACdABj).

An interview with a Coinjar employee revealed that a typical hot wallet service like Coinjar would have roughly 400 BTC at any one time: "incoming payments land there and outgoing payments come from there". This 400 BTC is not stored in a single address (public key) but a few thousand with a system defined by the Coinjar software for deciding which coins are used for the next transaction (i.e. the 'oldest' coins).[13] To authorise a transaction the software plucks a private key from their servers stored on the cloud and signs it with the corresponding public key on a Coinjar-operated Bitcoin full node. This is the first point from when I began 'following' this bitcoin transaction that the Bitcoin blockchain is actually interacted with (although the value of that bitcoin had always been stored 'there').

Unsurprisingly, there is ample tension in the Bitcoin community over the good and evil of Bitcoin companies that restructure trust around centralisation associated with traditional banking practices. I

---

[12] Other Bitcoin and blockchain companies working out of Level39 have included GoCoin, BitFury, Applied Blockchain, BTL, capitalDIGI, Casha, CEX.IO, Coinfirm, and Euklid.

[13] The 'change' from the transaction will then go into a new address controlled by the software that will then become the 'newest' coins. This process is explained later in the chapter.

was told by different people at the same meet-up in San Francisco (coincidentally sponsored by Coinbase) to "never to trust companies like Coinbase as they are merely Bitcoin banks" and by another that they "always direct first timers to Coinbase because they are certain to have a great experience and encourage Bitcoin use". This personifies the tension in the Bitcoin cultural economy of a disdainful, yet acknowledged, necessity for centralised institutions as gateways to Bitcoin. There is a certain difference to traditional nation state monetary models in these frameworks however: start-ups may control private keys but there is no central bank in charge of the currency's monetary policy. Instead it is subject to the contours of control present in open source software (see Chapter 4) and miner voting (this chapter).

The centralisation of transaction administration through start-up companies can have catastrophic consequences too. In July 2010 programmer Jed McCaleb created the Bitcoin exchange Mt. Gox which became extremely popular thanks to a fluid interface that allowed people to hold both bitcoins and dollars with their accounts. Behind the surface, users of the exchange were trusting one person, McCaleb, with their finances: the company was quite literally run from wherever McCaleb took his laptop. Nevertheless, Mt. Gox grew into what would become the largest bitcoin start-up company name in the industry. In March 2011, McCaleb sold his exchange to a French programmer living in Tokyo called Mark Karpelès. By July 2011 it was clear Mt. Gox held a monopoly position over currency exchange administrating 80% of all bitcoin trading (Vigna & Casey, 2015). However, at the end of 2013, early warning signs of some internal struggle began to appear: withdrawals for customers were delayed for weeks and in some cases months. The company claimed this was a necessary restriction because a bug in the Bitcoin software, that became known as transaction malleability, made it possible for users to double spend coins. On the 4th February 2014, Mt. Gox announced possible insolvency having lost 744,448 bitcoins which had a value at the time of $473 million USD (Donnelly, 2014) and would have cost within the region of $15 billion USD at the 2017 peak. While the software bug did exist, and was corrected by the Bitcoin Core programmers, it has since been, through statistical analysis, disproven for being responsible for such a colossal loss of bitcoins (Decker & Wattenhofer, 2014). The reasoning has instead been widely put down to company incompetency that gave way for theft via the hacking of centrally stored private keys. This collapse reinforced the view of Bitcoin purists who claim any kind of centralisation creates internal vulnerabilities and defies the point of cryptocurrencies. Additionally, these centralised points go against the grain of cryptoanarchist ideologies as they reattach public addresses to the identity of customers and places them within the legislative reach of state governments (see Chapter 6). On the plus side, start-up companies increase accessibility and provide new financial tools by offering a variety of services maintained by software layers that rest in between users and blockchains.

Through the Internet

To add to the geographic complexity of the transaction facilitated by Coinjar, the servers that signed the transaction are not based in the United Kingdom or Australia, but in the United States. Therefore when I press the 'Pay now' button on the Coinjar webpage I am using a UK registered company, operating (largely) out of Australia, administrated by North American servers. What's more, for this to work, the signals that I prompt with the click are carried through infrastructures owned by a plethora of different actors like Internet service providers (ISPs) and telephone companies between Australia and the United States. I initiated this transaction on my laptop from the Institute for Culture and Society at Western Sydney University where it processed the information as electrical signals (resembling bits) that are passed down the software stack and split up into manageable chunks of data by my computer's Transmission Control Protocol (TCP). These packets are digitally ordered and labelled so the Coinjar server on the other side can make sense of and reassemble them. Because I was using the university wi-fi the information was turned into radio waves by my computer to be transmitted to the wireless router. The router picked up this information and translated it back into digital information (electrical impulses) as the radio waves vibrate electrons in the antenna producing electrical current. It was then modulated into bursts of electromagnetic waves by the router that were sent down an Ethernet cable and the copper wires of telephone poles to a router owned by an ISP. This router read the packet header containing the destination Internet Protocol (IP). The data then crossed through peered infrastructures owned by various ISPs.

The packets are 'dumb' and do not know where they are going but since their target has been labelled by my laptop's TCP they can be scanned by the router and passed on depending whether the destination IP address is in its logging table or not: if it is, the router sends the packet towards that IP address and if it is not, the router sends the packet to a parent router that contains a greater number of logging tables. This process can continue until it reaches 'the top' of an ISP network where, if the router does not contain the destination IP address, it will pass on the packet to the network of another ISP until the IP address is found. Once located, the packet will be passed 'down' subsequent routers until it reaches the machine with the correct IP address: in this case an Amazon server located in Seattle rented by Coinjar (see Figure 17). Different packets will follow alternative paths to their destination because routers will send them down wires with less network traffic to dissipate data 'traffic jams'. Packets will not necessarily take the shortest or quickest route so their mobile geographies are randomised and data corresponding to the same file can be sent around the world in completely different directions.[14] This is why the Internet is often referred to as distributed (Galloway, 2004).

[14] The IP packets may arrive in a different order or not at all. The recipient IP sends a signal back to the sending IP when the packet arrives, so if the sending IP does not get back this 'received' signal in a certain amount of time it will re-send the same packet until it gets a confirmation that it got there.

Throughout this process the packet will be modulated into various physical mediums to reach the destination IP address. For example, the packet may be in the form of light in order to travel through transoceanic undersea fibre optic cables but electromagnetic waves in copper wires. All these translations of information have to occur through space in order for these signals move. Using the software Visual Traceroute the hops between routers, and therefore a partial mobile geography of the packet, can be outlined. Figure 18 shows the partial topological geography of a packet moving through space via telephone lines and fibre optic cables: being relayed by the IP addresses shown. The packet made 13 hops on its way to the Coinjar server to be reassembled as information. The TCP part of the protocol on the receiving end then builds the data back together by using the labels given by the sending TCP/IP and transfers this data up the server's software stack so that it can be computed. This seems like a purely mechanical process but it would be a fallacy to neglect the vast quantities of necessary human labour needed to maintain the infrastructural networks and geographic territories in which data moves (Star, 1999, 2002; Larkin, 2013; Easterling, 2014; Starosielski, 2015). When the packets sent by my computer 'finally' reach the Coinjar servers (taking a matter of seconds), the software housed there recognises my request and makes a transaction on the blockchain via a Bitcoin node. To do this, the Coinjar servers use the private keys stored in their hot wallet database to sign one or more of their public keys containing a sufficient amount of bitcoin to make a transaction that fulfils the parameters I provided. The algorithmic protocol of the Bitcoin network then 'manoeuvres' to process my transaction.

[Image removed for copyright purposes]

Figure 18: The map shows the route that a data packet takes to reach Coinjar's servers in Seattle, Washington using the software Visual Traceroute

Unlocking and Locking Scripts

To follow a 'moving' bitcoin across a transaction on the Bitcoin network, it is necessary to understand it as an entry in an algorithmic ledger: a number cryptographically locked into the blockchain (or multiple blockchains) by a line of computer code. A value of bitcoin is, quite simply, a yet unspent transaction waiting to be spent or 'unlocked'. It is spendable only to those who can 'prove ownership' by composing a script using their digital signature that will subsequently 'unlock' it and encumber it to another address with a locking script (where someone can again prove ownership in the future with their own private key and therefore spend that value). This is how the value of bitcoins are transferred/ spent.[15] When I clicked the 'Pay now' button and the information that I typed in on the Coinjar website reached its servers, a 'layer' of software interacted with Coinjar's copy of the blockchain to issue a transaction to the network. Using the Bitcoin client downloaded on my computer, I can make queries to the blockchain to pull up specific information about it. The hash of my transaction acts as a unique identifier (72dee1f9722f2e2b8cf1e0adc2f848960cdbba258995c5c538721792627cb4de) and I can find out more about it with the following command:

```
$ bitcoin-cli getrawtransaction 72dee1f9722f2e2b8cf1e0adc2f848960cdbba258995c5c538721792627cb4de
```

This brings up a raw hex string which is "exactly as it exists on the bitcoin network" (Antonopoulos, 2015, 45):


```
{
	"result":
"0100000002f9602c9dd2210b9a766cd77af63509c512a5462f0b5d80f95e1f932bca3e04a3000000008a4730440220394e84e4482d686f2306f3de319dd631197c
bcbe19ec124bbc1469e5cdacb4b602206989027dd07584478258c8731a4ef55999c75d78e9f7966194d441986245c0070141041bf03370fbda6cdff62d00f981b89
974d04d3e65f81afda2f5432ad46d79a105729d53d53109add7415a4e6fe678c1b4570b12abb80c6a70b51e201f7866f098ffffffff15bc0ed0c9dae2afac8e8be5f51f
92b73118814fd2af7947c5001b8ded37eb13000000008b48304502210087ff990beeca5da432cfb9fc8cd43fa9bcd5964c19f46037a690802f8bb5cdcc02202f4ee9
ac4a252e4982c3a3d3ab1cb2346b363152f6c9fbdf3eb0aefc596a386e014104b2751828d69e39f5f441e935cc0068aa1feff5c6124e22c61e6fd1c39c39a12f948be0
4986bc729ba35b8e42d4271a2bd7b6b3fccbd00db4f78ac25f9043e7b5ffffffff0200e1f505000000001976a9142c7e06efc6a370c453d72b633b50d88b54410eb98
8ac4d2efc97000000001976a9144e57959a52cc56e930bd9dd2005c06c9b4380f3288ac00000000",
	"error": null,
	"id": null
}
```


It can be decoded into a human-readable JSON data structure with the following command:

```
$ bitcoin-cli decoderawtransaction
0100000002f9602c9dd2210b9a766cd77af63509c512a5462f0b5d80f95e1f932bca3e04a3000000008a4730440220394e84e4482d686f2306f3de319dd631197cb
cbe19ec124bbc1469e5cdacb4b602206989027dd07584478258c8731a4ef55999c75d78e9f7966194d441986245c0070141041bf03370fbda6cdff62d00f981b899
74d04d3e65f81afda2f5432ad46d79a105729d53d53109add7415a4e6fe678c1b4570b12abb80c6a70b51e201f7866f098ffffffff15bc0ed0c9dae2afac8e8be5f51f9
2b73118814fd2af7947c5001b8ded37eb13000000008b48304502210087ff990beeca5da432cfb9fc8cd43fa9bcd5964c19f46037a690802f8bb5cdcc02202f4ee9ac
4a252e4982c3a3d3ab1cb2346b363152f6c9fbdf3eb0aefc596a386e014104b2751828d69e39f5f441e935cc0068aa1feff5c6124e22c61e6fd1c39c39a12f948be049
```

---

[15] In actual fact, this is not too dissimilar to the spending of fiat currency in the form of a digital bank balance or physical cash that are also a store of value and a future claim on resources (unspent transactions). It is the mechanism for doing so that differs.

86bc729ba35b8e42d4271a2bd7b6b3fccbd00db4f78ac25f9043e7b5ffffffff0200e1f505000000001976a9142c7e06efc6a370c453d72b633b50d88b54410eb988a
c4d2efc97000000001976a9144e57959a52cc56e930bd9dd2005c06c9b4380f3288ac00000000

This gives back the following result:


```
{
	"result": {
		"txid": "72dee1f9722f2e2b8cf1e0adc2f848960cdbba258995c5c538721792627cb4de",
		"hash": "72dee1f9722f2e2b8cf1e0adc2f848960cdbba258995c5c538721792627cb4de",
		"version": 1,
		"size": 437,
		"vsize": 437,
		"locktime": 0,
		"vin": [
			{
				"txid": "a3043eca2b931f5ef9805d0b2f46a512c50935f67ad76c769a0b21d29d2c60f9",
				"vout": 0,
				"scriptSig": {
					"asm":
"30440220394e84e4482d686f2306f3de319dd631197cbcbe19ec124bbc1469e5cdacb4b602206989027dd07584478258c8731a4ef55999c75d78e9f7966194d44
1986245c007[ALL]
041bf03370fbda6cdff62d00f981b89974d04d3e65f81afda2f5432ad46d79a105729d53d53109add7415a4e6fe678c1b4570b12abb80c6a70b51e201f7866f098",
					"hex":
"4730440220394e84e4482d686f2306f3de319dd631197cbcbe19ec124bbc1469e5cdacb4b602206989027dd07584478258c8731a4ef55999c75d78e9f7966194d
441986245c0070141041bf03370fbda6cdff62d00f981b89974d04d3e65f81afda2f5432ad46d79a105729d53d53109add7415a4e6fe678c1b4570b12abb80c6a70
b51e201f7866f098"
				},
				"sequence": 4294967295
			},
			{
				"txid": "13eb37ed8d1b00c54779afd24f811831b7921ff5e58b8eacafe2dac9d00ebc15",
				"vout": 0,
				"scriptSig": {
					"asm":
"304502210087ff990beeca5da432cfb9fc8cd43fa9bcd5964c19f46037a690802f8bb5cdcc02202f4ee9ac4a252e4982c3a3d3ab1cb2346b363152f6c9fbdf3eb0aef
c596a386e[ALL]
04b2751828d69e39f5f441e935cc0068aa1feff5c6124e22c61e6fd1c39c39a12f948be04986bc729ba35b8e42d4271a2bd7b6b3fccbd00db4f78ac25f9043e7b5",
					"hex":
"48304502210087ff990beeca5da432cfb9fc8cd43fa9bcd5964c19f46037a690802f8bb5cdcc02202f4ee9ac4a252e4982c3a3d3ab1cb2346b363152f6c9fbdf3eb0a
efc596a386e014104b2751828d69e39f5f441e935cc0068aa1feff5c6124e22c61e6fd1c39c39a12f948be04986bc729ba35b8e42d4271a2bd7b6b3fccbd00db4f78a
c25f9043e7b5"
				},
				"sequence": 4294967295
			}
		],
		"vout": [
			{
				"value": 1.00000000,
				"n": 0,
				"scriptPubKey": {
					"asm": "OP_DUP OP_HASH160 2c7e06efc6a370c453d72b633b50d88b54410eb9
OP_EQUALVERIFY OP_CHECKSIG",
					"hex": "76a9142c7e06efc6a370c453d72b633b50d88b54410eb988ac",
					"reqSigs": 1,
					"type": "pubkeyhash",
					"addresses": [
						"154FhxVKSgL1LHqdazwHHQVB9bhoACdABj"
					]
				}
			},
			{
				"value": 25.49886541,
				"n": 1,
				"scriptPubKey": {
					"asm": "OP_DUP OP_HASH160 4e57959a52cc56e930bd9dd2005c06c9b4380f32
OP_EQUALVERIFY OP_CHECKSIG",
					"hex": "76a9144e57959a52cc56e930bd9dd2005c06c9b4380f3288ac",
					"reqSigs": 1,
					"type": "pubkeyhash",
					"addresses": [
						"189EdS6GUt2xBYNuUwAkuaun4hVeUHNGLb"
					]
				}
			}
		],
```

"hex":
"0100000002f9602c9dd2210b9a766cd77af63509c512a5462f0b5d80f95e1f932bca3e04a3000000008a4730440220394e84e4482d686f2306f3de319dd631197c
bcbe19ec124bbc1469e5cdacb4b602206989027dd07584478258c8731a4ef55999c75d78e9f7966194d441986245c0070141041bf03370fbda6cdff62d00f981b89
974d04d3e65f81afda2f5432ad46d79a105729d53d53109add7415a4e6fe678c1b4570b12abb80c6a70b51e201f7866f098ffffffff15bc0ed0c9dae2afac8e8be5f51f
92b73118814fd2af7947c5001b8ded37eb13000000008b48304502210087ff990beeca5da432cfb9fc8cd43fa9bcd5964c19f46037a690802f8bb5cdcc02202f4ee9
ac4a252e4982c3a3d3ab1cb2346b363152f6c9fbdf3eb0aefc596a386e014104b2751828d69e39f5f441e935cc0068aa1feff5c6124e22c61e6fd1c39c39a12f948be0
4986bc729ba35b8e42d4271a2bd7b6b3fccbd00db4f78ac25f9043e7b5ffffffff0200e1f505000000001976a9142c7e06efc6a370c453d72b633b50d88b54410eb98
8ac4d2efc97000000001976a9144e57959a52cc56e930bd9dd2005c06c9b4380f3288ac00000000",
"blockhash": "00000000000000000cfb1ac5f1ff134d2af6fb28a480b1803f826660d6a3eb65",
"confirmations": 132538,
"time": 1444905414,
"blocktime": 1444905414
},
"error": null,
"id": null
}

Here, the value of my 1 BTC can be clearly seen in the transaction as it is sent to the public key of the address 154FhxVKSgL1LHqdazwHHQVB9bhoACdABj. This can be visualised differently by using third party block explorer software from Blockchain.info (see Figure 19). In this instance, the private keys stored in Coinjar's hot wallets executed a transaction using two inputs from two different public keys under its control: 0.03766541 BTC from 16gS8FzUN8rbno5Jgr6G1psBtzqiMbLyiN and 26.4614 BTC from 19c7a88YqDWfst6WeQK3sBAxQ ktsTzhWvQ. This works in the following way:

> The fundamental building block of a bitcoin transaction is an *unspent transaction output* or UTXO. UTXO are indivisible chunks of bitcoin currency locked to a specific owner, recorded on the blockchain, and recognized as currency units by the entire network. The bitcoin network tracks all available (unspent) UTXO, currently numbering in the millions. Whenever a user receives bitcoin, that amount is recorded within the blockchain as a UTXO. Thus, a user's bitcoin may be scattered as UTXO amongst hundreds of transactions and hundreds of blocks. In effect, there is no such thing as a stored balance of a bitcoin address or account; there are only scattered UTXO, locked to specific owners. (Antonopoulos, 2014, 114)

Elaborating further:

> The UTXO consumed by a transaction are called transaction inputs, while the UTXO created by a transaction are called transaction outputs. This way, chunks of bitcoin value move forward from owner to owner in a chain of transactions consuming and creating UTXO. Transactions consume UTXO unlocking it with the signature of the current owner and create UTXO locking it to the bitcoin address of the new owner. (Antonopoulos, 2014, 115)

So the bitcoin attributed to both input addresses in Figure 19 are actually just bundles of unspent transactions locked to a public key, the value of which is stored in multiple blocks in the blockchain. What the blockchain actually records is the 'location' of these unspent transactions and so "bitcoin[s]

[Image removed for copyright purposes]

Figure 19: A summary of my Bitcoin transaction as shown by Blockchain.info

[Image removed for copyright purposes]

Figure 20: A partial history of the chain of transactions that constitute the bitcoin that I am following through the blockchain

can be thought of as a chain of *transactions* from one owner to the next, where owners are identified by a *public key* that serves as a pseudonym [for that person/machine]" (Meiklejohn et al., 2016, 87).[16] Figure 20 shows a partial transaction history of these values of bitcoin (and the different addresses they were locked to before they were spent by each) that traces back to when those amounts of bitcoin were first

[16] I add the word 'machine' here because Bitcoin, as programmable cash, has been envisioned as a currency that enable machine-to-machine payments for the Internet of Things (Swan, 2015).

mined into existence via a mining block reward referred to as the 'coinbase'—from which the (capitalised) company takes its name. Essentially, a transaction allows bitcoin to 'change hands' algorithmically. Thanks to the cryptographic manner in which this is achieved the geographies of ownership (where bitcoin is moving to and from) are deliberately opaque despite the fact that the transparency of the ledger openly displays which addresses are spending and receiving coins.

The Coinjar node executes (spends) this transaction by creating an unlocking script (*scriptSig*) that fulfils the conditions of the previous locking script (*scriptPubKey*)—that is, the one that 'paid' that bitcoin value into the public key where it currently resides. Coinjar "produces unlocking scripts containing signatures for each of the UTXO, thereby making them spendable by satisfying their locking script conditions. The wallet adds these UTXO references and unlocking scripts as inputs to the transaction" (Antonopoulos, 2014, 119). It then creates a locking script to my Coinbase public key (1 BTC to address 154FhxVKSgL1LHqdazwHHQVB9bhoACdABj) that defines the parameters of how the coins can be spent in the future: anyone who can provide an unlocking script with the corresponding private key to its public key (i.e. Coinbase).[17] The transaction has two outputs as the Bitcoin code insists that all bitcoin from a wallet in a transaction must be spent. The rest (25.49886541 sent to 189EdS6GUt2xBYNuUwAkuaun4hVeUHNGLb) acts as the 'change' of the transaction and goes into another address owned by Coinjar. There is also a difference between the total inputs (26.4990654 BTC) and total outputs (26.49886541 BTC) of 0.0068 BTC that acts as a transaction fee for the miner who puts them into a block.

Cryptography via a peer-to-peer network does something interesting here: it allows for the dispersion, or rather individualisation, of control over spending bitcoins. The logic of locking and unlocking coins —despite being performed materially by cryptographic code running on machines in the boundaries of nation states—is what defies territoriality because a public key can be used to sign a transaction to a Bitcoin node from anywhere in the world submitting it to the network. This allows those with coding skills to spend bitcoins 'autonomously' without permission from third parties. But most people do not have this expertise and so the vast majority of network transactions move coins (UTXO) from one island of (start-up company) proprietary software to another. Since the control of private keys *is* the mechanism for storing and spending bitcoins, whatever the geographic dispersion of the Bitcoin nodes, spatial centralisation can occur through private key management: start-up company software is enrolled as multiple obligatory passage points that the majority of the market must pass through to access the protocol. There are, then, two stratum to the Bitcoin network based on private key control: 1) a proprietary layer where transactions are controlled by institutions, and 2) a discrete layer where transactions are controlled by individuals. This can be likened to the surface web where the majority of

---

[17] These parameters are what have led people to refer to Bitcoin as "programmable cash" because certain rules (such as time frames) can be placed on the spending of coins.

Internet use takes place supported by regulated companies and the dark web where content can slide under the surface out of view if one has the knowledge and skill to access it. The centralisation of private keys occurs via the proprietary layer which reattaches the control of spending coins to Bitcoin banks and acts as a limitation to algorithmic decentralisation.[18]

Broadcasting Transactions

At this stage the transaction has only been executed on a single version of the Bitcoin core software located on Amazon's Seattle-based servers rented by Coinjar. To move the value between addresses the transaction must become part of the networked consensus by being mined into a block in (multiple copies of) the blockchain. Before this can be done the transaction needs to be broadcast to other nodes in the network.

> Bitcoin is structured as a peer-to-peer network architecture on top of the Internet. The term peer-to-peer or P2P means that the computers that participate in the network are peers to each other, that they are all equal, that there are no 'special' nodes and that all nodes share the burden of providing network services. The network nodes interconnect in a mesh network with a 'flat' topology. There is no 'server', no centralized service, and no hierarchy within the network. Nodes in a peer-to-peer network both provide and consume services at the same time with reciprocity acting as the incentive for participation. (Antonopoulos, 2014, 139)

This "flat" topology is important to the spatial configuration of Bitcoin because the nodes, shown in Figure 17, are structurally equal creating a systematic protocol that is greater than the sum of its parts. Each Bitcoin node

> …is connected to a few other bitcoin nodes that it discovers during startup through the peer-to-peer protocol. The entire network forms a loosely connected mesh without a fixed topology or any structure making all nodes equal peers. Messages, including transactions and blocks, are propagated from each node to the peers to which it is connected. A new validated transaction injected into any node on the network will be sent to 3 to 4 of the neighboring nodes, each of which will send it to 3 to 4 more nodes and so on. In this way, within a few seconds a valid transaction will propagate in an exponentially expanding ripple across the network until all connected nodes have received it. (Antonopoulos, 2014, 113)

---

[18] The companies also illuminate the identities of people behind cryptographic strings due to strict 'know your customer' (KYC) regulation within nation state territories (see Chapter 6).

Therefore, the Coinjar node is only connected to a small number of "neighbouring" nodes that it discovers in order to participate. The term "neighbouring" is topologically, as opposed to topographically, defined: nodes are selected at random across the network as opposed to being chosen due to their proximity (ibid.). But just because the protocological logic of discovering other nodes is not defined by spatial scales it does not mean space itself is moribund. It is in the very process of forming random connections, as identified earlier, that the network becomes resilient and allows Bitcoin to maintain spatial stability as a protocol. By connecting to random peers a node establishes diverse paths into the Bitcoin network:

> Paths are not reliable, nodes come and go, and so the node must continue to discover new nodes as it loses old connections as well as assist other nodes when they bootstrap. Only one connection is needed to bootstrap, as the first node can offer introductions to its peer nodes and those peers can offer further introductions. (Antonopoulos, 2014, 146)

It is across this randomised, fluid, mutating, algorithmic, spatial fabric—running (almost parasitically) on top of the (relatively) fixed, anchored, rigid infrastructural host of the Internet—that transactions flow. Figure 21 shows the randomised propagation of nodes across the networks that interact via Internet infrastructures. Here, the codified logic of the protocol produces a convincing computational, stigmergic relationship between all participating nodes fulfilling the ideal of a collective and collaborative self-organising system where distributed agency eradicates hierarchal interaction (Bonabeau et al., 1997; Tkacz, 2015).

The server-based Coinjar client executes my transaction and broadcasts it to the few nodes it is connected to (that could be located anywhere in the world). It does this using the same TCP/IP protocol that delivered data packets from my computer to the Coinjar server (because the transaction

[Image removed for copyright purposes]

Figure 21: My Bitcoin transaction propagating across the network as shown by Blockchain.info

contains no sensitive information about the transactor it can be broadcast across insecure networks). The receiving nodes refer to their own copy of the blockchain and the rules laid out in the locking scripts from where the UTXOs are coming from. If the transaction is invalid these nodes will not send it any further instead they will send an error message back to the Coinjar node. In this instance, however, the nodes validate the transaction and send it on to their neighbouring nodes. The result is the transaction propagating across the Bitcoin network, which takes a couple of seconds to reach all nodes. Despite such an apparently distributed and stigmergic system entrenched by the codified neutrality of nodes and protocological control (Galloway, 2004), asymmetrical power can still form in different ways that nullifies the ideal of network neutrality (Lovink, 2002; Rossiter, 2006). The spatial distribution of Bitcoin mining is one example of this.

Making a 'Hash' of 'Things'

The geography of bitcoin mining is complex and relatively black-boxed although certain characteristics can be discerned. I have so far followed my bitcoin to a point where the transaction has saturated the network. As of yet, however, my transaction has not been recorded in the blockchain but rather is sitting in the mempool of each network node. At a technical level this means that each computer running a Bitcoin client is storing the transaction in its memory temporarily; the network knows the transaction is there but it has not yet become solidified in the ledger. Using a web-based blockchain monitoring software created by TradeBlock my transaction can be seen entering the mempool with other transactions that have been submitted to the network (see Figure 22). Figure 23 represents an overall visualisation of the mempool at this time: the transaction was one of 8,129 waiting to be mined into a block with a total transaction value of 95,310 BTC (1.0065 BTC accounting for mining fees) and a total size of 4.29 megabytes (MB). Some of the network nodes are miners who are looking to add these transactions to the distributed ledger in return for a block reward and transaction fees. To understand these actors it is crucial to understand hashing in context to Bitcoin.

Cryptographically, hash functions are the backbone to the Bitcoin protocol.[19] They are "algorithms that compress messages into fixed-length strings of bits (usually called hashes, message digests, or fingerprints). That is, given as input a digital object of arbitrary length (e.g., a document, an image, a software program), the hash function will output a fixed-length (e.g., 128- or 160-bit) fingerprint" (Blanchette, 2012, 68). In other words:

> A hash function is an easy-to-compute compression function that takes a variable-length input and converts it to a fixed-length output. The hashes in which we are interested,

[19] Ralph Merkle, a "co-inventor of public-key cryptography, calls hashes the 'duct tape' of cryptography" (Landau, 2006, 330).

[Image removed for copyright purposes]

Figure 22: My transaction amongst other transactions in the mempool as shown by TradeBlock

[Image removed for copyright purposes]

Figure 23: Visualisation of the mempool as shown by TradeBlock

[Image removed for copyright purposes]

Figure 24: Transactions hashed together into a Merkle root and then hashed with a nonce and the overall hash of the previous block to form a chronological chain (Nakamoto, 2008)

> called cryptographic hash functions, are 'one-way', which is to say, they should be easy to compute and 'hard', or computationally expensive, to invert. Hash functions are used as a compact representation of a longer piece of data—a *digital fingerprint*—and to provide message integrity. (Landau, 2006, 330)

These characteristics have led to hash functions becoming integral to digital security systems (Perrig & Song; 1999; Stinson, 2006; Landau, 2006). Bitcoin utilises hash functions in many parts of the protocol: transactions in a block are hashed together to form a Merkle root, a fingerprint that references all transactions in that block; each block contains the hash of the previous block to ensure that it mathematically links to all other blocks (and therefore transactions) in the entire chain (for both of these see Figure 24); individual transactions are identified with their hash (see Figure 19); public key cryptography (the process of creating wallets and signing transactions) is based on hash functions, and mining uses hash functions to prove that work has gone into forming blocks, personifying network security. Cryptographic hashes are what gives bitcoins stability as digital 'things'.

It is the last process, mining, that solidifies my transaction now waiting in the mempool into the blockchain. Bitcoin mining is a process that accomplishes four things: 1) administrates transactions 2) negates double spending 3) mints new coins, and 4) secures the protocol. To do so it utilises the codified mechanism proof-of-work, which is a vehicle for effectively proving that someone (a machine) has engaged in a significant amount of computational effort to solve a problem—while challenging to solve, the *proof* of said work is easy to verify. The protocol enforces this process by demanding that a block hash has to fit a certain format in order to be validated (i.e. it has to start with a certain amount of zeroes). A random piece of data called a nonce is added to transaction data in order to alter the appearance of the block's hash. It is the miners' job to find a nonce that produces an acceptable hash. If the hash does not fit the required format, by having the requisite amount of zeroes, it will be rejected and a new nonce can be tried. Since there is no way of knowing what the hash will look like there is no way of shortcutting the system and so the only way of finding a desired hash is with brute force (trying as many nonces as possible). These attempts are made at an incredible speed: at the time of my transaction the cumulative hashing power was 465,548,432 Giga hashes per second (GH/s). The protocol changes the difficulty for finding a valid nonce on a sliding scale depending on the entire network hash rate to maintain an average constant block formation rate of 1 every 10 minutes.

Mining machines around the world hash together all the transactions they wish to include in the next block (normally the ones with the highest transaction fees) and rapidly fire nonces at this value to create a resultant block hash that fits the parameters of the protocol (correct amount of preceding zeroes). Over time, most of these computers have evolved from small-scale operations into large-scale mining farms that house rigs composed of thousands upon thousands of linked, tailor-made ASIC chips

(Taylor, 2013). These are simple yet powerful pieces of hardware: "you can heat your house with them, you can toast bread with them and if you don't dissipate the heat from them they will melt" (Antonopoulos, 2015b). One estimate put the yearly energy consumption of Bitcoin at 30.1 Terawatt Hours in 2017, equivalent to the entire nation of Morocco (Kobie, 2017). This energy intensiveness is a crucial factor for mining geographies.

Into the Mines

Cryptocurrency mining has its own economic geography dependent on the costs of electricity (to reduce expenditure), atmospheric temperature (to help reduce overheating), and access to hardware. For example, some mining farms have been established in Iceland where cheap geothermal energy is in abundance and cold temperatures keep chips from overheating (Cuthbertson, 2014; Price, 2016). The state of Washington in the USA also houses a number of mining farms due to its cheap electricity in comparison to other states (Banse, 2014; Higgins, 2016c; CryptoNinjas, 2017). More commonly however, miners are found in China. Here, coal power stations (and local deals made with them) make the economics of mining considerably cheaper than the rest of the world leading to an overwhelming and increasing geographical concentration for this practice (Swanson, 2014b; Vincent, 2016). In fact, over 70% of mining power is based in China (Swanson, 2014b; Vincent, 2016; Tuwiner, 2017).

This geographic clustering was a key reason why Mike Hearn left Bitcoin Core in 2015 claiming that the project, as a decentralised system, had failed (see Chapter 4). He pointed to a conference called "Scaling Bitcoin" in Hong Kong where a handful of miners, sitting on a single stage, allegedly controlled 95% of the network hashing power. Because miners not only secure the network but vote on forks with their power, Hearn referred to this as centralisation of control—the majority of Bitcoiners have to ride along and accept the decisions made for them by these giants. So while the 'record keepers' of Bitcoin (people running full nodes) are heavily coalesced in Western countries, 'ledger writers' (miners) are predominantly located in China. This makes a system that is supposedly immune to geographical factors, especially the control of nation states, surprisingly vulnerable to any legislation made by the Chinese government—although the spatial flexibility of the network means that it should survive such imposition by relocating its dispersed algorithmic 'body'. More importantly, however, this pattern currently means that the release of new coins is mainly flowing to Chinese miners and thus, one would expect, exchanges.

Mining farms come in many different sizes from home operations in people's garages to industrial-sized warehouses. The Chinese giants exist predominantly in rural areas where connections with power stations that burn cheap coal, or increasingly, in the mountainous west where hydroelectric dams provide the most cost-effective enterprises (Mu, 2015; Vincent, 2016; Xingzhe, 2017). In 2015,

[Image removed for copyright purposes]

Figure 25: Bitcoin mining hardware
Above: Mu (2015)
Below: Vincent (2016)

Motherboard released a video of life inside a Chinese Bitcoin mine. It showed 3000 shelved mining chips, sitting row upon row, consuming 1250kw of energy 24 hours a day 7 days a week (see Figure 25). Electricity used to generate nonces in this building cost roughly $80,000 USD per month and filled the room with constant heat while the ventilation systems that prevent the rigs from overheating created a wind tunnel (ibid.). The noise of countless fans maintained a constant drone as predominantly male workers (some living in attached dormitories), equipped with a deep understanding of computers, conducted menial tasks to optimise the efficiency of the rigs (Mu, 2015; Vincent, 2016). The workload is particularly dull so workers fill their time with poker, computer games, mobile phones, and sleep (Motherboard, 2015). Meanwhile, the machines around them, that they tinker with from time to time, are constantly engaging with the global algorithmic fabric of the Bitcoin protocol. There is, then, technical labour involved with Bitcoin mining from both human and machine (Maurer et al., 2013):

> All of this human and nonhuman labor reminds us that alongside and partly hidden by Bitcoin's practical materialism[—digitally mimicking the properties of precious metals —]are other materialisms, infrastructures that support the Bitcoin code and the network of Bitcoin users… But first and foremost among such infrastructures is the electrical grid, on which miners draw, often heavily, to power their rigs and sustain the P2P network. The electricity 'expended' in the service of Bitcoin energizes not only the miners' race to generate the next block in the chain but also their interactions with one another, their own chatter in online forums and elsewhere. (272)

At 21:37 on the 15th October 2015, an unknown miner forged the block containing my transaction into 'existence' with the block hash 00000000000000000cfb1ac5f1ff134d2af6fb28a480b1803f826660d6a3e b65. This can be seen by running a command to my Bitcoin client:

```
$ bitcoin-cli getblock 00000000000000000cfb1ac5f1ff134d2af6fb28a480b1803f826660d6a3eb65
```

This returns an enormous hex string that I have truncated below:


```
{
	"result":
"03000000d8f7bc53da6945767141668b72a51888a206df827db5420e0000000000000000a442579809f75064f2dbfffc15d85577700a6d7763c600d32fa3ff00dc7
0ff08c6811f5672141218449d97cffdc70701000000010000000000000000000000000000000000000000000000000000000000000000ffffffff2e0373c8050004b
b811f5604c97b940c0c67a525809b4b0100000000000a2020202020200a2f72657365727665642ffffffff0105da1497000000001976a9148962b0e97f434b91304
e542940782b2db487a8cf88ac000000000100000001354a96799764a77fa77a935975419220f06759dff7a1a9aa74780e71b6968a11b010000006c493046022100cc
def778e1f8e829591473a2ca31e88420d4a67365645bdc016074e5e2f5cdb902210089f6a
…[many, many characters later]…
e36f7583f99b1c21b9739edb44e15c13caccb6ff96521105aac0b20fa8d605012103ac781768f01c110bf69db28f90f68465ce480a4114352b10f2f7278a9bebf5b1f
effffffc2d15ad0239147b19582fa65b3c118413a28ddd491fda0c1e4b14dc2a82ebacd010000006b483045022100e76203c3cbb79cfb85a7ba6ccac22d4aa5ccaa15
1f2b2adf7f0f13e4e2aa48030220752ea8d2611404e2429e761afaa74b3c41c3d10fdd841c913e2b9f5cb6704a7401210266e6c8a73c142e6fdfc8a1d5bbc14e2a74c
66e87dbccefad7771a8b98679b6cffeffffff02981e1e00000000001976a91495c57675d843edc7f0bf1cde402665c98ac187e688ac04005c00000000001976a914022
f8e86831b2fa9ef129987a62c266f6a64befe88ac68c80500",
	"error": null,
	"id": null
}
```


Decoding this into a JSON data structure, the block looks like this:


```
{
	"result": {
		"hash": "00000000000000000cfb1ac5f1ff134d2af6fb28a480b1803f826660d6a3eb65",
		"confirmations": 132541,
		"strippedsize": 749184,
		"size": 749184,
		"weight": 2996736,
		"height": 378995,
		"version": 3,
		"versionHex": "00000003",
		"merkleroot": "08ff70dc00ffa32fd300c663776d0a707755d815fcffdbf26450f709985742a4",
		"tx": [
			"569acc2a4c56bc601f99e1cef8574fdf356ab771231b84c71fc30655ec8a8dbf",
			"711c305fd880f43923088e11a090d1bbaf7ab9cfd99abe84bd0e961cbe933b6a",
			"9f1e00a24e9f0bb821da316f3c371b60a2a55b455f214ba81a63bbc418d65376",
```

```
                "e8a9628b62e01b3c1236811e91ada0756d20619a14b771957e3ea146159828a2",
                "6a8822212445776eacc105920fa4e6329b13a676747296a3b8e635ee2f9ffc6c",
                "7ffb94b9127c146e2e778f32489a5fcbcb1aa2d8a8856091d1bbd6697b44a83a",
        …[many transactions later]…
                "72dee1f9722f2e2b8cf1e0adc2f848960cdbba258995c5c538721792627cb4de",
        …[many transactions later]…
                "9ff74257f73ae805b77d4969dc48e1fda71fbea728b7e617a9ae00d344bd21fe",
                "a951edcb8c9ce00b408a2c3a2e9d42e331cc8c7ae1799bf8c9d63966d448dc44",
                "d6e1402845ac1db4b18983639cce533b01b2ab97b411ca993e32d92090ec5c82",
                "2ec7bf22343e323eaef34b06e8491b63e4a94c476e4ac041dd2c71e86f806c8a",
                "c67d0da73fc1fd965961a1f459da1c1af6f2a742ca0fc0653a46a57034c70920",
                "35d552247630e952081da94673a64561f1f9d18103c693536cf82e75ebb4fec5"
            ],
            "time": 1444905414,
            "mediantime": 1444900044,
            "nonce": 3482819908,
            "bits": "18121472",
            "difficulty": 60813224039.44035,
            "chainwork": "0000000000000000000000000000000000000000000b1eb7bd1b599ea52996b8",
            "previousblockhash": "00000000000000000e42b57d82df06a28818a5728b664171764569da53bcf7d8",
            "nextblockhash": "000000000000000003f48e42bb6ad8f85826009a129f1e5f65a747fbee47c989"
        },
        "error": null,
        "id": null
}
```


Here the transition can be seen among hundreds of others in block number 378,995. These transactions are hashed together to form the Merkle root which is then hashed with the nonce 3482819908 (found by the winning miner at a difficulty value of 60813224039.44035). These lines and lines of code are supported by thousands upon thousands of electrical signals that tie together mathematically to form a functioning blockchain. The TradeBlock software measures the information of the shared blockchain in real time to construct its blueprint. The block 378,995 and contained 1,990 other transactions having a size of 731.63 kilobytes (added to every node/machine maintaining the blockchain). When the winning miner finds a correct nonce they broadcast their newly formed block to the network, which is checked by the node's peers in the same way that a transaction is, with the block hash acting as proof of the work done to form it (00000000000000000cfb1ac5f1ff134d2a f6fb28a480b1803f826660d6a3eb65).[20] The reason why some miners can be distinguished is because blocks have the space to contain a certain amount of arbitrary metadata and miners now tend to use this space for tagging the block as a promotional measure.[21] For my own block, this was not the case, but the previous blocks were mined by 21 Inc., BTCChina, AntPool and F2PPool (see Figure 26). This demonstrates that mining is not just geographically centralised but also institutionally. Individual mining operations rarely mine on their own but rather join their resources together with other miners to increase the likelihood of a consistent financial income. The organisations in the tags above are not individual stakeholders but a pool of miners who club their power together for a share of the block reward.

---

[20] Note the 17 zeroes that begin the hash.

[21] This space for metadata is what Satoshi Nakamoto once used in the gems block to suggest that Bitcoin was a response to the 2008 global financial crisis by referencing a newspaper headline (see Chapter 1).

[Image removed for copyright purposes]

Figure 26: A visualisation of the blockchain by TradeBlock

The dominance of mining pools has come under scrutiny in the Bitcoin community due to the possibility of what has been called the 51% attack. This states that if a single party or group gather over half of the Bitcoin mining power they can hijack the network (Kroll et al., 2013; Eyal & Sirer, 2014). In other words, if a centralised cartel controls mining they can rewrite the historical record to double-spend coins and alter the rules forced by consensus since they become the network majority. The game-theoretical nature of Bitcoin protects against this outcome because those securing the network for economic incentive should not act in a way that will damage its integrity as this would result in their own bitcoins becoming less valuable (Nakamoto, 2008)—however, this technique could be used by a malicious attacker with enough resources. Similarly, as mining pools grow they also endanger the distributed nature of the mining economy by advancing their own power over the network. This was famously personified by the company CEX.IO in 2014 (Gill, 2014). The start-up not only allowed independent miners to join the pool but also offered a cloud mining service called Ghash.io where customers could essentially buy shares in mining rigs that it privately ran. As the company approached 51% a backlash from the Bitcoin community caused CEX.IO to cull their mining power to stay below 40% of the network, and urged other mining pools to do the same (Wilhelm, 2014; Bershidsky, 2014).

This coalescence of the Bitcoin mining network through centralised pools remains a concern as miner voting power and block rewards are funnelled through a small amount of institutions with considerable power over the network. When outlining the senatorial governance of Bitcoin in Chapter 4, it was mentioned that after the accidental hard fork in 2013 (where version 0.7 and 0.8 fell out of sync), the Core developers encouraged the large mining pools to revert back to the 0.7 client to fix the problem. Mining pools, then, hold considerable power over the network. Like the centralised GitHub version control system that the Core developers operate through to absorb the brain power of programmers from all over the world, mining pools are a bottlenecks that collect and harness hashing/voting power. While these organisations consolidate their contributors' hashing power, the contributors are not represented with the equivalent miner voting power. Some have claimed that this maintains decentralisation because individual miners can swop between pools at any point thereby using their power to vote for pool owners like elected politicians acting on their behalf (Buterin, 2013a). However, mining pool dominance and possible collusion is within the contours of senatorial governance and represents a very real material-economic limitation to algorithmic decentralisation.

When the miner locked my transaction into a block and broadcast it to the rest of the network, other miners were then able to check the proof of work and start mining on top of that block. As more blocks 'pile' on top of the block containing my transaction it becomes 'buried' in the ledger's transactional history making it harder for miners to build a forked blockchain that could omit it. My transaction therefore becomes more stable over time as it becomes exponentially unlikely that this singular version of history can change—although this is not always the case (see Chapter 4 and Chapter

[Image removed for copyright purposes]

Figure 27: "Sell Bitcoin" tab on the Coinbase website

[Image removed for copyright purposes]

Figure 28: "Sell Confirmation" tab from Coinbase

7). This can be seen in the JSON data structure as "confirmations": 132541 (the getblock command was run over two years after the time of the transaction which accounts for the large amount of confirmations). The bitcoin locked into this block was then under the control of Coinbase instead of Coinjar. From here I logged onto my account, typed in the value of 1 BTC (at an exchange rate of $253 USD) and clicked the 'Sell bitcoin' button (see Figure 27). The Bitcoin value disappeared from my account and the company sent a bank transfer to my Wells Fargo account (see Figure 28). Monetary value had now moved across borders via the Bitcoin network supported by a plethora of paraphernalia. Yet the bitcoin value had not really *moved* anywhere: it was merely an update of an algorithmic ledger's state where claims upon it from different parties had changed. All the 'moving parts' across different world spaces joined across the vast algorithmic fabric of Bitcoin, intersecting with institutions and borders in new ways to facilitate my transaction. When seen through the lens of Arjun Appadurai's (1990) work on global cultural flows, while mining farms are often stationary operations, the Bitcoin protocol is constantly (re)assembling as they join different pools, all the while catering for the flow of information across its polyfurcated, restless, algorithmic body. Here, the global depends on the local, the material on the semiotic, and vice-versa.

The Material-Digital

The geography of the Bitcoin protocol is indicative of how materiality and mathematical algorithms are achieved through each other. Here the immaterial is material, the virtual is real, and vice versa. The translation between code logic and electrical signals demonstrates how information (whether writing, imagination, code, narrative, mathematics) is *always* material. In 1914, Alfred Michell Innes proclaimed that "[t]he eye has never seen, nor the hand touched a dollar… [as n]o one has ever seen an ounce or a foot or an hour" (155). This point of abstraction is thought provoking and alludes to the fact that all money is on some level virtual (Bek-Thomsen et al., 2014)—see Chapter 1 for the double consciousness of money. However, measurements are certainly materially constructed: standard units are often maintained with physical prototypes or 'universal constants' like the speed of light, not to mention the tools of measurement like rulers or stopwatches. No matter how intangible a thought or an idea might appear, it is always generated, performed, and enacted materially. And so, many hands have, indeed, but only in part, 'touched' a dollar. Bitcoin, then, is not a *de*materialisation but a *re*materialisation of money (Maurer et al., 2013).[22]

The dispersion of Bitcoin nodes, process of encumbering balances to different cryptographic strings, and the 'permanent' sedimentation of these values in a shared ledger through mining is what allows

[22] Maurer et al. (2013) describe the Bitcoin code as presenting a "digital metallism", that is the codified parameters of the protocol attempt to mirror that of naturally occurring metallic ores, like gold, that have been historically used as money (see Chapter 1). In this way, Bitcoin was designed with matter in mind (e.g. imitating the limited supply of gold).

these balances to perform as money. A robustness achieved by this system is what first caused cryptographers and other programmers to part with fiat currencies in exchange for bitcoins. Initially, bitcoins held no financial value: they were traded amongst cryptographers mainly as a means for testing the functionality of the system. Value arose slowly over time as more and more people were enrolled within its network and became prepared to give up other valuable assets, such as fiat currency or food, in order to own quantities of bitcoin. On the 5th October 2009 a user of the Bitcoin forum, going by the name of New Liberty Standard, established the first Bitcoin exchange rate by dividing their electricity costs of mining by the amount of bitcoins generated from their mining practices. The calculation gave the official exchange rate of 1 BTC = $0.0008 USD or 1 USD = 1,309 BTC. In conjunction with this, Bitcoin's cryptographically inclined users trusted the security of the algorithmic protocol that underlies the flow of currency units. New Liberty Standard also established the first Bitcoin exchange and slowly a market for trading its digital tokens began to grow.

Later that year, on the 22nd of May, what is widely regarded as the first Bitcoin transaction for a tangible good took place. Laszlo Hanyecz, a programmer from Florida, offered to pay anyone on the Bitcoin Forum, a website dedicated to the cryptocurrency's discussion, who bought him a pizza 10,000 BTC. A user from London with the screen name jercos placed a long distant phone call to Hanyecz's local Papa Johns and paid for two pizzas with a credit card that were delivered to Hanyecz's house and who subsequently sent 10,000 BTC to jercos's digital wallet (those same bitcoin would be worth $195,000,000 USD at the time of the 2017 price peak).[23] It is the material-semiotic networks that formed around Bitcoin that 'willed' the value of its tokens into being.[24]

The equation above takes the security and stability of the Bitcoin protocol as given: the codified architecture is trusted and black-boxed in the same move, concentrating instead on the inputs (cost of electricity in) and outputs (bitcoin quantity) of mining. But this form of black-boxing does not mean that the inner workings of the machinery is not understood. Rather, this is where the fiduciary trust of a bitcoin-token-as-money emanates from. To practise cryptography is to see cryptographic proof (deciphering with private keys) as a mathematical and universal truth (see Chapter 3). Bitcoin's cryptographically inclined users trusted the security of the algorithmic protocol that underlies the flow

---

23 The 22nd of May has since become a significant cultural event in the Bitcoin community where many will eat pizza to commemorate the transaction.

24 Many early adopters have benefited financially as the value of bitcoins has risen so that some commentators have labelled it a Ponzi scheme. While Bitcoin is no more a Ponzi scheme than Apple shares were in the early 1980s, this does have serious implications for the distribution of wealth. Like the global distribution of money, bitcoins tend to be concentrated among a relatively small amount of 'whales' which gives them significant control within exchange markets. Analytics show that 97% of all bitcoins are held by 4% of addresses (Chaparro, 2018), some of which could belong to the same entity. However, it can be assumed that a vast proportion of these bitcoins are now 'dead' and can never be used due to the loss of private keys by early adopters—although there is no way of telling how much. Satoshi Nakamoto, for example, owns 980,000 bitcoins valued at $19.4 billion USD in December 2012 (Wong, 2017a) but has never touched this hoard other than tinkering with the project in its early days.

of currency units and so the value of bitcoins were, quite literally, 'willed' into being (see Chapter 1 for the subjectivity of value). The crypto-spatial ties of the Bitcoin network—theoretically unbreakable by modern technological standards—allows an unlockable and transferable balance tied to a cryptographic string to act as a monetary coin. This is why understanding the Bitcoin code is so important—the alignment of its material-semiotic, human and non-human network is what gives it value (to some):

> Bitcoin's practical materialism allows the chatter in the code, the proof of work, the materiality of the machines humming and whirring in mining rigs to be simultaneously backgrounded and foregrounded. This is not simply commodity fetishism. The code and the labor are backgrounded when Bitcoin adherents become latter-day goldbugs. But the code and the labor are foregrounded because they are practically all that Bitcoin enthusiasts ever talk about. (Maurer et al., 2013, 274)

Slowly, people began to speculate over a bitcoin's price subjecting its value formation to market mechanisms; many were willing to pay more than the costs of electricity for something they saw as having more inherent financial value (as a mark in a distributed ledger) and the price began to rise.

Although bitcoins derive value from being part of a network, where "decentralization, as well as the public-key encryption of users' identities, is hardwired into the system" (Maurer et al., 2013, 268), the spatial coalescence of certain practices and trajectories outlined in this chapter illuminate geographies of centralisation. Ideological preconceptions of the digital tend to imagine distributed networks in opposition to materiality: while the software logic is radically distributed, fulfilling cypherpunk dreams, material constraints limit the effects of the process of decentralisation (like Bitcoin banks and mining pools). Sy Taffel (2015c) explains:

> Although software does play a crucial role in contemporary societies, this role is a relational one that is entirely dependent on a series of other equally crucial areas, such as human attention and reliable sources of electrical energy, silicon and other essential materials for constructing digital architectures. Digital materiality includes the materiality of software but must also go beyond code to explore the broader technocultural assemblages that software is dependent upon. (332)

So while exploring the technical apparatus of software is important for Bitcoin's money/code/space, other materialities must be considered to understand power across the network. For example, "significant economic forces push towards de facto centralization and concentration among a small number of intermediaries at various levels of the Bitcoin ecosystem" (Böhme et al., 2015, 219-220). In other words, crypto*economics* is not immune to forms of capital accumulation that demand centralisation to enhance profits (see Chapter 6). Like algorithmic trading (Beverungen & Lange, 2017), humans are not omitted from the 'automation' of the Bitcoin algorithm but compete (with their own material strategies and as materials themselves) for different aspects of its architecture (Bitcoin banks for private key control; mining pools for block rewards).[25] It has a distinct and dynamic algorithmic geography.

Blockchain architectures, however, relate to time as much as space. This is in one sense obvious; Bitcoin has a brief but rich history. In another, this claim is much more poignant. Kitchin and Dodge (2011) observe that digital code increasingly shapes the world and produces spaces but its role in producing time is just as crucial. This is especially true of software architectures like Bitcoin that groups individual transactions in blocks synchronised through the network at the predetermined average rate of 1 block every 10 minutes.[26] This is the pulse or heartbeat of the crypto-financial system, regularised by, and also conditioned by the entire downstream series of activities, conditional upon the transfer of currency units. Here then are the beginnings of new a sense of temporality—neither the slow cycles of conventional money transfers, nor the millisecond response times of high frequency trading, but rather a constant metronomic pulse, a block of transactions 'pushed' to every blockchain on a global network in 600-second intervals. It could be imagined then, blockchains offering a geographic, and an algorithmic genealogy—an indelible, persistent sequence of interlinked events that, paraphrasing Kitchin and Dodge, shape the world.

Conclusion

For Stephen Graham (1998), and as this chapter has demonstrated, "there is not one single, unified cyberspace; rather, there are multiple, heterogeneous networks, within which telecommunications and information technologies become closely enrolled with human actors, and with other technologies, into systems of sociotechnical relations across space" (178). Bitcoin forms part of this fragmented multiplicity. Furthermore, within the Bitcoin architecture different networks of control can be carved out, personified by a start-up company's management of private keys. Infrastructural research is, then, always partial: it "is a moment of tearing into those heterogeneous networks to define which aspect of which network is to be discussed and which parts will be ignored" (Larkin, 2013, 330). Through tracing the material-semiotic networks of Bitcoin's code with different methods, 'segments' of its money/code/space, on an infrastructural level, can be better discerned.

[25] Following the trajectories of spatial ties can illuminate these points of power in networks: like other 'things' bitcoins are an "invisible part of countless people's lives... [l]ike any thing you could try to follow. Unravelling and becoming more entangled in the process" (Cook et al., 2004, 662). This is bittersweet as these "direct connections [can't always] be traced, between... places and people" (Cook & Harrison, 2007, 58), particularly when cryptography intentionally conceals connections. But these "linkages do not just stop at a certain point... they just get flimsier, more difficult to discern" (Miller, 1998, 363). It is through "unravelling" and "entangling" that an array or material-semiotic linkages can (and cannot) be discerned unearthing an array of heterogenous local-global relationships (Marcus, 1995, 106-108).

[26] Although, at times this 'beat' can be considerably faster or slower as nonce finding is down to chance.

If the recent turn to the materiality of the digital is acquiesced, there comes a resistance of what remains resolutely symbolic—signs, symbols, data, algorithms, information, and informatic structures. Certainly these do not sit on, but are enacted by, hardware (Kitler, 1995). Digital things, therefore, should not escape the scrutiny of material culture scholarship. At the intersection between the 'cryptographic' and the 'geographic' is a methodological query. Precisely, the desire to reveal, unveil or lay bare—all elaborations of the Greek word 'graphein', to write or draw—lie in the background of efforts to map the material (to make geographic) the apparently disembodied and immaterial operations of the digital. Yet it is worth noting, in the limits of method, the difficulties of tracing, at the level of secure IP packets or Bitcoin transactions, that which is written in such a way as to be hidden. An obvious point here is to draw the lines at where method may begin to delineate the contours, boundaries, and perimeters of what it can survey, and conversely, what remains, in these novel digital spaces, intentional 'terra incognita'.

As a strategic device for explaining Bitcoin, following the thing as methodology may prompt more questions than it answers. It raises the question of what difficulties the digital ethnographer is likely to encounter when they try to trace what is designed to be obscured even from US federal agencies such as the NSA; and how much of these new algorithmic geographies remain crypto-geographies, moving beneath the surface, a subterranean set of operations that only leave behind hints of their passage? What it does clearly show, on some level, is a specific geography of abstraction that somewhat undermines the political claim of Bitcoin existing as a radically distributed, alternative currency/economy, showing a reiteration of inequalities geographically produced in other existing currencies. So although I have presented a Bitcoin transaction as a linear system, different aspects of the codified architecture maintain their own pure boundaries around its/their logic. The metageographies and deeply localised material architecture supports an entire network of social relations from Sydney to San Francisco, Iceland to China. This reflects Arjun Appadurai's (1990) materiality of global cultural flows that are on one hand fluid and global but on the other very deeply immobile and local. As the industries around Bitcoin evolve it becomes clear that there is only a partial severance of coins in the economy from inspection. Cryptospaces are, materially, in a continuous tension between the known and the unknown.

Chapter 6

Embedded Centralisation: The Bitcoin Start-up Ecology in Silicon Valley

Introduction

Digitisation has been referred to as a globalising, dematerialising, and disembedding force. In the world of finance this supposedly generates untethered transactions that can circulate instantaneously and cut across conventional borders; the hypermobility of information through digital networks lifts economic transactions away from their social and spatial settings to create an efficient (at least for advocates of finance capitalism) and abstracted world market (Martin, 1978; Toffler, 1981; Giddens, 1990; Naisbitt, 1995; Negroponte, 1995; Knoke, 1996). Recently, this dominating view of the economy has been rendered empirically dislocated by a range of historians, anthropologists, sociologists, and geographers who have instead gathered around ethnographies of cultural-economic embeddedness (Leyshon & Thrift, 1997; Ross, 2003; Amin & Thrift, 2004; Tsing, 2005; Zaloom, 2006). This suggests, perhaps counterintuitively to discourses of hypermobility, the embedded role of financial centres, like London and New York City, has not lessened but become ever more prominent for organising finance as digitised practices have increasingly saturated 'modern' economic systems since the Second World War (Graham & Marvin, 1996; Sassen, 1991, 2005; Clark & Thrift, 2005). The concept of embeddedness has been used in a variety of ways but ultimately stands here to explain the lasting presence of global cities by reattaching the economic to the social and looking at the (asymmetric) connections maintained between actors on a number of different spatial scales (Hess, 2004). Far from an imaginary of free-flowing transactions, this understanding highlights urban spaces as centres of calculation that can act like financial or monetary valves within networks (McNeill, 2017).

In this chapter, I extend the critique of algorithmic decentralisation by following Bitcoin into Silicon Valley where a blossoming Bitcoin start-up ecology has taken root. This ecosystem emerges as an integral site of production, performance, contention, regulation, and normalisation for the development of cryptocurrencies and blockchain technology. Through the analytical lens of industrial embeddedness—the proximity of interdependent firms in a specific economic space—I use ethnographic material gathered in/on/from start-up companies and meet-up groups to understand more clearly the cultural economy of the Bitcoin ecosystem at an entrepreneurial level and to trace out the connections that are (dis)assembled within this complex industry. The chapter, then, provides an account of embeddedness detailing the geographies that are produced at this intersection of finance and technology thus continuing a theoretical development of money/code/space and algorithmic decentralisation.

I set the scene by describing the rise of FinTech: an industrial sector that Bitcoin and blockchain technology have become a significant part of. From here, Silicon Valley is shown to be a key economic site for Bitcoin entrepreneurial activity thanks to its dense historical and geographic networks. This cultural specifity is expanded on to introduce the tensions at play in the San Francisco Bay Area's urban environment and how this both reinforces, and intersects with, the growing Bitcoin industry. I reintroduce Barbrook and Cameron's concept of the Californian Ideology (see Chapter 3) and draw on it to explore the Bitcoin scene where it is enacted in new ways across different spaces, influencing the way in which different actors interact with each other. The chapter demonstrates how disruptive technology is normalised into the economic status quo as start-ups replace traditional financial services and become increasingly embedded into situated industrial networks with the help of venture capitalists. The chapter goes on to address the fragmentation of a once monolithic online community to understand Silicon Valley's burgeoning role as a guarantor of finance in blockchain economies. This ideological and cultural narrative is used to trace out the connectivities of embeddedness in the Bitcoin start-up economy and highlight how this relates to algorithmic (de)centralisation.

The Rise of FinTech

The term FinTech was first coined in 1993 by Citigroup to refer to their Financial Services Technology Consortium (Kutler, 2015; Hochstein, 2015). However, it did not become a popular idiom within the financial services sector until the mid 2000s; it then began to be used as an umbrella term that encompasses both the more mature, time-tested technologies used by financial institutions in addition to the innovative financial technologies created by start-ups who are forcing their more traditional counterparts to keep up with the pace of innovation achieved within more flexible and less bureaucratic companies (Hochstein, 2015).

FinTech start-ups represent a paradigm shift of banking services from Wall Street to Silicon Valley.[1] Traditionally, the global financial sector has been one of the largest markets for technology producers with its vast hunger for hardware, software systems, and databases (Lodge et al., 2015; Holley, 2015). Currently, segments of the high technology sector are stepping away from their historical contractual role and attempting to displace existing financial providers through services like PayPal, Google Wallet, Apple Pay, Square, Stripe, Dwolla, TransferWise, Venmo, and Monzo that are increasingly

[1] Some would say merely into the hands of new technocrats.

commonplace in everyday life. In terms of capitalisation, from 2010 to 2015 more than $50 billion USD was invested in 2,500 FinTech companies (Accenture, 2016) and in 2016 there was a global total of 27 FinTech unicorns, nine of which were based in Silicon Valley (Fintech News, 2016).[2]

Cryptocurrencies and blockchain technology have not only been part of this wave but have catalysed FinTech's momentum by imagining and providing alternative frameworks for facilitating value and governing transactions, all the while brandishing the 'superior' doctrine of decentralisation. Many new start-ups use the consensus mechanisms of the Bitcoin blockchain, what the *The Economist* (2015) calls "the trust machine", as a financial base: a carrier of value, a payment network, and a database for representing 'true' information. With the institutional shift of finance into the technology industry, the boundaries of the financial sector have moved to encapsulate global tech hubs. As such, global finance has, in part, begun to absorb the liberatory ideas of the Californian Ideology that strives for technological-economic decentralism.

Post-2008, Wall Street and the City of London were subject to a degree of demonisation personified by the Occupy Wall Street protest. On the other hand, the positive images associated with technology start-ups of the New Economy have largely survived the 2001 tech wreck maintaining 'cool' company cultures with flattened hierarchies where employees are liberated to make a palpable internal impact, 'change the world', and are rewarded with appealing stock options (Ross, 2003).[3] This depiction is helped by the saturation of glorified products within everyday life such as the iPhone and Google search, as well as popular culture movies like the *The Social Network* (2010) that celebrates the innovation of Silicon Valley whereas *The Big Short* (2015) vilifies the testosterone-fuelled recklessness of Wall Street.[4] As Mathew Bishop, US business editor of *The Economist*, humorously puts it: "Google [is] the company that can do no evil and [Goldman Sachs is] the giant vampire squid" (The Economist, 2013).[5] Layoffs on Wall Street and the enormous accumulation of capital gathered by successful technology entrepreneurs, in an industry barely touched by the financial crisis, has contributed to a growing trend of graduates and careerists moving to Silicon Valley generating a talent war between banks and technology companies (The Wall Street Journal, 2013). FinTech, then, is not just used as an analytical term to describe a growing sector but is a *movement* with a dual meaning: 1) a series of actions and events that are taking place to foster a new trend of financial services taken up by the technology

---

[2] Unicorns are private companies with a valuation of over $1 billion USD given the name due to their rarity (Lee, 2013).

[3] Although technology companies have received their own level of condemnation following the revelations made by Edward Snowden: it came to light that many were involved in surrendering their users' privacy to governments (see Chapter 2).

[4] Public polls showed that four of the top ten most disliked brands in the United States during 2014 were financial services (VLAB, 2015).

[5] Goldman Sachs was first described as the "great vampire squid" by Matt Taibbi (2010) in *Rolling Stone*.

industry (akin to a political movement), and; 2) the more physical migration of talent and services across geographical space from financial to technological hubs. This curious cultural osmosis at the intersection of finance and technology, particularly in blockchain industries, is creating an image based on a form of start-up moral economy that creates 'fairer' infrastructures free from the hierarchal control, giant overheads, and massive fees manifested by the big banks that are notorious for their lack of innovation and role in creating boom and bust cycles.

This is not a straightforward transition from old to new ways of transacting money/value but a contention over competing systems and an ensuing power struggle for potential future profits that can come by taking a leading position within financial markets. Bitcoin is sitting uncomfortably between conflicting ideologies as its trajectory becomes tangled and incongruent amidst a growing number of stakeholders. This chapter goes on to address this fragmentation of a once monolithic online community to better understand Silicon Valley's burgeoning role as a guarantor of finance in blockchain economies. I now turn to the development of embeddedness as a concept and detail the specific historical economic geography of the San Francisco Bay Area—a key site for the production of blockchains.

The Silicon Valley Model

The regional economy of industrialised technology development in Silicon Valley—which I use to include San Francisco—nurtures an incredibly high start-up creation rate (Zhang, 2003). The locational reasons behind the Valley's industrial success and high-tech agglomeration has been the subject of many academic papers and corporate white papers since the early 1980s (Saxenian, 1983, 1990, 1996; Hall & Markusen, 1985; Markusen & Bloch, 1985; Angel, 1991, 2000; Zook, 2002; Hellmann & Puri, 2002; Farlie & Chatterii, 2009; Harris & Junglas, 2013). Arguments have included positive feedback effects (Arthur, 1994), venture capital presence (Lee et al., 2000; Ferrary & Granovetter, 2009), knowledge spillovers (Jaffe et al., 1993; Audretsch & Feldman, 2003), highly skilled mobile labour (Saxenian, 1989a; Angel, 1991; Benner, 2003; Huber, 2011), exceptionally high employment turnover rates (Parden, 1981; Rogers & Larsen, 1984; Angel, 1991; Kenney, 2000; Koepp, 2002; Zhang, 2003), and niche culture (Delbecq & Weiss, 1990; Harris & Junglas, 2013). I use embeddedness in this chapter to explain why the regional economy of Silicon Valley has become a centre for technological, and now increasingly financial, development. Because the term can encompass a wide variety of factors (i.e. the processes listed before it), embeddedness is a useful theoretical tool for understanding how algorithmic (de)centralisation is reshaped through entrepreneurial activity.

Despite many endeavours (described below), Silicon Valley is incredibly hard to replicate thanks to a genealogy that is historically and geographically specific (Sturgeon, 2000): the economy has evolved contextually and contingently within specific networks that resonate together interdependently to amplify the economic productivity of the regional whole (see Appendix 13). The Valley first rose to fame in the 1950s for its silicon chip production and, while the technology sector has experienced a degree of turbulence in terms of its outputs, Silicon Valley's proven overall flexibility has allowed it to mutate with a rapidly changing industrial landscape. It did this predominantly by diversifying into

> …new industrial sectors such as personal computers (Apple) and software (Oracle, Sun Microsystems, Symantec, Electronic Arts, Intuit). Later, Silicon Valley gave rise to telecommunication equipment start-ups (Cisco System, Juniper Networks, 3Com) and finally to the internet industry (Netscape, Excite, eBay, Yahoo!, Google). Each new industry was supported by the previous industries. (Ferrary & Granovetter, 2009, 338)

Throughout, Silicon Valley has persistently been the envy of every declining industrial region (Markusen cited in Saxenian, 1981) and the standard setter for technological production (Gordon, 2001). With varying degrees of success, countless municipalities worldwide have thus attempted to imitate its cultural-industrial milieu and, in turn, its economic output (Malecki, 1981; Taylor, 1983; Miller & Côté, 1985; Saxenian, 1989b; Leslie 1993; 2000; McNeill, 2017). For example, Silicon Alley (New York), Silicon Docks (Dublin), Silicon Roundabout (London), Silicon Beach (Sydney), Silicon Glen (Central Belt, Scotland), and Silicon Cape (Cape Town) have all been modelled on the area.[6]

The primary difficulty of replication lies in the problem of 'synthetically injecting' deeply embedded relationships between firms that have been 'organically cultivated' over a long period of time. It is this geographical history of entrepreneurship that created Silicon Valley's fertile environment of industrial connections that can be called upon to support pioneers of technological enterprise. While this culture is difficult to export, it can be ethnographically examined to understand distinct nuances as well as the role of Silicon Valley as a technological-financial centre for the maintenance of blockchains. I argue that this strong cultural economic geography, or "institutional thickness" (Amin & Thrift, 1994), has a poignant effect on the trajectory of Bitcoin start-ups. The embedded connectivities of the space, that (dis)allow companies to grow, caters for radical technological ideas but also tames them so they are rendered manageable and profitable under the Silicon Valley model. Centralisation is very much part of this domestication: the absorption of start-ups within larger entrepreneurial networks, and by proxy, aspects of the Bitcoin protocol, dilutes radical disruption to pull the company in on itself as a centre of bureaucratic control.

[6] These spaces brandish the capitalised version of the word 'Silicon' to promote an imagery of high technology development that no longer refers to semiconductors but is more synonymous with high technology as a whole.

The concept of embeddedness helps ground economic theory back to the places of material action and cultural practice. However, it has become a fuzzy concept with a plethora of applications (Hess, 2004). It was first used by Karl Polanyi (1944, et al. 1957) to describe place-based, pre-market economies in opposition to more modern variations; he saw modern market economies as disembedded and disembodied from the tangibilities of place to the extent that they resemble abstract systems that can be modelled mathematically as a reflection of pure or rational sentiment. Subsequent scholars have worked hard to dismantle this vision of separated global markets by replacing it with an understanding of social relations and spatial ties being implicit to all economies (Granovetter, 1985; Hess, 2004). Here, economies are always assembled by a plethora of actors (traders, economists, tickers, computer screens, traders, paper, texts) that work together to bind and enact markets (Callon, 1998a, 1998b, 2007; Callon & Muniesa, 2005). Similar to Stephen Graham's (1998) theorisation of the Internet as a multiplicity of different networks, the 'global market' is composed of many networked spaces that are heterogeneously layered so that there are, in fact, a multitude of interlocking markets operating simultaneously on different scales.

It is these markets that bleed into each other to form the 'world economy' yet they continue to maintain (in part) their own distinct boundaries—for example, Islamic banking practices are conducted between certain citizens within the United States (Maurer, 2005) while nation state economies themselves retain unique characteristics (Whitley, 1999). When talking about the role of a specific space in economic performance, then, as this chapter does, it is important to understand linkages are maintained at different scales (not just the simplified local-global dualism). This is a "shift in the analytical focus, away from fairly abstract economies and societies towards the analytical scales of actors and networks of interpersonal relationships" (Hess, 2004, 170). Embeddedness then, as it is used here, must be understood within contextual specifics and socio/spatial/material/semiotic/political networks. Otherwise, nested and networked relationships are overlooked. In other words, researchers must pay close attention to how things are becoming embedded amongst other things (Pike et al., 2000) lest embeddedness becomes a slippery term. Adopting this actor-network approach, I define embeddedness as a concentration of spatially specific (dis)connections between an assemblage of humans and non-humans that work together to form economies. These relationships, I argue, play into the enactment of (de)centralisation.

The strong presence of Bitcoin firms in the San Francisco Bay Area is largely down to a continuation of the "historical process of embedding" (Dicken & Thrift, 1992, 287). Up until early 2012, Bitcoin companies were, for the most part, experimental projects with little to no capital investment run by opportunistic coders who had spotted a gap in an emerging market (Epicenter Bitcoin, 2015)—even in 2015 I was often handed a business card with the letters 'CEO' printed under the person's name to later find out they were the only person running the company.[7] Initially, Bitcoin start-ups were geographically dispersed due to the widely cast net of Bitcoin proponents collaborating online. As more and more companies appeared they started to settle into particular categories: wallet providers, exchanges, payment processors, mining companies, infrastructural development, financial services, and investors. At the same time the value of individual bitcoins continued to grow providing some companies with an injection of capital from their appreciating hordes. More importantly, for Bitcoin's cultural economy at least, by 2012 this embryonic industry had begun catching the eye of venture capitalists.

The lucrative potential of Bitcoin start-up companies entered the world stage when articles such as Bloomberg's "Meet the Bitcoin Millionaires" hit global headlines (Raskin, 2013). Investors first to the table included Roger Ver, Marc Andreessen, David Azar, Cameron and Tyler Winkelvoss, Barry Silbert, Wences Casares, Fred Wilson, Pete Briger, and David Marcus (Popper, 2015a). Most of the early companies, however, have since disappeared due to technical incompetencies, hacks, regulation procedures, a failure to scale, banks refusing to provide business accounts, a lack of demand for their services, or being revealed as scams. For example, BitInstant was shut down from a lack of compliance with US regulation, TradeHill was forced to close when their bank stopped servicing them, and Mt. Gox collapsed spectacularly from an astonishing lack of due diligence (see Chapter 5). The resilient few that survived, like Coinbase, Bitstamp, and BitPay, are now largely considered to be market leaders.[8] In 2013, with growing media attention and more readily available venture capital, they were joined by a second wave of start-ups (Ludwig, 2013). This pattern was explained to me by the managing partner of a cryptocurrency venture capitalist fund:

> Sometimes being an early mover is overrated. You can add up a lot of errors on your back. A lot of the early guys were passionate about Bitcoin but they weren't good entrepreneurs. It's not good enough to love Bitcoin. You've got to be a good operator, a good entrepreneur, and a good executive… This second wave consists of guys that have built companies before and are frankly more credible.

This trend was personified by the exponential rise in capital investment in the Bitcoin sector (see Figure 29): rising from 2.2 million in 2012, to 50.1 million in 2014 and 1.15 billion USD in 2016 (CoinDesk, 2016b, 2016c). The sudden landslide fell predominantly in one place: Silicon Valley (Young, 2015a; Popper, 2015b). By 2016 nearly a third of venture-backed Bitcoin companies were based in the area, which accounted for over half of all global venture capital streaming into the industry (see Figure 30).

---

[7] This romantically mirrors the genesis stories of hardware companies like Apple and Intel that were set up by a two men in a garage and software companies like Google and Facebook created by students in dorm rooms.

[8] As Amazon, Google, and eBay were following the dotcom crash.

[Image removed for copyright purposes]

Figure 29: Cumulative total of global venture capital investment in Bitcoin companies (CoinDesk, 2016)

[Image removed for copyright purposes]

Figure 30: Distribution of venture capital investment and number of venture capital backed companies between Silicon Valley and the Rest of the World at the start of 2014 and 2015 (CoinDesk, 2015, 2016c)

The cryptocurrency sector is not unique in this as Silicon Valley firms receive 41 per cent of the United States' venture capital total (Harris & Junglas, 2013). This concentration of investment has been a dominant force in the local technology industry since the 1950s (Saxenian, 1989a) and its embeddedness has been pinpointed as one of the key factors in the regional economy's success (Saxenian, 1983; Florida & Kenney, 1988; DiBona et al., 1999). Here, free-flowing investment fuels the development of new technology like no other place on the planet (Gershon, 2014).

The Mission District: A Crucible of Tension

Walk into most cafes in the San Francisco Mission District today and they will be filled row upon row of people tapping away on their laptops. A small but growing group that now sits amongst them are cryptocurrency proponents, many of whom adhere to the libertarian counterculture and liberal activism that has been flowing through the city's blood since the 1950s (see Chapter 3). Usually in the financial world hacking is relegated to credit card fraud and identity theft but for cryptocurrency proponents the recent evangelistic battle to wrench monetary control away from banks and place it into the hands of publics, in an almost Robin Hood-like manner, is changing this relationship. However, the practices involved for doing so comes with their own tensions as Bitcoin is caught uncomfortably between hacker and high tech culture.

A documentary called *The Rise and Rise of Bitcoin*, once described to me by a strategic advisor at a wallet company as "Bitcoin porn", outlines the conception and growth of the cryptocurrency through its adolescence from 2008 to 2013 (Mross, 2014). Throughout, start-ups are pinpointed as a key catalyst for Bitcoin's growth and normalisation. The filmmaker visits a hacker hotel—buildings otherwise known as hacker houses or hostels (McNeill, 2016)—called 20Mission situated in the Mission District of San Francisco to interview Jered Kenner, founder and then CEO of the US based Bitcoin exchange TradeHill. Not only did Kenner operate TradeHill from inside 20Mission, he was also the landlord of the 41-bedroom co-living and co-working space that housed mostly Bitcoin and other tech start-ups (Khoshaba, 2014; Gilbertson, 2015). The wider Mission District within which 20Mission sits, however, is not so accommodating—a trait that became particularly palpable during the dotcom boom when the city rose as one of the densest locational nodes for companies in the global Internet industry (Zook, 2005).

Away from the technology crowds I mixed with for my research, my social life led me to another world/space. The gentrification-fuelled inflation of rental rates perpetuated by an influx of 'techies' into the area had pushed my housemates deep into the Outer Mission and they had taken with them a disdain for workers in the tech industry.[9] On one occasion I ended up at a Mission District party in a fully functioning industrial warehouse that had been simultaneously compartmentalised into an illegal hostel secretly holding thirteen residents from all over the world in disguised rooms. Sitting on a mismatch of chairs encircling a makeshift table, I was initially met with a degree of hostility when I mentioned that I was conducting an ethnographic investigation within "Silicon Valley". However, when I explained I was examining the Bitcoin community, who brandish a hacker ethos that looks to wrestle the control of money from centralised institutions, the tone immediately changed. Here, the struggle for bottom-up disruption by hackers was endorsed but the top-down power of giant technology companies was vilified. Rightly or wrongly, Bitcoiners are often tarred with the same 'techie brush' as the latter.

In April 2015, I attended a book signing party for *The Age of Cryptocurrency* (Vigna & Casey 2015) held at 20Mission where I met Jared Kenner and many of the hacker hotel residents (see Figure 31). The

Figure 31: 20Mission book signing party for *The Age of Cryptocurrency*

[9] There had also recently been many house-fires in the Mission District that many blamed on their owners who, not being able to profit from gentrifying their buildings either because of rent control or zoning laws, were intentionally burning them down. These events exasperated the tension between long term residents and the migrating techies, whose presence was generating a demand for gentrification, because some locals had lost their lives from being caught in the blazes.

building had already become an integral component for the development of the Bitcoin community in San Francisco: it had once held the San Francisco Bitcoin Developers Meet-up but the group was forced to move because, as I was told by the meet-up's organiser, "the locals didn't like the idea of white techies hanging around".[10] Members of the Mission District community notified their municipality explaining that the lower floor was operating as an office space when it was legally zoned for retail. While Bitcoiners saw themselves as altruistic techno-philanthropists, flattening the financial structures of power with hacker ideologies, the local residents could not distinguish them from their technological cousins at Google or Facebook. Perhaps, though, there is no irony to this story as many of the countercultural hackers are becoming caught in the jetsam of capitalism (and centralisation) through the modes of their ambitious start-ups. These situated scenarios perfectly evoke the political tensions and contradictory perceptions of urban space and demonstrate how these intersect with Bitcoin and the wider technology industry. I now turn to highlight the persistence of the Californian Ideology in cryptocurrency cultures, particularly in Silicon Valley.

Blockchain Global Impact Conference: Cyberlibertarian Hangovers

On the 23rd March 2015 I attended the Blockchain Global Impact conference at Stanford University in Palo Alto (see Figure 32). The room was littered with key figures of the Bitcoin world from Bitcoin Core Developer, Peter Todd, to Erik Voorhees, founder of Satoshi Dice, Coinapult, and Shapeshift.io. Keynote speaker and cyberlibertarian political activist John Perry Barlow opened the conference. Barlow was a founding member of the Electronic Frontier Foundation (EEF), formed in 1990 to campaign for the preservation of personal freedoms and online civil liberties; he was a key figure for the cyberpunks, writing the Declaration of the Independence of Cyberspace in 1996 (see Chapter 4). The manifesto wielded the "social liberalism of New Left and the economic liberalism of New Right [that] converged into an ambiguous dream of a hi-tech "Jeffersonian democracy"" (Barbrook & Cameron, 1996, 14). Like Thomas Jefferson's allegorical tone of discovery and freedom that came with an expansion into the West of North America, cyberspace was conceptualised as an unchartered space of possibility and liberation (ibid.).[11] By "insisting on decentralization, multiplicity, plurality, and identity fragmentation, these movements rejected traditional forms of institutional authority (parental, educational, state) that were considered to be constraints on individual emancipation" (Ouellet, 2010, 182). With the widespread utilisation of encryption, many cyberlibertarians believed that "free-spirited individuals [would] be able to live within a virtual world free from censorship, taxes, and all the other

---

[10] The 20Mission ground floor has since been turned into a retail space for local artists and manufacturers. All of the products on the floor can be purchased with bitcoin—this is how I paid for my copy of *The Age of Cryptocurrency* a week earlier.

[11] This rosy rhetoric overlooks the genocide and displacement of indigenous populations in North America as well as the practice of slavery that were both crucial to Western expansion and the European colonisation of land (Barbrook & Cameron, 1996).

Figure 32: Conference hall for the Blockchain Global Impact conference at the Arrillaga Alumni Center, Stanford University

evils of big government" (Barbrook, 2001, 52). Unsurprisingly, the EFF became a "leading cheerleader for the individualist fantasies of the Californian [I]deology" (51). One might think that these chimerical tropes would have died off with the 2001 dotcom crash but they have, in fact survived it so that they continue to resonate in technology hubs around the word. In 2015, for example, a key figurehead for the EFF was headlining a Bitcoin/blockchain conference at Stanford University—a key academic institute that nurtured the empowering free-to-use DIY culture of the early Internet (Auletta, 2009; Hillis et al., 2013).

Barlow's speech held a nostalgic romanticism for the Internet's adolescence referring to it as, upon his initial discovery, a "nervous system" for a "collective organism of mind". Reminiscent of the historical anti-statist resistance from cyberpunks, alloyed with more modern twangs of resistance to government surveillance in light of Edward Snowden's revelations, his rhetoric carried the underlying message that "the Internet was always going to be on some level about freedom from authority". That being said, it was certainly a more sobering account of cyberlibertarianism than its historical incantations—Barlow even claimed that upon writing his declaration he actually "knew better" than to expect an ungoverned global digital space but thought it would be a good idea to subvert "the greatest surveillance tool ever devised as a liberty granting utopia". Whether this is true or not matters less than what actually happened: the Internet became swamped by enterprise. Yet Californian Ideologues tend to champion the dominance of corporations as expressions of the market: a necessary and unadulterated power. This aligns the 'free' market with personal 'freedom' so that positions of power, 'voted for by dollars', are seen as legitimate. The capitalisation of cyberspace echoes sentiments of Walter Wriston's (1992) *The Twilight of Sovereignty: How the Information Revolution is Changing Our World* that sees unregulated markets as a mechanism that can "take over the responsibility of running much of society from the politicians" (Curtis, 2011). From this Hayekian viewpoint, government-imposed democracy is tyrannical whereas market-imposed democracy embodies true freedom representative of 'the people'.

The cyberlibertarian vision of economic freedom has translated into blockchain discourse with substantial potency. Erik Voorhees, for example, who later that day talked on alternative economies, sees the enrolment of citizens into the banking industry via state-enforced currencies as a form of coercive centralisation (Voorhees, 2015). However, from his point of view, financial services offered by different Bitcoin companies instil a just market-based centralisation. This distinction, he claims, is crucial: in a world of centralised Bitcoin companies, freedom of choice keeps them from acting with impropriety and thus "Bitcoin enables users to withdraw into the neutral pasture of decentralized finance at any time, which means that any centralized service within the sphere exists only at the pleasure of its customers" (ibid.). Here, the "key to judging the legitimacy of centralization is always the ability of users to opt out" (ibid.). Under this definition, it is the choice available to use other services that makes an industry decentralised and the intrusion of the state that imposes a corrupt form of centralisation. Overlooking or legitimising the power of centralised private companies is a common cultural trait within the cryptocurrency community: a cyberlibertarian hangover that persists.

Incongruities like this are promoted by successful Silicon Valley entrepreneurs who continue to see the digital as a new frontier separate from material space. Peter Thiel, the founder of PayPal and early investor of Facebook, promotes this disconnect, seeing technology as a means for moving beyond the political into "some undiscovered country" that creates "a new space for freedom" (Thiel, 2009). He states:

> In our time, the great task for libertarians is to find an escape from politics in all its forms—from the totalitarian and fundamentalist catastrophes to the unthinking demos that guides so-called 'social democracy'… In the late 1990s, the founding vision of PayPal centered on the creation of a new world currency, free from all government control and dilution—the end of monetary sovereignty, as it were. In the 2000s, companies like Facebook create the space for new modes of dissent and new ways to form communities

> not bounded by historical nation-states. By starting a new Internet business, an entrepreneur may create a new world. The hope of the Internet is that these new worlds will impact and force change on the existing social and political order… We are in a deadly race between politics and technology… The fate of our world may depend on the effort of a single person who builds or propagates the machinery of freedom that makes the world safe for capitalism. (ibid.)

Thiel's claim that PayPal releases citizens from the monetary control of nation states is also a lasting spectre and delusion of the Californian Ideology (see Appendix 14). Despite its cyberlibertarian goals, the increasing impotency of the company in continuing to achieve them as it matured was even recognised by Barlow at the Blockchain Global Impact Conference:

> PayPal came along and it was a pretty good shot at it but they really, at the last critical moment, did decide that it was better, whatever their philosophical beliefs, to be an incredibly successful company and become ridiculously rich than to fight over the principle that had been the downfall of many people, like David Chaum, up until then.

If stubbornness over political principles killed Chaum's DigiCash (see Chapter 3) then it was the malleability of Thiel's PayPal that allowed it to succeed. In Silicon Valley, technological liberation is held up like a beacon of power-opposition while the industry overlooks its own role in promoting new technologies of control that perpetuate the capitalist system. It was with an insightful conclusory remark reflecting this notion that Barlow ended his speech, announcing to the room that they were "designing the architecture of liberty and enslavement both in these tools that are being derived around the blockchain".

Bitcoin Meet-ups: Hackers vs. Suits

The point in the Californian Ideology where libertarianism and capitalism meet is a powerful intersection. As such, from the inside, Silicon Valley is not so much a monoculture as Rebecca Solnit's (2014a, 2014b, 2016a) writing and the previous discussion on the Mission convey (see also Appendix 15).[12] There are, upon closer inspection, different ecosystems that are somewhat separate but overlapping at work, from sectors in the regional economy (venture capital firms, law firms, etc.) to coding practices (Angular JS, Python, etc.). This bricolage was evident within the Bitcoin community as explained to me by the COO of a Bitcoin start-up based in Sunnyvale:

---

[12] Although it is certainly true that in comparison to the rest of San Francisco tech culture appears to be a xenolithic cultural intrusion.

> It's really interesting to see how many different lines there are. Because there are efficiency nuts to "I just want my payments better" to like "fuck the government, don't pay taxes". To "I want my drugs" or "I love cryptography"… Right now everyone's together and we're united by a desire to create a Bitcoin economy. Once the Bitcoin economy is created there's less… holding all these people together.

The sheer quantity of Bitcoin and blockchain meet-ups in the San Francisco Bay Area during my research also reflected this diversity.[13]

Meet-ups started emerging in 2011 when Bitcoin proponents, who had previously only gathered online, began seeking each other out face-to-face. The groups became important venues for community building and acted as a springboard for the creation of some early Bitcoin start-ups (Fletcher, 2013). They started out as a loose handful of enthusiasts talking over beers but many have now evolved into more formalised, focused, and goal-orientated events with specific weekly agendas, particularly in Silicon Valley. As spaces that facilitate dense networks among many different strands of both the Silicon Valley and Bitcoin communities, meet-ups were an extremely useful entry point for my snowball sampling.

The first meet-up I attended in the Bay Area was the same San Francisco Bitcoin Developers Meet-up that had been ostracised from 20Mission. That Sunday morning they were meeting in the SoMa district at StartupHouse—a building that rented out space to small companies and group events such as this one. At the door I met a man who had programmed a Bitcoin client that uses the coding language Python as opposed to Bitcoin's C++. Together, we entered the building that emanated a rustic décor: an aesthetic that had become popular in the dotcom era due to the limited finances of start-up companies and the availability of large urban building spaces, such as lofts and old industrial warehouses, that had lost their primary function with the deindustrialisation of city centres (Ross, 2003; Indergaard, 2004). Here, however there was an inauthentic and contrived unfinishedness about the place: a regurgitated romanticism and imaginary of what 'start-updom' should look like. The exposed bricks, open pipes, and naked fittings looked as though they had been searched for and intentionally revealed instead of simply being left uncovered due to the added costs of concealing them (see Figure 33). The iconic traditional imagery of the start-up that emerged as a spatial necessity underwritten by a lack of funds was purposefully being reproduced in its own historical-cultural image to promote a sense of authenticity. Although many companies now have the capital to escape from

---

[13] These included the San Francisco Bitcoin Meetup; San Francisco Bitcoin Meetup Group; San Francisco Bitcoin; SF Bitcoin Devs; Bitcoin/Cryptocurrency Mining Group (SF Bay Area); Digital Currency Entrepreneurship & Startups (Bay Area); Women in Bitcoin (San Francisco); SF Ethereum Meetup; Decentralized Autonomous Society Meetup (Palo Alto); Future of Payments; Brettonwoods: Trade Cryptocurrencies' Proof of Drink; Berkeley Bitcoin Meetup; East Bay Bitcoin Meetup; Silicon Valley Bitcoin; Silicon Valley Ethereum Meetup, and; Stanford Bitcoin Meetup. However, some of the groups had already become inactive by the time I arrived in the Bay Area and many others have popped up since.

Figure 33: San Francisco Bitcoin Devs Hack Day at StartupHouse, SoMa

techno-bohemia it lives on through the material culture of office space that creates a (pseudo)impression of creativity; an aspirational hangover of commercialism.

Upon entering a room at the back of the building I took a seat around a long table where a small group of programmers (it was Sunday after all) sat around me, coding and taking notes on their laptops. I mentioned to the developer next to me that I was impressed by the variety of meet-ups in the Bay Area to which he laughed and said "I used to go to all those other social meet-ups before they were infiltrated by suits". Some of the groups had become a direct meeting point for both the more disruptive 'hacker' and the more capitalist 'suit' but this space undoubtedly belonged to the coding crowd—I was the only one in the room who was not a software developer—stimulated by the intellectual challenges of Bitcoin technology and its promises of freedom from control.

The meet-up was titled "SF Bitcoin Devs Hack Day: Proof-of-Stake and its Improvements". A developer for the cryptocurrency NXT was giving an in-depth talk on the dynamics of its consensus algorithm while everyone else chimed in collaboratively. In that small room I was struck by the focus of the developer-centric betterment of concepts that were at the frontier of this new technological

[Image removed for copyright purposes]

Figure 34: Stellar present at the SF Bitcoin Devs Meet-up in Galvanize, SoMa (Lewis, 2015)

arena.[14] Attendees were there to learn, solve problems, and extend knowledge collectively. Industry leaders that are invited to talk at these events do not just impart wisdom; knowledge is created and developed in these sites amongst a tight group of specialist and non-specialist programmers.[15] Five hours of poking holes in models, critiquing theories, proposing new ideas, and solving problems (intermitted with updating each other on topical developments in the Bitcoin world) meant the attendees, many of whom worked at other Bitcoin-related start-ups, left with a greater understanding of the topic at hand and with new concepts to utilise. Additionally, the situated industry knowledge and coding practices were often recorded and posted online in an effort to promote open source software development on a global level and benefit the Bitcoin ecosystem as a whole.

I continued attending the SF Bitcoin Devs meet-up over the coming months. At one such event, a former Google Wallet employee and now developer at cryptocurrency start-up Stellar was giving a presentation titled "Advanced Stellar Development for Bitcoin Developers" at Galvanize in SoMa (see Figure 34). The meet-up came weeks after a lengthy article in *The Observer* that described Stellar as a blatant Ripple fork (Craig, 2015): CEO Jed McCaleb had previously co-founded Ripple (and before that Mt. Gox) but had left to start another company with his girlfriend, and Executive Director of the new

---

14 Beforehand, I had only been to Bitcoin meet-ups held in pubs.

15 For companies that actively present at meet-ups there is a certain trade-off between showing their cards and keeping them close to their chest. While it is beneficial for the industry as a whole if companies share knowledge and develop ideas collaboratively, the individual Bitcoin firm must also stay competitive. Even inside firms, there are levels of clearance to company information for certain employees as I learnt working inside a number of Bitcoin and blockchain start-ups. With such mobile labour coming and going in start-ups (Saxenian, 1989a; Angel, 1991; Benner, 2003; Huber, 2011) this is a tightrope for the Bitcoin firm to navigate.

enterprise, Joyce Kim.[16] Stellar builds on Ripple's functionality by acting as a platform that provides gateways between different world currencies including fiat and cryptocurrencies. As the attendees sipped on bottles of IPA and ate slices of pizza, paid for by the start-up BitPay who sponsored the meet-up, the SF Bitcoin Devs organiser opened by announcing that there was a "rock star in the room". Someone jokingly asked if it was Satoshi Nakamoto to which the organiser replied, "No, it's his cousin Jed McCaleb!".[17] Behind me sat McCaleb and Kim, figureheads of their new company (see Figure 35). When the presentation was over they both engaged with the open discussion that followed. Kim addressed the room by explaining that the attendees were "a unique breed of devs because [they had] picked an area that is one of the hardest industries to build a company in due to regulatory frameworks and because people are so attached to how they deal with money". Subsequently, Kim explained that their biggest impact would be in the developing world where inferior and fragmented monetary systems underserved citizens.[18] This is part of a wider shift in narrative described to me by a

[Image removed for copyright purposes]

Figure 35: Me, Jed McCalleb, and Joyce Kim (Lewis, 2015)

[16] The piece explained that there were 177 instances where Ripple and Stellar's (open) source software was identical not to mention that the word "Ripple" repeatedly appeared in Stellar's code. This was evidence given as an obvious copy and paste job from Ripple's open source repository on GitHub and a failed search-and-replace command by Stellar's developers (Craig, 2015).

[17] To some in the room this may have had an unintended weight as Kim, who had also presented at the Blockchain Global Impact Conference a couple of weeks earlier, had allegedly spread rumours that McCaleb was Satoshi as a marketing ploy during her short vocation at Ripple (Craig, 2015).

[18] It is worth noting here that there is a degree of dislocation between this emancipatory narrative and the uptake of cryptocurrencies in the developing world. During my time working at a Silicon Valley Bitcoin start-up I handled a marketing scheme directing their service towards countries that had experienced internal currency problems such as Greece, Argentina, and Zimbabwe, as well as unbanked populations in Africa, South America, and Asia, and countries with high a proportion of migrant workers that send money home through Western Union such as the Philippines. Despite efforts made by companies to promote Bitcoin as a currency solution in these countries, uptake has been extremely underwhelming. Enforcing new and alien currencies on populations in a top-down manner neglects how value is culturally constructed and can therefore be rejected as forms of money like the colonial French Guinea in West Africa (see Appendix 5). Perhaps there are more poignant lessons to be learned from the smooth bottom-up adoption of M-Pesa.

Bitcoin consultant who explained that the industry had gone from "fuck the banks and destroy fiat currency in 2012 to more bubbly things like banking the unbanked and facilitating remittances". Anarchy was already being repackaged for a sanitised corporate environment.

Jed McCaleb has been described as a "pure coder" whose crowd "market themselves as libertarian idealists who will pry the grubby fingers of the capitalists from their pristine idea of a frictionless currency" (ibid.). However, this incongruity is not alien to cyberlibertarianism: by "promiscuously mixing the New Left and New Right together, the Californian ideology attracts those individuals who hope that they're smart—or lucky—enough to seize the opportunities presented by the rapid changes in the technological basis of social production" (Barbrook, 2001, 55).

Adding to the oxymoron of 'corporate hackers' is a simple predicament: the start-ups constructed by such 'anarchists' need to be banked—from simply holding accounts to attracting investments. In the cryptocurrency world there has been a common problem for banks to refuse Bitcoin companies their services.[19] The saviour for many of them is Silicon Valley Bank (SVB) who have provided accounts and investments for big names in the Bitcoin sphere, such as Coinbase and Xapo—taking risks among regulatory uncertainty where other banks have refused. In a chance encounter on the CalTrain, a railway that carries commuters up and down the spine of Silicon Valley between San Francisco and San Jose, I met a Vice President of SVB who focused on their pre-seed and seed funded start-ups in San Francisco. She clearly outlined the importance of connecting and funding these sapling companies for the success of both the bank and its start-ups.

Even the most libertarian hacker needs banking contacts if they are to succeed in making their company dreams a reality: "when these guys get together they have to talk disruption, disruption, disruption, blowing everything up, and they are just full of themselves. But then they've got to get on a plane and go to New York looking for capital because it ain't coming from anywhere else" (Craig, 2015). It is this same crowd who "make things uncomfortable with the exact starched shirt banker types" (ibid.). This friction between coders and bankers is emblematic of the Bitcoin cultural economy where both worlds enigmatically collide. I encountered this many times at meet-ups, conferences, and FinTech Expos: watching 'collars' and 'no-collars' (suits and t-shirts) mingling in the same room as they looked to benefit from their alien counterparts[20]. This

> …dichotomy affects all of Silicon Valley to some degree—blasphemous "Jobs Couldn't Code" T-shirts have even been spotted. Coders and purist disruptors are automatically cool; dealmakers and executives are tolerated but lame. This dynamic affects financial tech more

[19] For example, TradeHill were forced to shut down operations after their bank closed down its business accounts.

[20] "No-collar" is a term first used by Andrew Ross (2003).

> than any other sector. The need to present a pinstriped and responsible visage to the most highly regulated industry in the world faces off against the need to appear revolutionary when recruiting talent to actually build the systems. (ibid.)[21]

The financer and the innovator depend on each other for success. They collide in a productive storm that pushes the concepts reified in their start-ups forward into the economy to chase profit: a productive friction.

In such a volatile ecosystem, the Bitcoin meet-up is an essential space for binding the community together and creating important links for the successful growth of the Bitcoin start-up economy. They act as bridging spaces that bring together a multifaceted community under one banner. Organisers have repeatedly told me that the value of meet-ups lies in their ability to be a productive platform for networking.[22] A CEO at a blockchain company, that builds smart contracts on top of the Ethereum blockchain, described to me the strength of this embedded ecology:

> So basically you need some sort of ecosystem right? So you need somebody who can plug you in. Somebody who can introduce you to investors, introduce you to potential customers. In order to get those things there has to be some sort of active ecosystem. You mentioned meet-ups. So there has to be some sort of culture of people who are interested in these things, who get together. So here there's a fintech movement, sort of, if you will. Like last night we went to BNY Mellon innovation labs. So they had a meet-up there and I met some interesting people, made some good connections. And so BNY Mellon has a

---

21 Similarly, there is a classic scene in the HBO series, *Silicon Valley* (Altschuler et al., 2014), where a struggling investor, Erlich Bachman, is speaking to the CEO of a start-up that he has invested in, Richard Hendricks:

Bachman: When I sold my company, Aviato, I wanted to give back. That's why I started this place, to do something big, to make a difference, you know, like Steve.

Hendricks: Jobs or Wozniak?

Bachman: [Pause]

Hendricks: Er, Steve Jobs or Steve Wozniak?

Bachman: No, I heard you.

Hendricks: Which one?

Bachman: Jobs.

Hendricks: Well, I mean, Jobs was a poser. He didn't even write code.

22 I noticed a certain global overlap at Bitcoin meet-ups as I attended them in the San Francisco Bay Area, New York City, London, Washington DC, and Sydney. I would bump into the same people in different parts of the world—as Bitcoiners moved around they would attend meet-ups in other cities and countries to help extend their networks.

> blockchain kind of program and would get in contact with those kind of people. I would not have been able to do this anywhere else.

Such an ingrained industrial ecosystem with spaces of overlap between different layers is a crucial feature of Silicon Valley. The term "knowledge spillover" (Audretsch & Feldman, 2003; Woodward et al., 2006; Huber, 2011) has been used to capture cross-firm learning networks (Benner, 2003). Meet-ups act like a receptacle for catching this knowledge as well as a melting pot for mixing disparate actors in an embedded networked cultural economy. This is particularly useful for smaller, unstable start-ups (Jansson, 2011), who have not yet received venture capital, because meet-ups act as a support network in a volatile industry as well as an avenue for cultivating networks to find investment. Ultimately, though, those without investment usually fade away so that the venture-backed start-up remains the main model for disruption in the Bitcoin sector that embeds blockchain practices in more specific geographical spaces.

Bitcoin Start-ups: Tying it all Together

Cryptocurrency companies are relatively unique in the FinTech world in that they rest upon an open source, free-to-access algorithmic protocol developed via consensus. Bitcoin, with its own mechanisms of algorithmic fiscal policy, public cryptographic ledger, network neutrality, open source code maintenance, dispersed mode of transaction clearing, pseudoanonymous privacy model, and consensus-based governance structure, facilitates a medium of exchange non-reliant on centralised parties. With this in mind, Bitcoin can be viewed through a particular lens: its role as a form of global codified currency commons. In other words, a public-owned and regulated shared pool of currency that can be used by people across the world. The purpose of Bitcoin therefore is to create an ontologically flat transaction platform that neutralises power within the network via distribution. It is, however, a commons with a catch—participants must be relatively well versed in programming languages and cryptographic key management to operate their own finances securely, using a personal copy of the Bitcoin protocol. What's more, potential users must buy-in or mine-in to the currency—this creates significant technical and acquisitional barriers to entry. These impediments have presented opportunities for start-up companies who have positioned themselves to enclose this currency commons by building centralised software systems, or gateways, on top of the blockchain (see Chapter 5).

Companies streamline access for non-programmers by providing user-friendly on and off ramps while accumulating capital from fees in the process (see Figure 36). Yet they also acts as valves for Bitcoin transactions controlled by a small amount of experts and these networks have a wider role of making the Bitcoin blockchain calculable. Blockchains may provide their own global forms of information but,

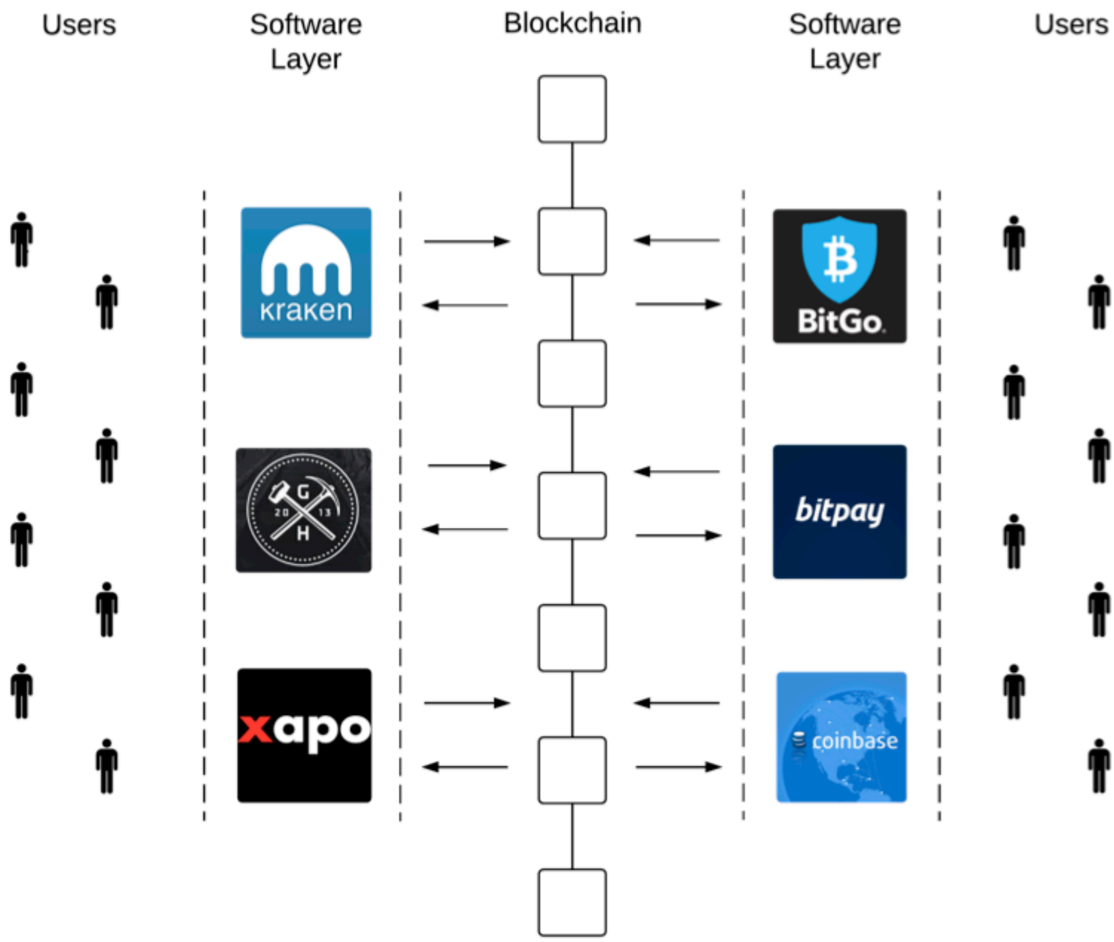

Figure 36: Layers of software built on top of the Bitcoin blockchain that interact with the protocol on their customers' behalf creating channels (or bottlenecks) of user activity

as it is with more traditional finance, a second layer "akin to interpretation/evaluation/judgement… requires a complicated mixture of elements—the social infrastructure for global connectivity— which gives major financial centers a leading edge" (Sassen, 2005, 27). It is here that centralisation becomes important for blockchain economies. Although the blockchain is a distributed ledger of information, more complex, stratified, and meaningful visualisations of this data are compiled by monitoring software developed by centralised companies. These centres of calculation create silos of private information not available on the public blockchain and clusters of them in Silicon Valley make it a consolidated centre for such activity—a localised network of experts.

Venture Capitalists: Global Signallers

Networks of knowledge/capital are as much historical as they are geographical and many scholars have recognised the presence of venture capitalists as a key factor for Silicon Valley's on-going success and ability to innovate (Saxenian, 1983; Florida & Kenney, 1988; DiBona et al., 1999; Lee et al., 2000;

Ferrary & Granovetter, 2009). Adam Draper is a third generation venture capitalist that runs Boost VC out of "Draper University of Heroes" in San Mateo. His father, Tim Draper, is the managing director of VC firm Draper Fisher Jurvetson and is famous for coining the term "viral marketing" (Sparkes, 2015). Going back further, his grandfather, William Draper, author of *The Startup Game* (Draper, 2011), created the first West Coast venture firm in Silicon Valley with Horace Gaither and Frederick Anderson in 1958 (Florida & Kenney, 2000; Zhang, 2003; Ferrary & Granovetter, 2009). The family has since moved into the Bitcoin space: in 2012, Adam Draper moved to position himself as one of the first investors in Coinbase (Money & Tech, 2014). The Drapers later became the owner of a vast quantity of bitcoins. When the FBI arrested the founder of Silk Road, Ross Ulbricht, in October 2013 they seized roughly 150,000 bitcoins and in June 2014, the US government sold 30,000 of them in a blind auction to a group of pre-registered bidders when their value was around $19 million USD (Keneally, 2014; Rizzo, 2014; Rizzo, 2015a; Sparkes, 2015). Tim Draper won the bid and Adam has since financed Bitcoin start-ups with those purchased bitcoin at his community-driven accelerator, Boost VC—each company receiving $15,000-25,000 USD worth of bitcoin in return for a 6% share (Epicenter Bitcoin, 2015).[23] At Hero City, Draper University, a group of over twenty start-up companies, what Draper calls "tribes", periodically live and work together for three months in the same shared living and office space to help grow their businesses (see Figure 37).

Silicon Valley is a hotbed for investors like the Drapers who retain an enormous amount of entrepreneurial knowledge and draw upon a vast industrial network. As such, their investments act as signals to the rest of the world, indicating the next big start-ups and innovative new technologies (Ferrary & Granovetter, 2009). This creates a form of global centrality towards which smaller investors' heads are turned: all eyes rest upon Silicon Valley. The words/actions of prominent venture capitalists, therefore, have a normalising effect on what can first appear to be quite radical technologies, such as Bitcoin, by signalling them as revolutionary. For example, Marc Andreessen, cofounder of Silicon Valley-based Andreessen Horowitz, widely regarded as one of the world's largest venture capital funds (Schonfield, 2011; Vanity Fair, 2011), compares Bitcoin to other historically revolutionary technologies in a cri de couer featured by *The New York Times*:

> Eventually mainstream products, companies and industries emerge to commercialize it; its effects become profound; and later, many people wonder why its powerful promise wasn't more obvious from the start. What technology am I talking about? Personal computers in 1975, the Internet in 1993, and—I believe—Bitcoin in 2014. (Andreessen, 2014a)

Elsewhere, his words have resonated with a maturation process that I have repeatedly framed in this chapter with the heuristic device of the Californian Ideology:

---

[23] Adam once had an ambitious plan to fund 100 Bitcoin companies by 2017 (Cawrey, 2014).

> I think the relevant comparison point for Bitcoin is actually 1994 for the consumer Internet… [I]t was really fringe, and really weird, and really new, and really scary, and really odd… I don't know how you get fringe technology without fringe politics and fringe characters. You just have to go through a maturation process where you come out the other end and the fringe technology goes mainstream and gets widely adopted. Along the way, the fringe characters and fringe politics tend to get alienated and move onto the next fringe technology. (Andreessen, 2014b)

This quotation formed part of a fireside chat at CoinSummit: an invitation-only conference designed to "connect virtual currency entrepreneurs, angel and VC investors, hedge fund professionals and Bitcoin enthusiasts" (Rizzo, 2014). Because Andreessen is a highly influential entrepreneur, investor, and software developer, having gained renown as a pioneer within the early Internet revolution by founding a number of successful companies such as Netscape, his words carry significant weight around the world. If his firm is viewed as a centre of calculation and successful investing, then Andreessen acts as a mouthpiece for a small group of experts that make informed and profitable decisions (Latour, 1987;

Figure 37: Hero City at Draper University in San Mateo

Tkacz, 2015). This again depicts how venture capitalists such as Andreesen and the Drapers play an important role as global signallers for upcoming successful start-up companies (Ferrary & Granovetter, 2009).

Examples abound. Atlanta-based BitPay were not looking for investment when Founders Fund approached them as potential financiers. They decided the opportunity to have such experienced entrepreneurs as Peter Thiel, Ken Howery, Luke Nosek, and Brian Singerman come on board was something they could not afford to miss out on (Lunden, 2013). Greylock Partners, whose investment team includes Max Levchin (investor in Pinterest, Yammer and Yelp) and Reid Hoffman (co-founder of LinkedIn and investor in Zynga, Facebook, Airbnb and Flickr), joined a $20 million USD Series A round in wallet company Xapo with Index Ventures and previous key investors Benchmark, Fortress Investment Group, and Ribbit Capital (del Castillo, 2014). Mining company 21 Inc., created by Balaji Srinivasan and his four cofounders, received $116 million USD in 2015 after a more secretive Series A round in 2013 that included personal investments from Peter Thiel, David Sacks, Marc Andreessen, Ben Horowitz, and the Winklevoss twins (Popper, 2015c). When rounds made by high profile venture capitalists are public, they act as votes of confidence for Bitcoin, instilling greater confidence and encouraging other investors to follow suit.

Technological Normalisation through Embeddedness

Risk-taking is normal, encouraged, and even glorified in Silicon Valley thanks to the endless list of success stories from pioneering companies such as Apple, Intel, Facebook, Google, and so on. Those brave enough to break off from technology giants and start their own projects are endowed with social value. This is exactly how Bitcoin wallet and exchange company Coinbase were formed. As a previous web entrepreneur, CEO and cofounder of Coinbase, Brian Armstrong, was no stranger to starting his own company (cofounding UniversityTutor.com in 2004 and founding BuyersVote.com and FreedmailPro.com in 2009). Armstrong was also one of the first 100 employees at Airbnb where he was working in San Francisco until he left to form Coinbase in 2012 (Epicenter Bitcoin, 2015). That year he met Adam Draper, managing director of venture capital firm Boost VC, at a coffee shop in Mountain View to pitch his company for financing. Impressed by Armstrong's vision, Draper contributed a $600,000 USD seed round investment with Garry Tan, Greg Kidd, Alexis Ohanian, Y Combinator, and FundersClub (Draper University, 2014; AngelList, 2016). Coinbase has since received $225.3 million USD from 38 investors in six rounds that include Andreesen Horowitz, Ribbit Capital, and the New York Stock Exchange (Crunchbase, 2018). The company is now a FinTech unicorn last valued at $1.6 billion USD in August 2017 (Raza, 2018). More recently, following a 1940% surge in a single bitcoin's value from $997 up to $19,343 USD over the course of 2017, the company generated a turnover of over $1 billion USD spurring a wave of interested investors that the company had to warn away from its employee's shares (ibid).

With such a dense concentration of venture capital, Silicon Valley generates a pull factor for the agglomeration of technology companies to the area (Hall & Markusen, 1985; Zook, 2002; Hellmann & Puri, 2002; Sturgeon, 2003; Harris & Junglas, 2013).[24] Some of the smaller Bitcoin start-ups I interviewed had specifically moved to the Valley hunting for capital or to take advantage of investor networks that they had already secured; others, like Coinbase, had emerged from the dense technological milieu themselves. Like financial firms in global cities (Thrift, 1994; Sassen, 2005), venture capitalists run in the same circles promoting collaboration as well as competition to ensure a rising tide lifts all boats. These "strategic alliances" (Sassen, 2005, 29) are often achieved through joint ventures, as explained to me by the managing partner of an investment firm in 2015:

> We have about 15 Bitcoin CEOs as our clients and another 35 operating companies. So we have a network of 50 Bitcoin CEOs, which is kind of an unparalleled resource in the sector. We position ourselves as a blockchain-dedicated investment firm—we don't compete with other venture firms. We want to be a value-added co-investor that brings a lot of domain expertise in a given syndicate or financing… So we cooperate with Boost quite a bit. We work with Pantera quite a bit. Barry Silbert at Bitcoin Opportunity Corp. We're all in a lot of the same deals. And those four groups are the only dedicated Bitcoin investors around.

The firm preferred companies to be local so that they could better keep track of progress and "get a feel for the culture in their office environments". This provinciality is important because it begins to unwind the dense proximate networks within which venture capitalists are deeply embedded and continually harness to increase the stability and success rate of their investments.

During my fieldwork I became friends with a couple of start-ups in Tribe 5 of Boost VC who had come from all over the world to be incubated at Hero City. During my visits, it was extremely evident that the venture capital firm was a connector as much as an investor (Ferrary & Granovetter, 2009). The companies were constantly thrown into the fray of Silicon Valley and encouraged to build a strong network of other investors and entrepreneurs that could benefit their companies and, by proxy, Boost VC. More than just the monetary fuel for innovative companies, venture capitalists, then, become partners and mentors while providing access to a secondary economy that simultaneously lives off and

---

[24] Many of these venture capitalists are equity holders from earlier successful start-ups who have previously made a fortune and continue to found and mentor new companies.

supports the high tech economy in a mutually dynamic symbiosis (Kenney & von Burg, 2000, 2001).[25] Venture capital firms, therefore, act as an obligatory passage point for connecting start-ups to "universities, large firms, research laboratories, [other] VC firms, law firms, investment banks, commercial banks, certified public accountants (CPA), consulting groups, recruitment agencies, public relation agencies and media" (Ferrary & Granovetter, 2009, 335). In short,

> …the deeply embedded venture capitalists are embedding agents for the isolated entrepreneurs they back… VC firms are the main hubs between entrepreneurs and the complex networks of Silicon Valley. They enable interactions between interdependent economic agents. They do this because the profitability of their investments depends on these interactions. Entrepreneurs have access to information, resources, service providers and business partners through their investors. (Ferrary & Granovetter, 2009, 352)

Despite Bitcoin's image as a distributed, spaceless, and self-governing algorithmic protocol, start-up companies, that are often crucial for breaking down technical barriers between the blockchain and wider markets, are fundamental in the embedding process of local ties necessary for the success of technology entrepreneurs. Such a concentration of these centralised institutions in Silicon Valley highlights it as a centre of industry practice and knowledge where webs of influencers can act as financial and informational valves. In this crucible, as a start-up is embedded into denser and denser networks, a process of technological normalisation dilutes the radical and disruptive potential of its services. In other words, there appears to be an unavoidable fate awaiting disruptive technologies in cultures of entrepreneurship that domesticate the 'libertarian hacker'. I initially demonstrate this by stepping back in time to foreshadow any blockchain industry developments with a narrative of a famous precursor and, perhaps, earliest success story of a modern day 'radical' FinTech company: PayPal.

In 1998, amidst the frenzy of the dotcom bubble, Peter Thiel, and Max Levchin launched a start-up called Fieldlink that facilitated digital payments based on cryptographic software applied to personal digital assistant devices that would later evolve and merge to become PayPal (Jackson, 2004). The mission statement of the company was that of a deeply libertarian-fuelled disruption led by CEO Peter Thiel who had gathered a wariness of concentrated government power as he grew up in the Bay Area (Packer, 2011; see Appendix 16). This distrust of fiat currency revolved around its vulnerability to nation state corruption of monetary policy. The contours of Thiel's politically charged ideology bear a striking resemblance to early posts that echoed around the Bitcoin Forum as well as Satoshi Nakamoto's own rhetoric—there has even been speculation online that Nakamoto could be any

---

[25] Silicon Valley has already begun evolving to cater for the Bitcoin and blockchain industries evident by the specialisation of legal firms within this rapidly evolving field.

number of PayPal's old employers (Hacker News, 2013). The management team drank from the same anti-statist cup of the cypherpunks and shared similar literature: required reading "among the group was Cryptonomicon, written by the cyber-punk author Neil Stephenson—a cult novel among hackers, which imagines an anonymous internet banking system using electronic money" (Brown, 2014).

With the rise of copycat competitors, Thiel unleashed an aggressive marketing campaign in an attempt to achieve the 'network effect' as quickly as possible: a theory that involves enrolling a critical mass of the market so that "the more numerous the users who use a platform, the more valuable that platform becomes for everyone else" (Srnicek, 2017, 45). In other words, a "large, established network is very valuable to enter and very costly to leave; in essence it locks in its members and prevents would-be competitors from getting off the ground" (Jackson, 2004, 41). This was a turbulent time for the ambitious company and libertarian politics started to take a back seat as they became secondary to expansion and, by proxy, survival.[26] Some growing pains included "[s]cheming Mafioso, capricious regulators, opportunistic lawyers, savvy online identity thieves, volatile capital markets, [and] antagonistic press" (Jackson, 2004, 3). As the company turned to face these pressures they were forced to respond with increasing standardisation procedures.

Both PayPal and its customers became victims of fraudulent activity and the company responded by implementing sophisticated fraud deterrent and detection mechanisms that were welcomed by users (Jackson, 2004). From a different direction, increased pressure came via Mastercard and Visa, who PayPal still dealt with behind the scenes, to tighten up regulation compliance (Brown, 2014). Elsewhere, legal battles with state jurisdictions demanded a degree of accountability and when the company pushed for an initial public offering in a volatile climate, following the collapse of the dotcom bubble, they had to start playing by the rules of institutions such as investment banks, legal firms, and the Securities and Exchange Commission (Jackson, 2004). On completion, business interests also had to start reflecting the shareholder's interests. Then, in 2002, PayPal was bought by eBay for $1.5 billion USD. Here, it was enveloped further into a rigid and bureaucratic corporate structure lacking the same "audacious goal of empowering individuals by revolutionizing world currency markets" (Jackson, 2004, 256). As the company grew it was forced to shed its "original vision of global currency liberation" (Jackson, 2004, 226): disruption had been softened and sidelined for the bureaucratic boardrooms of big business. Indeed, most entrepreneurial activities "rely on bureaucratic routines for sustenance, whether these are embedded in software packages, organizational knowledge, or highly complex logistics" (Clark & Thrift, 2005, 239).

---

[26] This struggle stimulated a corybantic rotation of upper management that saw Bill Harris, Elon Musk, and then Peter Thiel (again) take the reins as CEO while other key figures, like Reid Hoffman and David Sacks, were relocated within the company structure (Jackson, 2004).

This narrative demonstrates the presence of an alternative culture of entrepreneurial payment systems on the West Coast that predates Bitcoin. More importantly for my argument, it shows how watered down technological radicalism is a byproduct of companies becoming amenable, acquiescent, and submissive to the business interests of the networks within which they are increasingly embedded. This diffusion of culture between disruptive pioneers and experienced bureaucrats is the rule not the exception in Silicon Valley and other global tech hubs. PayPal was, on one level, revolutionary—it indeed "empowered millions around the globe to move money with the click of a mouse" (Jackson, 2004, 312)—but the problem of scaling turned it into 'just another' corporate structure. The company certainly came from a different ideological place than Silicon Valley giants like Hewlett Packard or Oracle; PayPal also looked to disrupt alternative payment systems like Western Union with its bureaucratic political history (Wolff, 2013). But the radical economic politics of PayPal were made malleable to fit the moving trajectories of the company ultimately submitting to a desire for profit. In the process it mutated from 'radical disruption' to 'disruption lite'.

Similarly, Bitcoin companies are supposed to liberate their users from dated banking services yet they increasingly show signs of succumbing to business interests. When Bitcoin's price escalated from around $800 to $19,500 USD in 2017, a wave of newcomers flooded cryptocurrency platforms that experienced an enormous amount of strain. This led some companies, like Binance, to limit the amount of new accounts until both their platform and customer services could cater for such higher numbers. Coinbase, however, piled all of their resources into scaling their platform to onboard as many new customers as possible. Meanwhile, many existing users were forced to wait over four months to gain access to their funds as they watched the Bitcoin price plummet following a bursting bubble—a timeframe unheard of in the banking industry. This decision-making deeply reflects the interests of investors who want to see the company achieve the network effect as opposed to the users who are left stranded as the company scales.

These accounts of Silicon Valley technology companies again share lineages and genealogies with ideals and juxtapositions that have been called the Californian Ideology. Bitcoin, as both a concept and an industry, is caught within this prolonged schizophrenic arm-wrestle. This was personified in an interview that I conducted with a venture capitalist and an 'entrepreneur in residence' at a San Francisco venture capitalist firm:

> Venture Capitalist: We think we're in a pretty important part of history in terms of the innovation that's happening, the innovation that's happening right here in our backyard. And we're all California guys, born and raised in the Bay area. So it's a pretty, maybe Renaissance is too hokey of a term, but there is a special thing happening in Silicon Valley right now… and that's just Silicon Valley in general. If you take a look at Bitcoin or the

> blockchain over that, it's an incredibly disruptive technology, tons of innovation going on with it. So within the wider world we're in a very important part of the country and the state, and then in Silicon Valley. And within Silicon Valley the best and the brightest are interested in the blockchain, so we feel that we are on the vanguard of a really important technology that has the possibility to change the world. So there is kind of a social and political mission embedded into Bitcoin in our investment activity that we feel passionate about.
>
> Entrepreneur in Residence: And it's an opportunity to make a lot of money.
>
> Venture Capitalist**:** Yeah. We're not just doing this because we think banks suck and we want to revolutionise financial services. We want to change the world and make a lot of money doing it. Those are the dual mandates.

There is excitation and adrenaline behind Bitcoin's innovative potential and being on the forefront of world innovation. The double-bottom line in the above quotation is clear: "we want to change the world and make a lot of money doing it". This is a powerful worldview where each mandate is not seen as contradictory but rather can be achieved through the other. In this sense, the Californian Ideology encapsulates productivity by allowing innovation to occur on the political 'periphery' and absorbing it into the standardised 'centre'. Reincarnations of PayPal—centralised companies that are subject to market forces and state regulation—built on top of Bitcoin, and other blockchains, create a manageable economy of transactions.[27] Within this ecosystem technology is normalised and re-politicised echoing tropes of the Californian Ideology that continues to haunt the global technology space: although "new frontiers may be opened up by enterprising individuals, the original pioneers are quickly replaced by more collective forms of organization, such as joint-stock companies" (Barbrook, 2001, 53). Here, the "desire to attract a mass audience can be a far more effective method of inhibiting political radicalism and cultural experimentation than any half-baked censorship provisions" (54-55); many "people will happily accept corporate control over cyberspace if they are provided with well-produced online services" (55). In other words, in a capitalistic world where markets rule, the demand for security via authoritative bodies welcomes a degree of accountable centralisation for Bitcoin companies to cope with the 'real world' of risk and regulation. Perhaps then, through the guise of the persistent Californian Ideology, the "technologies of freedom" really are "turning into the machines of dominance" (Barbrook & Cameron, 1996, 13).

---

[27] It is important to remember that cryptographers and other skilled programmers can access the Bitcoin blockchain without the need for third party services and these practices create a different spatial relationship with the protocol.

Embedded States: Geographies of Compliance

It is no coincidence that governmental attitudes towards Bitcoin have shifted since its conception. Nation states were initially wary and even hostile towards Bitcoin companies as the Bitcoin protocol provided avenues of monetary practice outside of their control. Governments have now realised that the underlying network cannot be easily destroyed thanks to its proof-of-work mechanism and peer-to-peer network structure. As such, start-ups have revealed themselves as important loci of control, providing a grip on an otherwise 'vaporous' protocol in regulation terms. The Internet has always posed the "problem of squeezing transnational activity into the national legal straightjacket" (Kohl, 2007, 4) and the same is now true for Bitcoin. But start-ups, many of which control private keys, become centralised points of control over parts of the Bitcoin network. As enterprises that exist within nation state boundaries, Bitcoin companies must compete with well-established institutions in the most regulated industry in the world, finance. Compliance is critical to survival and Silicon Valley has become the largest hotspot for Bitcoin company regulation in the world. Through Know Your Customer (KYC) and Anti Money Laundering (AML) regulations, both of which I was rigorously tested on before I was allowed to work at a Bitcoin firm, governments can better monitor the Bitcoin economy reattaching identity back to cryptographic strings. Other common practices that occur within Bitcoin start-ups are the enforcement of withdrawal caps and the freezing of accounts when suspicious activity is flagged. While BitInstant was dismantled after CEO, Charlie Shrem, was found guilty of "aiding and abetting the operation of an unlicensed money transmitting business" (Spaven, 2014), San Francisco-based Coinbase has survived through the Bitcoin industry's turbulent growing pains by taking compliance extremely seriously. For some, regulation in the Bitcoin industry is crucial for its growing legitimacy but for others it resembles too closely the operations of Wall Street that are susceptible to government influence. As Bitcoin start-ups grow, this has the effect of extending the reach of the company and attracting a wider market but in a relational structural of a star as opposed to a mesh (see Figure 1). This trade-off between centralised usability and decentralised anonymity is a growing struggle within the industry and the community.

During the time of my research, authorities of territorialised space were also shaping the Bitcoin economy through mechanisms such as the BitLicense issued by the New York State Department of Financial Services (NYDFS, 2015). Here, companies conducting business in state of New York who transmitted, stored, held, or maintained custody over virtual currencies on the behalf of others were legally required to apply for this license. Some companies like Circle and Bitstamp conformed by paying the $5000 application fee to obtain a BitLicense—although Bitstamp said it cost "roughly $100,000, including time allocation, legal and compliance fees" (Perez, 2015). Others, especially the smaller firms who could not afford the license, stopped doing business in New York or moved their headquarters out of the state—what *New York Business Journal* called the "Great Bitcoin Exodus" (del Castillo, 2015).

Kraken (Young, 2015b), Shapeshift.io (Roberts, 2015), and BitFinex (Young, 2015c) saw the regulation as stifling innovation, creating unnecessary friction to their services and an invasion of their customer's privacy. More importantly, the BitLicense start-ups became a spatial link between Bitcoin users and governments. Meanwhile, the biggest fear amongst the different actors in Silicon Valley was that other states, or worse, the Federal government, might follow the example of the BitLicense with the effect of restricting innovation in the sector.[28] What this reinforces is that even in blockchain economies "the largely digitized global market for capital is embedded in a thick world of national policy and state agencies" (Sassen, 2004, 243). The growing control of private keys and other information is an important amalgamation of networks into a centre of calculation/control. This process actively attaches identity to pseudoanonymous cryptographic strings that not only affords cognitive power to start-up companies but allows the (de)centralised blockchain architecture to conjoin more tightly with other networks such as state modes of legislation.

Conclusion

This chapter has brought together a number of spaces in Silicon Valley that demonstrate the geographic embeddedness of the Bitcoin and blockchain start-up industries. With a cultural account of economic practices that show how the Californian Ideology continues to be negotiated and enacted within Bitcoin economies, I have shown how radical politics are normalised among different actors and how certain centralised institutions/investors redirect information and transaction management into their bottlenecks of control and capital accumulation. Silicon Valley is increasingly a place where the algorithmic mechanisms and metrics of the Bitcoin blockchain are made sense of by varying actors and institutions. Algorithmic decentralisation, then, is deeply affected by cultures of entrepreneurial activity that lend themselves to centralisation and bureaucracy: if economic transactions are surrendered to layers of proprietary software they become important islands of control in a (de)centralised algorithmic network. Blockchains only provide a transactional base of self-coordinating information (monetary or otherwise) whereas added applications are market driven.[29]

The centrality of Silicon Valley in this process is thus an important site for algorithmic decentralisation changing the relationship between money, code, and space in the Bitcoin network by creating obligatory passage points for using the protocol. As Bitcoin alters the Silicon Valley landscape, practices within Silicon Valley reshape the Bitcoin blockchain. In other words, despite encapsulating a decentralist vision, centres of calculation are not eradicated from blockchain economies as they remain relatively simple structures upon which centralised services can be built to provide more complex services from

---

[28] There was even a petition to withdraw the BitLicense on change.com that was brought to the attention of attendees at the beginning of a San Francisco Bitcoin Meet-up Group event.

[29] Of course, cryptoeconomics shows that the protocol layer is also on some level market driven.

which to accumulate capital. However, this is not to say that blockchains cannot be used as a means for more distributed and anonymous financial practices—the Silk Road market and its successors have proven this to some extent. Additionally, Blockchain.info utilises client-side encryption for their wallet service so that it does not control private keys itself. In other words, Blockchain.info does not store its users bitcoins but provides a software package that allows individuals to do so themselves. So, counter-intuitively, in this instance an additional proprietary layer, or centre, with its own cryptographic shrouding of customer funds, maintains privacy and does not systematically seize control from customers. Here, financial freedom is not necessarily synonymous with decentralisation. Elsewhere, cryptocurrencies with stronger privacy models, such as Zcash and Monero, have been developed to counteract the traceability of Bitcoin. Both protocols use additional cryptographic functions to obscure the addresses sending and receiving currency units so that (pseudo)identity is not publicly linked with the flow of funds. This reduces the amount third parties can know about transactions when operating on the behalf of individuals. Both of these examples remove power associated with embedded centralisation at both the firm and geographic level. So while tensions between centralisation and distribution certainly exist, this chapter has shown that it is the relational (dis)connections of third party institutions (and other actors) that are crucial for understanding these intricacies in blockchain economies. Amongst the processes of interconnectedness, embeddedness deeply affects algorithmic geographies of decentralisation.

At the same time, it is important to remember that Bitcoin still creates a different money/code/space to anything that has come before it. Bitcoin maintains its monetary policy even if the software start-ups control private keys and other information. Here, wallet companies are like commercial banks and the core developers are like the (de)central bank; meanwhile miners provide the service of network maintenance with their own shifting geographies. Is this a different spatial 'structure', or connectivity, for money? Arguably, yes. But is it free from points of control? No. Attention must be paid to how these connectivities are sustained from different points of view. For example, on an institutional level, the Internet, despite being a (largely) decentralised network itself, has increased the amount of users that a singular firm's star-shaped network can reach by connecting more people to its central hub (often people with less money across greater distances). The institution's own protocols enclose a part of the decentralised, infrastructural Internet in order to accumulate centralised capital. This is useful because it provides services such as Spotify, ASOS, Facebook, NASDAQ, or PayPal, but certain powers are also afforded to these centralised entities. The same is true within Bitcoin economies: these pockets of control can affect global flows of cryptocurrency capital. From here, other flows of power can start to 'grasp' at the distributed algorithmic protocol in different ways—start-up companies become their own black box but can be prised open, to a certain extent, by governments. The most control a nation state can hope to have over Bitcoin and blockchain technologies, then, is to allow start-ups to operate within their jurisdictions.

Chapter 7
The Blockchain Turn

Introduction

So far in the thesis I have made a critical analysis of the first instantiation of a blockchain, Bitcoin, accounting for its political motivations, modes of governance, material architecture, and start-up economy, and paying particular attention to how the contradictions at play within each affect Bitcoin's geographies of algorithmic (de)centralisation. In this chapter I break away from the Bitcoin blockchain and account for how its architecture is being repurposed for a plethora of different use cases that practise decentralisation in disparate and distinct manners. I refer to this as the 'blockchain turn' (although it has often been referred to as Bitcoin 2.0) to encapsulate its partial yet significant drift away from Bitcoin: the definition of a turn, here, is a "concerted reorientation of focus of attention and approach" (Ash et al., 2016, 10). Such a transition is an aspect of the fragmenting Bitcoin cultural economy that is increasingly branching away from its predecessor—stimulating untrodden technological imaginations, creating new political tensions, and dragging more stakeholders into the fray. In this chapter, I look at how these alternative blockchains, via 'platform capitalism', are being made to reorganise finance in various ways and what this means for algorithmic (de)centralisation.

The chapter contributes to an understanding of (de)centralisation by building on a recent body of knowledge called 'platform capitalism' that looks at how the gatekeepers of popular software packages increasingly control the data of citizens as nearly every digital practice can become monetised information. From the point of view of the platform capitalist, "apps are for capital simply a means to 'monetize' and 'accumulate' data about the body's movement while subsuming it ever more tightly in networks of consumption and surveillance" (Terranova, 2014). I adapt the term platform capitalism to explore what blockchain capitalism would, and is starting to, look like. This moves into a typology of different blockchains that are being produced with multiple visions to suit the stakeholders that build them. From here, I develop the concept of blockchain capitalism to show how it is realised in a number of ways but ultimately obligatory passage points create certain choke points of control across their 'decentralised', networked economies. Three case studies demonstrate the levels of control in blockchain ecosystems, the mutability of data in certain circumstances, and their roles as tools of capital accumulation.

The blockchain industry barely existed when I started researching Bitcoin in 2013. It has now grown into a vibrant, dynamic sector. To put this into perspective, the market capitalisation of cryptocurrencies alone on the 7th January 2018, discounting all related start-up companies, was $813.87 billion USD. As a result, the blockchain economy is extremely important for understanding the wider relationships between money, code, and space as the technology becomes normalised and absorbed within the global economy. The time I spent in Silicon Valley only heightened my awareness of the blockchain turn and it became apparent I could not research the Bitcoin community/economy without accounting for this evolution. To cater for this, I allowed my follow the thing research to 'stray' into different spaces such as Ethereum meet-ups and blockchain start-ups. My description of one such environment, called Blockchain University, that I was a part of in 2015, sets the scene for how blockchain architectures were starting to be used for imagining new economic transaction structures.

Blockchain University: Designing Decentralisation

> When I first started taking Bitcoin seriously in 2012, I thought it was just a currency. That was my first exposure to it and I was really excited for what it was going to do to the financial system—that it was really going to give it some liberty and freedom. One of the things that [has] really struck me [since], as I've grown in my understanding of what Bitcoin is, is how it really is just the first app on the blockchain. I've realised how impactful and exciting the blockchain actually is. This is…, and I think you'll all agree with me, the single most exciting, most revolutionary idea that has hit in probably the last one hundred years (in my opinion): this is going to change everything. And being here as part of this program, and all the things that each one of you is building—with the tools that many of the companies here have helped build previously—is really exciting. You're building the future... We're really excited to see what people here have built and where the future is going. You being here in these seats tonight means that you are some of the earliest adopters in the world in what will change every single industry on this planet. (Eric Martindale, BitPay)

I was sitting in a crowded room of the China Fortune Land Development (CFLD) TechCode Incubator located in Mountain View, Silicon Valley, as Eric Martindale of BitPay gave this enthusiastic speech. It was one of a handful of introductions that proceeded the Blockchain University demo night. Around me sat a plethora of programmers, lawyers, entrepreneurs, students, CEOs, start-up employees, consultants, and other business men and women from a range of different professions: some were about to present their projects and others had come to observe the products that had emerged from six weeks of learning and collaboration around the concept of blockchain. I had heard different variations of Eric's speech in the San Francisco Bay Area over the previous months as I attended meet-up groups and conferences, interviewed investors and start-ups, and immersed myself in the local Bitcoin community. It was mid 2015 and the buzzword in the Bitcoin industry, if it could still even be given that compartmentalised label, was "blockchain". The unique anatomy of the Bitcoin algorithm was the new disruptive spanner to be jammed into the traditional cogs of world systems.

Blockchain University, as described by its website, was "an organisation designed as a unique platform for education, talent development and ideation for the global blockchain ecosystem" (Blockchain University, 2015). Elsewhere, the press had described it as an institution that offers a developer-focused course taught by leading Silicon Valley blockchain start-up founders and programmers to "educate seasoned software engineers about cryptocurrency and provide them with the knowledge for developing applications" (Schuhmacher, 2014). Through public and private training programs, hackathons, and demo events, Blockchain University enabled start-ups and corporations to initiate blockchain innovations across industry sectors. The overall aim was to counter the skills shortage in Silicon Valley for emerging blockchain enterprises looking to design business models on top of varying blockchains. 'Students' included developers, product managers, attorneys, designers, builders, entrepreneurs, and intrepreneurs from Google, AT&T, Infosys, PwC, Oracle, Visa, Federal Reserve Bank of San Francisco, Raytheon, and Saint Gobain. Across the different cohorts they were taught by 'lecturers' such as Tom Ding (Koinify), Juan Benet (Protocol Labs), Ryan X Charles (BitGo), Ethan Buchman (Eris Industries), Vitalik Buterin (Ethereum), Matthieu Riou (BlockCypher), Greg Slepak (DNSChain), Atif Nazir (Block.io), Srinivasan Sriram (Skuchain), and Ryan Smith (Chain.com).

My educational journey began with the payment of two bitcoins to Blockchain University (then roughly the value of $500 USD but closer to $30,000 at the time of writing); it was culminating that evening with the presentation of different projects—our 'test' was the products we had designed and through them we would 'graduate'. During my weekends I had been going to the CFLD Incubator (affectionately dubbed Consensus HQ for Blockchain University purposes) and other venues in Silicon Valley, such as IDEO and Singularity University, to learn from industry specialists about the morphology and associated applications of different blockchains: coding, discussing, listening to presentations, solving problems, and designing business models.[1] On the 18th May 2015, it was finally time for the cohort to demonstrate this knowledge and showcase our newly learnt skills. The president of Blockchain University called a fellow team member and I to the stage to kick off the event (see Figure 38).

My group's product, Squirrel, utilised blockchain's non-repudiation system of record keeping by creating an application designed to streamline letters of credit. We aimed to use codified smart

[1] CFLD stands for China Fortune Land Development, a publicly traded Chinese real estate company, personifying the international links/investments maintained by Silicon Valley.

[Image removed for copyright purposes]

Figure 38: Robert Schwentker (right) introducing Sujata Menon (centre) and me (left) to present Squirrel (Rizzo, 2015)

contracts running on top of two blockchains to remove the risk from global supply chains that contractors are forced to take on when making purchase orders to vendors who may or may not fulfil them. Pete Rizzo from Coindesk, the world leader in news and information pertaining to Bitcoin and blockchain technology, was in the crowd and would later report:

> To attack this issue, Squirrel developed a system by which parties could enter into a purchasing agreement at a lower risk level. Funds, the team proposed, could be sent to escrow accounts by both manufacturers and vendors. Squirrel, in turn, could act as a source of capital and security so that projects can be produced. (Rizzo, 2015b)

Escrow accounts are a contractual arrangement where traditionally non-biased third parties, usually lawyers, handle money for the transacting parties to minimise the risk of a bad actor corrupting the agreement. As a programmable form of money, Bitcoin allows the building of smart contracts to manage funds based on the digital parameters of that contract: in essence removing the middle wo/

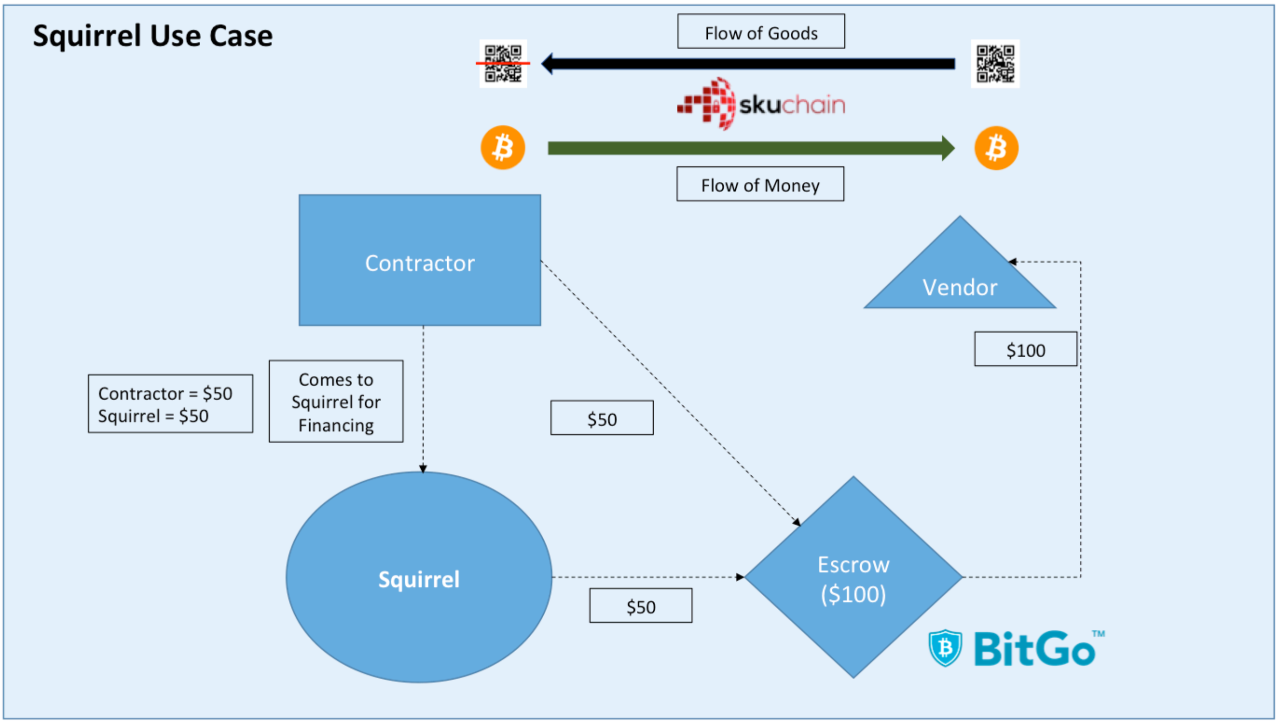

Figure 39: Slide three of the Squirrel presentation showing the flow of money between different actors involved in the smart contract.

man.[2] Because blockchains resemble 'sequential' and 'permanent' records of 'truth' the data they contain and build upon can be used to lock and unlock these smart contracts. My group had been working closely with start-up company Skuchain, who had created an alternative blockchain that tracks products via a digital identity achieved through proof-of-provenance codes. The Skuchain system not only records the movement of things chronologically in a digital irrefutable ledger, and thus provides real-time auditing of its 'life', the blockchain can also be used to trigger actions as they are validated through predetermined checkpoints. By building self-executing smart contracts using the BitGo API, that run on top of both the Bitcoin and Skuchain blockchains, we aimed to make a secure, transparent, and auditable system that makes money flow (bitcoin) symbiotic with product movements across a supply chain (see Figure 39).[3] Other group projects that followed were Chainmail, Kar.yt, Cardify, P2P insurance, In & Out Checkout, Revocable, BlockchainMe, and BlockNotary. Some of the Blockchain University projects have since gone on to become start-ups themselves such as Spritzle (from cohort

[2] Squirrel, as a builder of smart contracts, would still receive a fee but the code of the smart contract predetermined by all parties would execute the transaction. So Squirrel becomes a new kind of third party as a cooperative rule builder but once the parameters of the contract have been written they cannot be undone.

[3] For this to work the protocols of the two blockchain need to be trusted. And so, the governors and miners of the Bitcoin blockchain, as well as the builders of the Skuchain blockchain act as displaced and black-boxed middle wo/man.

one), now called HitFin, and BlockNotary that received angel investment from Silicon Valley Plug and Play.[4]

Blockchain University exemplifies the blockchain hype that was buzzing around Silicon Valley during 2015; the innervation of innovation was palpable. The organisation was a learning environment *and* a space where blockchains were being made—both on a technical level, with code, and on an ideological one, through discourse, debate, and design. According to the institution, decentralisation was the crux around which new economies could, or rather should, be built. And Blockchain University was not alone: as Bitcoin companies had done two years before, embryonic blockchain start-ups were beginning to emerge, taking an early position in the newly forming industry. I return to my experiences at Blockchain University throughout the chapter. For now I concentrate on outlining the process of platform capitalism and explain how it ties into my conceptual framework.

Platform Capitalism

The etymological roots of the word platform come from 16th century Middle French *plateforme*, which literally means flat (*plate*) form (*forme*). Although it has since gathered a myriad of different definitions under its banner they all share a notion of a standardised, uniformed, or levelled surface (whether structural, ideological, political, theatrical, geological, or theoretical) that often provides a foundation upon which something else can act or be constructed. A platform, therefore, is "an object, system or process that is built upon to practical effect… [and] provides the basis for practice of some kind" (Neilson, 2016b, 1). Gillespie (2010) notes four "semantic territories that the word 'platform' has signified" (349-350): computational, architectural, figurative and political. Today, the term is increasingly used in the digital context to describe company-owned software or computational services that "afford an opportunity to communicate, interact or sell" (351). As Kanngieser et al. (2014) explain:

> Within technological disciplines and fields the term 'platform' was originally synonymous with operating systems, however the acceleration of social networking services such as Facebook, Twitter, tumblr, Weibo and Renren reconfigured the notion of the platform as a catalysing method for internet user participation, content sharing and clustered organisation. (305-306)

---

[4] Plug and Play use a 'spray and pray' investment technique where they invest a small amount of money in a large amount of companies that they house in an enormous space in Sunnyvale, Silicon Valley. The business model is such that when companies succeed, such as Dropbox or Zoosk, the payoffs cover the costs of their other investments as well as creating profits. The group has provided a number of Bitcoin and blockchain companies, like BitWage, with venture capital and are the venue for the Silicon Valley Bitcoin Meet-up.

Put simply, a platform in this sense is a "term used to describe an environment in which digital intermediaries offer their services or content" (Scholz, 2017, 175). For example, Uber has emerged in the form of a smartphone application that connects 'taxi riders' and 'taxi drivers' together in a 'marketplace'. In this sense, "[p]latforms organise. They bring bodies and brains into relation" (Kanngieser et al., 2014). Today, the "Big Five" digital platform owners that wield the lion's share of organisational power are Google, Apple, Amazon, Facebook, and Microsoft (Scholz, 2017).

The upsurge of platforms has been coupled with claims their architectures have given rise to the sharing economy by which producers and consumers can conduct transactions more directly and seamlessly. This creates a medium by which citizens can profit from assets that would otherwise be difficult, for example cars (Uber) or spare rooms (Airbnb). With it has come a "proliferation of new terms: the gig economy, the sharing economy, the on-demand economy, the next industrial revolution, the surveillance economy, the app economy, the attention economy, and so on" (Srnicek, 2017, 37). However, while the builders of platforms promote a "seemingly flatter and more participatory model" (Morozov, 2015) of commerce, others have criticised the "confused usage" of the word 'sharing': "helping each other out by sharing resources is one thing while commodifying these resources by charging a fee for their use is quite another" (Olma, 2014). Further still, claims of disintermediation are nonsensical as platforms merely re-coordinate supply and demand replacing more traditional intermediaries with new digital architectures (ibid.). In other words, middle wo/men are merely camouflaged by platforms (Lobo, 2014). Meanwhile, platforms are raised up as the powerful monopolising gatekeepers of transactional bottlenecks with "unprecedented control over the markets they themselves create" so that "price is not the result of the free play of supply and demand but of specific algorithms supposedly simulating the market mechanism" (Olma, 2014). It is from here their owners can "control the governance over the rules of the game" (Srnicek, 2017). Platform capitalists, obligatory passage points between sellers and buyers (the market), thus reap remarkable profits and wield considerable power.

The platform, then, can be understood "as a distinct mode of socio-technical intermediary and business arrangement that is incorporated into wider processes of capitalization" (Langley & Leyshon, 2016, 1). As the "digital bridge builders" (Scholz, 2017), platform owners also extract and control immense amounts of data. Nick Srnicek (2017) relates this to mining a valuable raw material that can be "refined and used in a variety of ways" (14). Calls for greater anonymity in platforms, then, "miss how the suppression of privacy is at the heart of the business model" (Srnicek, 2017, 101). In fact, this data can be monetised into an indirect secondary revenue stream (Langley & Leyshon, 2016) by opening it up and selling access to the information of user activity to advertising companies and market researchers (O'Dwyer, 2015). This has been a powerful process, as per Tim Goodwin's (2015) words that have since become a common meme: "Uber, the world's largest taxi company, owns no vehicles.

Facebook, the world's most popular media owner, creates no content. Alibaba, the most valuable retailer, has no inventory. And Airbnb, the world's largest accommodation provider, owns no real estate. Something interesting is happening."

Sascha Lobo (2014) first used the term 'platform capitalism' to critique and debunk the so-called sharing economy, instead referring to it as a new mode of digital-economic order that takes advantage of oppressed labour resting in the "grey zones" of "regulation gaps". "Every day, one billion people in advanced economies have between two billion and six billion spare hours among them. Capturing and monetizing those hours is the goal of platform capitalism" (Srnicek, 2017, 4). By orchestrating and organising this untapped labour, the platform capitalist can take a cut. Here, platforms "offer new forms of competition and control, but in the end profitability is the great arbiter of success" (Srnicek, 2017, 114).

There is another, darker side to this 'market making': by legally defining their workers as independent contractors as opposed to employees, platform capitalists can cut labour costs by creating a workforce with no employer-paid health insurance, sick leave, paid overtime, holiday leave, pension plan, or basic worker protections against discrimination (Calloway, 2016; Scholz, 2017; Srnicek, 2017). This generates unpredictable working conditions that do not add up to a living wage (Calloway, 2016; Scholz, 2017; Srnicek, 2017). So behind the facade of creating new jobs, Brynjolfsson and McAffee (2016) argue, employment with a livable wage is actually destroyed, contributing to the increasing disparity between rich and poor and the decline of median income. In the process, platforms "reimpose hierarchical relations at the service of social reproduction and the production of surplus value" (Terranova, 2006, 33). This is not a utopian vision of technology where automated labour can cull the hours of the working week (Keynes, 1930), but rather jobs are made menial and meaningless for those who are 'lucky' enough to have them (Graeber, 2015).

Blockchains, however, have become the 'great disruptors' for these markets whose architectures can connect participants through space without the need for a centralised third party. In this way, or so the imaginary goes, no entity is positioned to control the market and dictate the price of goods: the digital overseers would be dismantled as transactions can be conducted on distributed blockchains. Drawing from my own experiences, critically examining the centrality behind these modes of organisation complicates this rosy image brimming with technological 'solutionism'. By paying close attention to this pattern, I develop what I call blockchain capitalism: a process by which organisations construct blockchains as a means for capital gain. This has important connotations for algorithmic (de)centralisation and adds to the complexity of money/code/space constructed through blockchains. As the first step, I describe the plurality of blockchains.

Dissecting Blockchains

On the 3rd January 2009, Bitcoin became the first ever example of an algorithmic and protocological structure that would later be labelled 'the blockchain'. Later, on the 21st October 2010, the Bitcoin Testnet was released to become (technically) the first alternative blockchain in existence and the first of what would come to be known as altcoins—however, this protocol was not designed to carry value but formed as an experimental environment for developers.[5] The first value-carrying version fork of the Bitcoin open source software was the cryptocurrency Namecoin, launched on the 18th April 2011, that enabled the storing of information in its blockchain transaction database, thus supporting the added functionality of censorship-resistant, secure, decentralised, and human-readable domain names—solving the technical problem of Zooko's triangle (Wilcox-O'Hearn, 2001; Swartz, 2011). A cascade of altcoins have since followed.[6]

As "early as 2011, people were using the lower digits of Bitcoin transactions as a way of encoding messages within the [Bitcoin] blockchain" (Buterin, 2012b): attention rapidly started to shift towards how the blockchain concept could be used for more than just money.[7] In December 2013, nearly five years after Bitcoin's original release, Vitalik Buterin published a whitepaper titled "Ethereum: A Next Generation Smart Contract and Decentralized Application Platform". Bitcoin's lack of a robust scripting language for developing applications led Buterin to design the blueprint for Ethereum, a virtual machine that could run Turing-complete script. This would allow Ethereum to become the Swiss army knife of blockchains by supporting a myriad of applications. The project attracted a large pool of talented developers from across the world, among them (and beginning to suggest some ideological tension) "two former Goldman Sachs employees—which has been a matter of some dismay in the heavily libertarian, anti-establishment cryptocurrency community" (Schneider, 2014). The team raised $18 million USD worth of funding in bitcoin (which, incidentally, only cost a total of $350 USD in fees to transfer) and began working on the project. Ethereum was released in July 2015, 19 months after Buterin's paper was published. Over this time, global interest in blockchains had turned into hype, for example, Melanie Swan (2015) opens her book *Blockchain: Blueprint for a New Economy* with the following paragraph:

---

[5] The Bitcoin Testnet demonstrates how money is brought into being through the practice of people in sociotechnical networks because it mimics the exact functionality of Bitcoin but does not carry the same value.

[6] Zooko's triangle is a trilemma conjecturing that no single network protocol can achieve more than two of the following characteristics: secure, decentralised, and human-readable.

[7] Satoshi Nakamoto was the first to encode metadata in the Bitcoin blockchain by leaving a politically charged message in the genesis block (see Chapter 1).

> We should think about the blockchain as another class of thing like the Internet—a comprehensive information technology with tiered technical levels and multiple classes of applications for any form of asset registry, inventory, and exchange, including every area of finance, economics, and money; hard assets (physical property, homes, cars); and intangible assets (votes, ideas, reputation, intention, health data, information, etc.). But the blockchain concept is even more; it is a new organizing paradigm for the discovery, valuation, and transfer of quanta (discrete units) of anything, and potentially for the coordination of all human activity at a much larger scale than has been possible before. (vii)

A pre-published copy of this book was passed around to students at the first lecture of Blockchain University. Similarly, Don and Alex Tapscott (2016), in their book *Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money, Business and the World*, provide a compelling compilation of similar mental gymnastics being performed around the concept of blockchains but often take them at face value. Such euphoric descriptions of the potentiality of blockchain quickly became the norm and the technology industry started flowering with business concepts that utilised the blockchain's characteristics of non-repudiation, decentralisation, and/or transparency. Even *The Economist* (2015) noted blockchain's potential to "transform how the economy works". Today companies and organisations have arisen to disrupt banking (Vault OS), payments and money transfers (Abra), cybersecurity (Guardtime), academic records (Holbertson School), voting (Follow My Vote), car leasing and sales (Visa and Docusign partnership), networking and the Internet of Things (ADEPT and Filament), forecasting (Augur), online music (Peertracks, Mycelia and Ujo Music), ride sharing (La'Zooz), stock trading (TØ.com), real estate (Ubitquity), insurance (Stratumn), healthcare (Gem and Tierion), supply chain management (Provenance, Fluent, and Skuchain), cloud storage (Storj), energy management (Transactive Grid), sports management (The Jetcoin Institute), gift cards and loyalty programs (Gyft Block), government and public benefits (GovCoin Systems Limited), gun tracking (Blocksafe), wills and inheritances (Blockchain Technologies Corp), retail (OpenBazaar), charity (BitGive Foundation), law enforcement (Chronicled and Elliptic), human resources (Recruit Technologies and ascribe.io partnership), and ride hailing (Arcade City) (CB Insights, 2017).

Different stakeholders imagine blockchains in different ways and so variations of their architectures are being developed according to the (political) task at hand, and leading to a great deal of dispute as to what constitutes a blockchain. Three broad typologies of blockchains have been proposed: public, private, and consortium chains (BlockchainHub, 2017). Public blockchains are open in their design allowing anyone to conduct transactions, view the ledger, or join the consensus process (such as Bitcoin or Ethereum). A public blockchain is designed to remove intermediation by eliminating the need to trust a centralised entity—using cryptoeconomics, the combination of financial incentives and cryptographic verification, to secure a distributed ledger. Private blockchains are closed in their design constraining write permissions to one entity whereas read permissions may be made public or restricted to certain actors (such as Eris Industries, MultiChain, or Skuchain—I was shown the code of this last blockchain by a cofounder of the company in their offices). These permissioned chains can be used for database management or auditing "internal to a single company, and so public readability may not be necessary in many cases at all, though in other cases public auditability is desired" (Buterin, 2015). Alternative to intermediaries, then, private blockchains "should be considered for any situation in which two or more organizations need a shared view of reality, and that view does not originate from a single source" (Greenspan, 2016). Consortium blockchains lie between the two where write permissions are controlled by a pre-selected set of nodes whereas read permissions might be open or closed depending on preference (such as R3—although this organisation increasingly uses the term 'distributed ledger technology' inspired by blockchains). For example, "one might imagine a consortium of 15 financial institutions, each of which operates a node and of which 10 must sign every block in order for the block to be valid" (Buterin, 2015). These three types of blockchain produce different architectures of trust depending on the problems they are designed to solve.

In Silicon Valley during 2015, innovation ran along the lines of, what I often called, "treating every global problem as a nail and every solution as a blockchain hammer".[8] This was certainly true for Blockchain University and was also evident within the wider economy (see Figure 40). This hype led to criticisms from others within the Bitcoin cultural economy: "you don't need blockchain *per se*, you need a solution to some problems that eventually could become a blockchain" (Meunier, 2016). In Meunier's essay he offers five models, or flow charts, for deciding whether a problem needs a blockchain—based on permissions, transparency, and privacy—and on most occasions the answer is no.[9] Gideon Greenspan (2015), CEO of MulitChain, echoes this sentiment, claiming blockchains are overhyped:

> Here's how it plays out. Big company hears that blockchains are the next big thing. Big company finds some people internally who are interested in the subject. Big company gives them a budget and tells them to go do something blockchainy. Soon enough they come knocking on our door, waving dollar bills, asking *us* to help *them* think up a use case.

Greenspan's company, which profits from such consultations and by building applications around their own private blockchain, still warns interested parties away from the idea of blockchain for blockchain's

---

[8] In other words, these pioneers innovated with the following mindset: "blockchan is the answer. Now, what is the question?" Programmers and entrepreneurs in Silicon Valley were essentially throwing blockchain at the wall and seeing where it stuck.

[9] In his own check list, Meunier provides 10 questions that system builders must ask themselves before thinking of using. blockchain—these questions relate to network, performance, business logic, and consensus. Anything below 7/10 may need a shared ledger but this should not necessarily be a blockchain. In a lot of cases a database will do.

Figure 40: Sticker given to me by BitPay at the Blockchain University demo night

sake.[10] Others critique the functional efficacy of private and consortium blockchains entirely. For example, Andreas Antonopoulos, a blockchain purist, sees any blockchain that is not open as worthless (O'Connell, 2016a):

> Not only is decentralization, open protocols, open source, collaborative development and living in the wild a feature of Bitcoin, that's the whole point. And if you take a permissioned ledger and say, that's all nice, we like the database part of it, can we have it without the open decentralized P2P open source non-controlled distributed nature of it[? W]ell you just threw out the baby with the bathwater. (cited in O'Connell, 2016b)

He states elsewhere:

> This is the big argument of 2015. It's the "let's take bitcoin, cut off its beard, take away its piercings, put it in a suit, call it blockchain, and present it to the board." It's safe. It's got borders. We can apply the same regulations. We can put barriers to entry and create anti-competitive environment to control who has access. (cited in Frauenfelder, 2016)

The disruptive potential of blockchains for Antonopoulos lies in openness and the growing technological opportunities this has for operating economies with reduced central oversight.

---

10 Such hype is personified by the share price of an Internet company that changed its name from On-line Plc to Online Blockchain Plc and rose as much as 394% (Pham, 2017). Tim Swanson (2017c) calls this phenomenon "chainwashing".

Blockchains, he says, are a trade-off between freedom and efficiency where the most efficient system is a database that can "process billions of transactions per second, as long as you give all the authority and trust to a single party" (ibid.). So Bitcoin, as opposed to Visa, is "paying an efficiency price in order to maintain neutrality of the network, that decentralization of trust" (ibid.).

Alternatively, others believe openness is not necessarily the only benefit of blockchains as private and consortium chains can be implemented to provide other benefits; these include "lower costs, faster transactions, automatic reconciliation, new regulation or a simple inability to find a suitable intermediary" (Greenspan, 2015). Here, they enable "databases with non-trusting writers to be modified directly [where transactions can be] independently verified and process by every node" (ibid.). The two most important distinctions between blockchains and centralised databases are disintermediation (where blockchains enable multiple untrusted parties to share a single database) and confidentiality (where blockchains wear all the transactions taking place on their sleeves) (Greenspan, 2016). From this point of view blockchains "represent a trade-off in which disintermediation is gained at the cost of confidentiality" (ibid.). As I have already argued, blockchains remain an intermediary in a different form: where writers (miners) of the ledger are randomised intermediaries (that in the Bitcoin case are increasingly clustered in pools) through the protocol's mechanisms or codified rules pre-programmed and maintained by particular governance structures. There is then, thus far, no such thing as complete disintermediation.

Primavera de Filippi (2015) casts Greenspan's same argument in a different way: "if the price of centralisation is trust (as users need to trust centralised operators with their data), decentralisation comes at the price of transparency (as everyone's interactions are made visible to all [of the] network's nodes)". And so 'distributed' infrastructures may "end up being more vulnerable to governmental agencies or corporate scrutiny than their centralised counterparts" (ibid.). This was proven to be the case when the US government followed transactions on the immutable Bitcoin blockchain using network analytics to track down two corrupt federal agents—who had been on the Silk Road task force and had stolen vast amounts of bitcoins on the job—despite the fact they had used their agent status to destroy more vulnerable evidence on government databases (Haun, 2016). At the same time, while "it might be harder to implement a decentralised system that is fully privacy-compliant, transparency and privacy should, however, not be regarded as being in a fundamental conflict" (de Filippi, 2015). This is where all manner of experiments are going on in the blockchain world. For, example there are "hybrid routes" being developed where "root hashes of the blocks [are] public together with an API that allows members of the public to make a limited number of queries and get back cryptographic proofs of some parts of the blockchain state" (Buterin, 2015). All these different incantations of blockchains are important for how algorithmic (de)centralisation plays out and, as is already clear, this is in a plethora of ways. As the second step in illuminating the complexity of money/code/space constructed through the plurality of blockchains, I now examine the concept of blockchain capitalism that describes a process of centralisation around certain points in the distributed architectures of blockchains (similar to the software companies described in Chapter 6).

Blockchain Capitalism

Blockchains are platforms with a twist. As I described earlier, instead of the market connections having to pass through a bottleneck, as is true with Amazon, Uber, and AirBnB, blockchains are supposed to facilitate disintermediated transactions between parties. In other words, they promise to pull away from the centralising monopolistic tendencies of platform capitalism as alternative distributed architectures that can democratise a plethora of marketplaces by cutting out organisational middle wo/men. I will now describe three examples built on top of Ethereum before outlining what blockchain capitalism is beginning to look like. The first is Storj: a platform and token (STORJ) designed to decentralise data storage across the Internet. Today, the majority of the world's hard drive space goes unused on millions of people's devices whereas cloud storage passes almost exclusively through giant platform monopolies such as Google, Apple, or Amazon, and relies on enormous data centres owned by companies like Digital Reality Trust, Equinix, and Global Switch. In their own words, Storj is a "peer-to-peer cloud storage network implementing client-side encryption" allowing "users to share data without the reliance on a third party storage provider" (Wilkinson et al., 2016, 1). In short, the system allows people to rent out their unused hard drive space in return for a monetary token. This can "mitigate most traditional data failures and outages, as well as significantly increase security, privacy, and data control" (ibid.). In an explanatory video on their website, Storj explain

> …each file is shredded, encrypted, and spread across the network until you're ready to use it again. And you can be sure the files are safe because the keys are in your pocket not a company's. Only you have access to your stuff. Because the network is shared, you don't have to worry about slow download speeds coming from one place: we're all helping to make the system blazing fast. And if you have some extra space lying around you'll get paid by users who need more than they can share. It's like renting out your empty hard drives. A cloud with security, no downtime, and speed at a fraction of the cost. (Storj, 2018)

This is not only a company with a different mentality to platform capitalism, but one that seeks to abolish many of its disadvantages such as the centralisation/commodification of information and the profits made from data mining.

Another blockchain venture, Arcade City, is a ride sharing web and mobile application with an inbuilt token (once ARC, now ARCD) used to create "decentralized marketplaces owned and operated by the participants themselves" (David, 2017). The company is a response to Uber who it vilifies for being a "corporate overlord" (Arcade City, 2018):

> Tech companies like Uber and AirBnB have seized on this 'sharing economy' trend to build billion-dollar corporations facilitating pseudo peer-to-peer transactions at global scale. As central intermediaries and gatekeepers, they restrict access to their marketplaces and dictate the terms of each transaction. (David et al., 2016, 1)

The alternative is a mix of open source development, cryptoequity via blockchain technology, platform cooperativism, and a swarm model of decentralised autonomous organisation (Arcade City Hall, 2016; David et al., 2016). The platform's greatest success story to date is in the city of Austin, Texas, where Uber and Lyft were forced to withdraw operations after they lost a legal battle where they tried to influence the local municipality over company-regulated background checks: the city voted to retain its strict policies for ride sharing vehicles (Hern, 2016). This left a vacuum for Arcade City who quickly assembled over 30,000 members through a Facebook page with no set costs or payment mechanisms for rides (Woolf, 2016; Wistrom, 2017; Koebler, 2017)—users can pay with Arcade City tokens, bitcoin, credit card, "cash, Venmo, or hugs" (Tepper, 2016b). Spontaneously, some drivers assembled themselves into 'pods' that provide specialised services, such as a "group of female Arcade City drivers who take special care to get women home safely late at night" (Arcade City Hall, 2016). This inspired the company to encourage a swarm model of self-organisation between their users while allowing stakeholders to 'own' equity with the network by allocating tokens to the public, development team, existing investors, founders, and swarmers, and as future rewards (David et al., 2016).

The final example of a blockchain economy I highlight here is Power Ledger, an Australian company that is aiming to create a "peer-to-peer marketplace for renewable energy" (Power Ledger, 2018a):

> Through Power Ledger hardware and an easy-to-use app, participants can trade a unit called Sparkz, which are backed up by a blockchain bond called POWR tokens. The platform makes the trade easy, frictionless, and instantaneous so people who produce electricity get a more realistic price and people who consume it get a much better deal. (ibid.)

In other words, Sparkz are community-specific tokens issued by "Application Hosts" (such as energy retailers, network utility providers, and local councils) that can be used to transact electricity among the participants within their home market: these are "individual trading platforms hosting closed-loop

[Image removed for copyright purposes]

Figure 41: The Power Ledger (2018b) retail model for working with existing market structures on the (left) and the direct peer-to-peer model for working within deregulated market structures (right)

exchanges for energy and sparks" (Power Ledger, 2018b, 10). This creates many small-scale, regulated networks where prosumers and consumers can purchase or redeem Sparkz with local fiat currency through their Application Hosts and trade for energy amongst themselves (see Figure 41).[11] To make Sparkz available for community members, Application Hosts must hold POWR tokens that are "escrowed for Sparkz in an Ethereum Smart Bond, and can only be unlocked from the Smart Bond upon the return of the Sparkz" (Power Ledger, 2018b, 23). In other words, these bespoke electricity currencies (Sparkz) can be traded with another (global) layer of tokens called POWRs that allow access to the platform and interoperability between markets. If Application Hosts run out of Sparkz for their communities, they must purchase more POWRs from the open market creating greater demand for the cryptocurrency as the platform scales. Alternatively, in a deregulated market without intermediaries participants "will be able [to] convert their POWR tokens directly [for] Sparkz and transact on the

[11] At a Sydney hackathon in 2016, I was part of a team that was looking to do something similar to Power Ledger by decentralising solar power trading via a cryptocurrency that we called BitWatt. Our main difficulty was navigating the existing infrastructure of the electrical grid which was already owned by centralised companies. Power Ledger attempts to solve this dilemma by servicing off-grid pools of energy provision or by providing existing power companies the on ramps and incentives for using their service.

[Image removed for copyright purposes]

Figure 42: The Power Ledger (2018b) ecosystem realised by a number of technology layers

platform without an Application Host" (ibid.; see Figure 41). The overall system is managed by different protocol layers that facilitate the dual currencies: the Application layer is built on top of the Ecochain, which is built on top of the Power Ledger Core, which is built on top of the Ethereum blockchain (see Figure 42).

These three case studies provide examples of decentralised economic practices that are sustained by blockchains. What the applications share in common is they use, or rather rent, the Ethereum blockchain as a trusted foundational architecture; they are all ERC20 coins that use Ethereum addresses and transactions to function. Others, such as a financial company that came from Blockchain University, use the Ethereum blockchain for its smart contract capabilities without the creation of a native coin: the start-up was building a derivatives trading and settlement platform using ether as a currency that would be paid out under certain time limits.[12] In order to run an application on the Ethereum chain the programmers (or users) of the application must pay a fee with its inbuilt cryptocurrency, ether, creating demand and encouraging miners to operate machines that secure the network for currency rewards (cryptoeconomics). This is inherently capitalistic (as were the majority of projects at Blockchain University). Storj, Arcade City, and Power Ledger are not necessary harbingers of a 'sharing' economy because they still commodify cloud storage, spare seats, and surplus energy—they merely transform the dynamics of these markets.

In this form of blockchain capitalism, Ethereum miners become the third parties who are paid for facilitating the transactions on the underlying layer of the Ethereum blockchain. Movements towards mining pool centralisation aside (see Chapter 5), this can reduce the monopolistic tendencies of platform capitalism by ensuring the platform pays dispersed and randomised miners as opposed to one centralised institution, while keeping certain datum cryptographically sealed. In this way, Ethereum may be the rail tracks for other applications to run on, having to follow certain rules, but with miners not controlling the data of the applications running on top of it. In these cases, the Ethereum blockchain makes the middle wo/man more indirect and (possibly) distributed but it does not eradicate them.

Blockchains in these scenarios are not free services but use game theoretical crytpoeconomic incentives to secure the network where application builders must foot the bill. In order to do so, cuts must be taken from the transactions they facilitate so Ethereum miners can be paid. Both the application currencies and ether float on the market via exchanges so they can be traded for each other (see Figure 43). Thus, the same capitalistic logic of fee-based services applies only with a different payment framework. Here, service customers are indirectly paying Ethereum miners as an intermediary through a series of steps. At the ERC20 token layer, the companies that develop them can take transaction fees in order to pay for access to Ethereum and to pay for expenses but also to accumulate capital. These decisions are subject to centralised institutions, particularly during their early stage design process.

Institutions who build applications on top of blockchains are in a position to make important decisions over their networks and are ultimately in control of the codified parameters. The extent of power over the rules and monetary policy can be predetermined; for example, Storj decided to withhold 245 million tokens ($300 million USD) and release them incrementally with the view of creating economic stability whereas many other projects deem it beneficial to release initial coin offerings (ICOs, see below) all at once (Dale, 2017). This is a new model for receiving investment, as Arcade City (2018) say in a promotional video: "we are not accepting traditional venture capital where we would need to trade control for money. Instead we are going directly to the people with a public token sale in 2018… that

[12] Some companies, however, will make their own blockchains and create their own cryptoeconomic models: sometimes with inbuilt currencies (such as Stellar) and sometimes without (such as Eris Industries).

[Image removed for copyright purposes]

Figure 43: The flow of currency between different actors within the Storj economy where Binance is a given cryptocurrency exchange

value will be held directly by you, the participants of the Arcade City network". These cryptocoins are becoming part of a new model for venture capital investment via ICOs: investors buy cryptocurrencies for certain platforms in the hope they will appreciate while the builders raise money for their projects. This model was used for Ethereum—tokens of ether (initially gas) were sold and used to support decentralised applications (Dapps). The total funding from ICOs in 2017 was $3 billion USD (CB Insights, 2017).

While companies cannot alter the rules of the Ethereum blockchain (unlike client developers and miners) they have the power to influence their own tokens. Often, the rules of these are preprogrammed: the (in)famous Decentralised Autonomous Application (DAO) built on the Ethereum blockchain, was coded so investors owned tokens that allowed stakeholders to vote on how their funds were used (see next section). The result of the initial Arcade City ICO shows how these rules can be troublesome and subject to bureaucracy. In forming the "Arcade City Council", intended to act as a temporary committee for decision-making, the company aimed to make a democratic political system where ether from a token sale was put into a smart contract that required 5 of the 7 members to sign in order for funds to be released (David et al., 2016). This budget was intended to go towards software development (15%), operations (35%), market balancing, (25%), contingency (15%), and marketing and community outreach (10%). It was "hijacked" by the council (through the codified voting contract) to form a new venture called Swarm City (David, 2016). Arcade City were left without 77,687.45 ETH, then worth $570,000 USD, but more recently $112.5 million, and had to continue operations without the council they had installed or the token sale funds—this was all technically legitimate thanks to the pre-codified contracts.

To run a ride sharing service also means to manage background checks for drivers, including holding and managing data pertaining to their identities. Arcade City hosts this data through its platform to provide a degree of safety for its riders. This centralisation of data puts the blockchain capitalist in a privileged position for monetising data like other platform capitalists. However, pushing this responsibility to the driver, in a manner that is easy to fake, creates a system where fraudulent, and perhaps dangerous, activity can occur (Tepper, 2016b). In the same vein, the company cannot issue or enforce insurance but rather leaves a space on a profile that drivers fill out. In essence, this means riders could choose to use drivers who are not insured, or indeed, at another extreme, do not even hold a license (ibid.). Decentralised ride sharing, then, with its apparent lack of accountability, can become vulnerable to miscreant activity and may therefore struggle to follow state legislation. Additionally, as noted earlier, Arcade City first used a Facebook group for connecting drivers and riders, demonstrating a reliance on a giant centralised company as an interim while their own platform was being built.

The ICO is another important point of interest for blockchain capitalism as it exposes the platform to the open market. Tokens act like a currency, fuel, and share of the platform, making them a particularly interesting monetary form embedded within new kinds of sociality and suspended by unique modes of cultural practice. For example, to own a Storj coin that has utility as a platform currency is also to have a stake in the future value of the platform. On the open market these coins are traded predominantly on exchanges as the latter: speculative assets. It is for this reason that Arcade City have asked speculators to stay away from their cryptocurrency so it can become a stable coin that serves a particular use but, of course, they cannot enforce this. The price discovery of cryptocurrencies—as new financial assets—that comes from this speculation makes them extremely volatile. The traditional barriers of market entry of buying unitary standards (e.g., 1 share or standard amount of gold) do not apply to most coins as they are devisable to many decimal places: price increases reflect increase in market size. In other words, the value of cryptocurrencies is, on the whole, a reflection of sentiment, which makes them spectacular bubble machines.[13] This puts a certain amount of power, that is ownership of coins, into the hands of the market—particularly centralised exchanges that handle the vast majority of transactions. All of this makes cryptocurrencies and blockchain technology as vulnerable to crises as their predecessors; indeed the industry is mirroring traditional finance in many ways.

---

[13] There have been four bubbles in Bitcoin's history: a rise from $1 to $32 in 2011, $13 to $184 in mid 2013, $68 to $1163 later in 2013, and a low of $152 in 2015 jumping to a high of $19,290 at the end of 2017.

Jill Carlson (2017), in her article "Why crypto looks a lot like Wall Street", expresses this eloquently. She says instead of the distributed dream that was promised,

> …we have constructed around crypto a warped version of the legacy financial system, with all the familiar players: issuers, broker dealers, exchanges and custodians. Along with these players come the legacy problems of centralized control, intermediation, systemic risk, market malpractice and—importantly—short-term greed. (ibid.)

In this sense, blockchain technology has truly "created more intermediaries than it has displaced" and, more poignantly, cryptocurrencies are equally as "exposed to each other as banks, exchanges, and custodians were in 2008" (ibid.). The "[c]ommingling of funds within wallets and exchanges, opaque accounting, cross-exchange exposure and unclear margin requirements are a few of the sources of institutional risk in the market" (ibid.). Similarly, "[m]arket manipulation, insider trading, shilling, spoofing, pumping-and-dumping and conflicts of interest [are] abound in cryptocurrency markets" (ibid). Interdependence between cryptocurrencies is indicated by how all altcoins continue to follow the general price pattern of Bitcoin: it remains the moon that moves the tides in the cryptosphere ocean (Haejin, 2018). Centralised services also hold certain powers within the market to influence the price of coins: when Coinbase launched the servicing of Bitcoin Cash on their platform the price unsurprisingly rocketed as its acceptance by one of the world's largest exchanges added legitimacy to the coin. However, the price had already experienced a dramatic spike hours before which caused suspicions of insider trading (Russell & Tepper, 2017; Koetsier, 2017). Old forms of centralised market manipulation are therefore not absent from blockchain economies and degrees of transparency for application layers are often merely just an option for the start-ups, that operate behind closed doors, to consider.

Blockchain resilience comes from its immutability. If the underlying network has the ability to hard fork under miner collusion, as it did with the DAO hard fork, then how does this effect decentralised applications like Storj, Arcade City, and Power Ledger? Rewriting the chain could have a major impact for thousands of ERC20 currencies. Furthermore, decision making comes via the obligatory passage points of code production from programmers who design the platforms—even if a decentralised voting system is based on the stakeholders of coins this is still ultimately a decision outlined by the coders. The enterprising centralised institutions are the gatekeepers of governance. This is important because another characteristic of code is its need to evolve within a forever changing landscape. Mutations are necessary for when bugs appear or when new services are required to increase its functionality (like Uber Eats that turned ride-sharing into a delivery service). These coders need to earn a living so are rarely ever volunteers. If economic incentives are built-in then the application becomes a capital accumulator and rule maker (Uber) in a different form. Additionally, an application running on blockchain infrastructures does not change the problems of informal labour inherent in platform capitalism. If crypto coins become a mode of income (perhaps a primary one), who provides pensions, holiday pay, sick leave, health insurance, paid overtime, or worker protection? For Sascha Lobo (2014) these conditions only exist because of a gap in law. Legislation can always be introduced to hold platform capitalists accountable for labour rights. Extrapolating the points I made earlier, without a middle wo/man, other than randomised and anonymised miners on the foundational blockchain, who pays for these employee rights in blockchain capitalism? Can worker protection really be programmed into (cold, hard) code or will this be the responsibility of the platform/blockchain builders? And when hard forking happens, should it be the users or the code builders who decide which version of reality to take on? Additionally, while only the macro movements of information can be seen on the Ethereum blockchain, applications, depending on how they are built, can become data silos vulnerable to monetisation when identity verification is a prerequisite for use. These are all problems of (de)centralisation for blockchain capitalism.

The final type of centralisation I concentrate on in this section is centralisation of use around a (de)centralised system. In other words, complete reliance on a blockchain begets its own wider form of centralisation. Don Tapscott (2016) describes the financial system as a Rube Goldberg machine: a complex system that performs a simple task. A famous example is a 2003 advertisement for Honda where an axle hits an exhaust pipe, swinging into a cascade of screws, that releases a tire, and so on, until a car is rolled onto a showroom floor. To use this as an analogy for the financial system is to understand a complex web of centres that perform different tasks (see Appendix 12 for a partial description of this latticework). With decentralised blockchains, Tapscott (2016) explains how this complexity can be avoided because "the payment and the settlement is the same action: it's just a change in the ledger". However, from a relational networked view of the financial industry this is its own manifestation of centralisation, albeit around a (de)centralised (to varying degrees) architecture (on this level, one big obligatory passage point into a system with a multitude of stakeholders: developers, miners, start-ups, etc.). If all other services branch off Bitcoin, they become completely dependent on it and thus if it is compromised, for example, via a malicious colluded 51% attack, the whole system comes tumbling down. From this perspective the current (de)centralised financial system (that is, many centres) that resembles a Rube Goldberg machine is surprisingly resilient. If one part fails, for example mortgage derivatives at investment banks during the 2008 financial crisis, it threatens to pull down the entire system in a domino effect due to interdependent risk. However, governments were able to prop up failing banks with a bail out and while some pieces were removed and all suffered, the financial system survived (albeit with a devastating effect for citizens all over the world). What happens if Bitcoin's value collapses from distrust in its ledger following a 51% attack (which is perfectly fair game within its codified rules) that takes the power away from the centralised governance of the Core developers? Must users trust these programmers to change the code to reflect new rules and then 'rewrite history' by orchestrating another horde of miners to start mining blocks before the attack via the new laws of code? Is this not centralisation by another means? What is more, blockchains are becoming codependent so they are forming their own Rude Goldberg machines of interlinked (de)centralised networks. These are all very real problems for a very real emerging industry and the following case study captures the tensions, contradictions and conflicts at work when distributed architectures are coerced and orchestrated around a singular decision thus pointing towards certain blockchains becoming (decentralist) capitalist devices.

The Decentralised Autonomous Organisation

It should be clear from the last section, however, that blockchains are not the holy grail of distribution but rather different levels and modes of (de)centralisation are played out on a number of scales. This mirrors the evolution of the Internet that, as it became colonised by corporate structures, bore modes of decentralisation and centralisation simultaneously, becoming sedimented into its complex infrastructure. The sensationalist and technologically deterministic promise of a distributed society enabled by the Internet, was never realised however and blockchains are now following this trend: blockchain technology, once again, is showing that there are always points of control in decentralised networks. These centralising tendencies, personified by the DAO, are promoted as a form of self-organising society based on smart contracts resting on the Ethereum blockchain.

The concept of a DAO is "to codify the rules and decision making apparatus of an organization, eliminating the need for documents and people in governing, creating a structure with decentralized control" (Siegel, 2016). The particular DAO in this case study "was meant to operate like a venture capital fund for the crypto and decentralized space" (Madeira, 2016):

> The DAO operates somewhat like a venture capital firm, in that it collects a pool of funds to invest in worthy proposals, but it differs in that all the individual investors are able to vote, in proportion to the size of their investment, on each investment proposal put forward to the fund. The aspirational goals for The DAO are to utilize the wisdom of the crowds for this decision-making process, and to eliminate the risks posed by middlemen using a programmatic approach to corporate management. (Mark et al., 2016)

The whitepaper that emerged with the DAO explained, thanks to blockchains, for the first time organisations could be created where "(1) participants maintain direct real-time control of contributed funds and (2) governance rules are formalized, automated and enforced using software" (Jentzsch, 2016). The project was created on 30th April 2016 and crowdfunded via a digital token sale where $150 million USD worth of ether was invested to become the largest crowdsourcing campaign in history

(Siegel, 2016; Waters, 2016). On the 27th May, one day before the crowd-sale closed, a scientific paper (Mark et al., 2016) was released disclosing seven possible attacks on the DAO which caused a dip in Ether's price devaluating the funds from $150 million to $132 million USD (Slashdot, 2016).[14]

The real trouble came on the 17th June when someone was found to be hacking the DAO and draining the investors' ether into a different "account" (Buterin, 2016). A total of 3.6 million ETH (or $70 million USD) was syphoned from the investors' pool of funds. Because the smart contract of the DAO was designed to administer the philosophy "code is law" (Lessig, 1999), by being built on a ledger of non-repudiation (the Ethereum blockchain), the investors were theoretically not able to get their money back. After all, blockchains are supposed to be a true version of history embodied by the longest chain (see Chapter 4). The Ethereum network was designed to support this dictum and carry with it network neutrality so that applications built on top of it would have to govern themselves. The only way to revoke the hacked transactions was to alter the underlying Ethereum backbone, something antithetical, and even anti-ethical, to blockchain philosophy. In this sense, hacks should be as permanent as legitimate transactions and recognised as a price that must be paid for a fair network with 'distributed' control. But 15% of all ether in existence was 'locked' within the DAO, with a large proportion now in the hands of a hacker. Although the bug exploited was unique to the DAO the success of this project was seen as imperative for the success of Ethereum as a whole. A group of Ethereum programmers, led by Vitalik Buterin decided to "hack the hacker" (Kar, 2016). They managed to move the stolen funds temporarily into another smart contract that would be frozen for 28 days while they came up with another plan. When all other ideas failed an intentional hard fork was proposed, which meant convincing miners to go back to an old block that predated the hack and mine on top of it—completely undermining the idea of a blockchain as a permanent record of transactions by re-mining this supposedly 'singular' record of history. The decision generated a great deal of backlash on Reddit (thehighfiveghost, 2016) from purists who regarded Ethereum as a

> …foundational infrastructure upon which a flurry of projects and experiments are supposed to blossom, and in order for them to blossom they need a foundation that is strong, and that has integrity in the face of challenges. The hard fork proposal is a compromise that ruins that integrity and signals that projects like the DAO can influence the underlying foundation to their own advantage. To me that is totally unacceptable and is a departure from the principles that drew me to Ethereum… The fact that the Ethereum foundation has been involved in and promoted the DAO project has been an error and it only usurps the trust that people have in Ethereum as a foundational infrastructure for other projects. (nustiudinastea, 2016)

[14] It is also interesting to note that Bitcoin's price surged at the same time, which could be a reflection of people jumping ship from Ethereum to Bitcoin (Bovaird, 2016).

Despite this disposition the decision was put to a vote for ether holders by sending transactions to a voting platform and the super majority of people (89%) voted for the hard fork—many of which were DAO stakeholders and thus effected by the hack (Madeira, 2016). From the point of view of the Ethereum ecosystem, like banks during the 2008 financial crisis, the DAO was deemed too big to fail (Siegel, 2016). On the 20th July the majority of miners rolled back to block 1920000 to rewrite a history of the Ethereum blockchain omitting the DAO hack.[15] The Ethereum website describes its blockchain as a "decentralized platform that runs smart contracts: applications that run exactly as programmed without any possibility of downtime, censorship, fraud or third party interference" (Ethereum, 2016). In this sense, smart contracts are supposed to "carry out corporate functions in accordance with the will of their shareholders, while being constrained by programmatic bylaw" (Mark et al., 2016, 2). However, this human intervention to save the DAO proves that blockchains can be theoretically and practically mutable. Some have gone as far to say that this turns "the bright prospect of a de-centrlized autonomous market into a gloomy centralized dictatorship" (Dovey, 2016).[16]

Some miners who were blockchain purists, however, refused to accept the changes. Theoretically, the longest chain from a forked blockchain should survive as it contains more cryptographic proof and encourages miners to gather cryptocurrency rewards that are exchangeable with others (see Chapter 4). Yet a smaller group continued mining the 'old chain' creating a hard fork bifurcation: a fragmenting of communities that do not see the same 'truth'. Like Bitcoin and Bitcoin Cash, instead of forking acting as a consensus mechanism to encourage miners to revert to the longest chain and carry forward one 'objective' view of historical truth, some forks show how blockchains can systematically carry competing views of legitimacy and authenticity. The two chains/coins in this instance are called ETH (Ethereum—omitting the DAO hack transactions) and ETC (Ethereum Classic—maintaining the DAO hack transactions). Ethereum Classic has "refused to die despite the Ethereum Foundation's repeated attempts to kill it" (Coppola, 2016). Another hard fork occurred on the 24th November when two of Ethereum's clients, Geth and Parity, "slipped out of synch" but this was later fixed when the Ethereum Core developer team warned miners that if they did not update their systems they would be working on an invalid chain with no support (ibid.): "[s]o much for the old chain dying out naturally because everyone freely decides to use the new one. This is more like Microsoft: 'old versions of Windows are no longer supported'. Devs rule, ok" (ibid.). If later hard forks occur, for example when Ethereum attempts to move onto a proof of stake consensus like it has planned (Hertig, 2017), the system may start to resemble a blocktree, as explained in Chapter 4. The governance of blockchain societies is

---

15 The roll back was enabled by the relative youth of the blockchain, which would have been much harder to do later on as more stakeholders joined the network to build applications on top of.

16 The DAO did represent a democracy of the majority rules but it also broke the immutable imaginary of the Ethereum chain showing instead that key figures can orchestrate its unravelling for the benefits of a single app (and thus the historical record for all other decentralised apps in the process that also use Ethereum as their chronological database).

evidently more complex than purely 'code is law' and the entire 'distributed' network can be centralised behind a common goal eradicating the promise of immutability in the process.[17]

Centralised companies are also integral to the shaping of these 'decentralised' ecosystems. During the Bitcoin and Bitcoin Cash split, while some wallet and exchange companies decided to support Bitcoin Cash, others did not due to uncertainty over its security. Coinjar, for example, called Bitcoin Cash an "altcoin" discursively siding with the 1 MB block size side of the hard fork (see Chapter 4). This decision was political although it was 'justified' due to a projected lower hashing rate of Bitcoin Cash and the possibility of (relatively speaking) untested source code bugs. Customers were given the chance to withdraw funds into alternative wallets before the hard fork occurred but those who did not surrendered their Bitcoin Cash value to the companies who controlled the private keys. After customer complaints, Coinjar gave its users another window to withdraw Bitcoin Cash coins following the fork. Elsewhere, Coinbase initially disclosed they would not support Bitcoin Cash but later revoked this decision, striving to provide a secure service for holding this cryptocurrency by the 1st January 2018. Although the survivability of forks is ultimately left to the market, they can be adopted or not by certain companies. Centralised parties, then, play an important role in enabling or disabling its usability and thereby promoting, or demoting, a fork's legitimacy. The DAO demonstrates how different stakeholders can create rifts in the supposed political hegemony of blockchains creating (de)centralised fragmentation across its architecture.

Banking on Blockchains: "The Empire Strikes Back"

Technical innovations are tweaking existing economic systems to create efficiency gains and also producing completely new models of business such as crowdfunding and peer-to-peer lending. These frameworks show how the rise of FinTech is threatening the 'embedded' and 'out-dated' financial

---

[17] Blockchains are also susceptible to protests similar to a DoS attack. The cost of transactions in Bitcoin is supposed to discourage this behaviour (see Adam Back's hashcash in Chapter 3) but it can still persist. The limit of 1 MB, that allows the protocol to execute 1000 transactions every 10 minutes, was not part of the original Bitcoin code but added in 2010 to control spam by preventing "would-be attackers from overloading the network with a flood of cheap transactions" (Smith, 2017). However, this has sometimes had the opposite effect. During the ensuing block size debate in 2015 (see Chapter 4), an unknown entity was submitting a bombardment of low value transactions to the protocol in an attempt to clog up and slow down the rate of transactions that were being processed. Figure 23 shows how 8,129 transactions were sitting in the mempool—a number much higher than usual at the time. This was described to me by a Coinjar employee as a "protest attack" against the current block size being too small (and in the process proving their point by slowing down the blockchains 'useful' transaction rate). I was attending a London Bitcoin meet-up called Coinscrum during the attack and decided to purchase an amount of bitcoin from a visiting American. He was in the country for a short amount of time and needed some pound sterling so I agreed to exchange him £100 GBP for the equivalent value in bitcoin. After getting some cash out from a nearby ATM he opened his Blockchain.info app on his mobile phone and scanned a QR code, that represents one of my own Bitcoin wallets, on my app. Given the saturation of the mempool we decided to make the miner's transaction fee higher than usual to encourage its inclusion within an upcoming block and therefore beat the rest of the network traffic. I handed over the cash and waited apprehensively for 30 minutes for the transaction to be mined into a block.

industry. The majority of disruptors, however, are platform capitalists who look to connect people through their systems (PayPal, Venmo, TransferWise) through via centralised architectures as opposed to traditional banking behemoths. Unsurprisingly, banks and other financial services are responding by developing their own financial innovations. Nick Shalek, partner at Ribbit Capital, describes this as "The Empire Strikes Back" (VLAB, 2015). Here financial firms have had no choice but to *partner* or *compete* with emerging FinTech start-ups or *acquire* and *co-opt* them (ibid.). Examples of partnering include Citigroup and Lending Club joining forces whereas the actions of bank and brokerage firm, Charles Schwab, demonstrate competition; disclosing in a public manner that their intelligent algorithmic investment strategy takes on the likes of Wealthfront and other software-based investing platforms (ibid.). Similarly, measures taken by established institutions to capture the innovation and energy in Silicon Valley include two accelerators funded by banks—FinTech Innovation Lab and Inno Tribe—while the acquisition of Level Money by Capital One, Check by Intuit, and Simple by BBVA represent the "if you can't beat them buy them" strategy (ibid.). Nationally and globally, regional control over the FinTech ecosystem is dominated by Silicon Valley while New York has become the fastest growing FinTech centre in the world as Wall Street recognises the danger of being left behind (Accenture, 2014).

Existing powerhouses in the banking industry are looking to benefit from their own forms of blockchain capitalism. My group, Squirrel for example, was approached by a blockchain consultant following our Blockchain University presentation who wanted to put us in touch with a bank who were looking to develop a similar project. Many of these banks are enclosing the ideas developed in open source software commons, that were initially posed as public tools for decentralisation, with aggressive patenting on blockchain technologies. This is a contrasting vision of decentralisation to the Bitcoin community as outlined in the previous chapters. Consortium blockchains, with their competing private vision/model of decentralisation, are generally being produced by the powers that be to maintain their hold on the capitalist market. In the case of R3, blockchain may not even be the right word. R3 is a "financial innovation firm that leads a consortium partnership with over 80 of the world's leading financial institutions and regulators… [who] work together to design and deliver advanced *distributed ledger technologies* to the global financial markets" (R3, 2017, my emphasis). The firm was created by former Wall Street executive David Rutter in 2015 and included stakeholders Goldman Sachs, Barclays, BBVA, Commonwealth Bank of Australia, Credit Suisse, JP Morgan, Royal Bank of Scotland, State Street and UBS (Vigna, 2015; Allison, 2015; Kelly, 2015; Williams-Grut, 2015). Goldman Sachs, however, pulled out in 2016 (Hackett, 2016), yet remain investors in other blockchain start-ups such as Digital Assets Holdings (McLannahan, 2016).[18]

While this consortium was a direct response to the rise of blockchains (and the term remains in their lexicon) they have moved towards "distributed ledger technology" to describe the subject of their "research, experimentation, design and engineering" (R3, 2017). They do, however, remain very much in the blockchain world. Their three strategic pillars are: 1) to develop "the base layer reference architecture to underpin a global financial-grade ledger" 2) to deploy a "secure, multi-institution collaborative lab to test and benchmark blockchain technologies", and 3) to run "use cases to identity and design 'up the stack' commercial applications" (ibid.). R3 boasts a myriad of seasoned finance professionals such as investment banker Jesse Edwards and FX trading manager Todd McDonald, technology professionals such as Richard Brown from IBM, and blockchain professionals such as ex-Bitcoin core developer Mike Hearn and revered industry writer/consultant Tim Swanson. For more radical Bitcoiners, this relocation of programmers who were once heavily involved in the 'Bitcoin movement' has been branded as 'switching sides'. R3 announced their distributed ledger platform, Corda, was designed to "record, manage and synchronise financial agreements between regulated financial institutions. It is heavily inspired by and captures the benefits of blockchain systems, without the design choices that make blockchains inappropriate for many banking scenarios" (Brown, 2016).[19] Managing Director, Charlie Cooper, explains, "changes must be made to satisfy regulatory, privacy and scalability concerns" (Peyton, 2017).

An introductory whitepaper describes Corda as taking "a unique approach to data distribution and transaction semantics while maintaining the features of distributed ledgers which first attracted institutions to projects such as R3, namely reliable execution of financial agreements in an automatable and enforceable fashion" (Brown et al., 2016, 15). Chief Technology Officer Richard Brown (2016), in his equally optimistic yet sobering R3 blogpost, describes five characteristics offered by the "blockchain bundle": consensus, validity, uniqueness, immutability and authentication. The culmination of these characteristics and the "thing that is *genuinely new* is the emergence of platforms, shared across the Internet between mutually distrusting actors, that allow them to reach consensus about the existence and evolution of facts shared between them" (ibid.). Brown states the financial industry is defined by these agreements but firms share a common problem that costs tens of billions of dollars a year to rectify: "the agreement is typically recorded by *both* parties, in *different* systems" (ibid.).

[18] Other banks that later joined the consortium include Banco Santander, Bank of America, BMO Financial Group, BNP Paribas, BNY Mellon, CIBC, Citi, Commerzbank, Danske Bank, Deutsche Bank, HSBC, ING Bank, Intesa Sanpaolo, Macquarie Bank, Mitsubishi UFJ Financial Group, Mizuho Financial Group, Morgan Stanley, National Australia Bank, Natixis, Nordea, Northern Trust, OP Financial Group, Royal Bank of Canada, Scotiabank, SEB, Societe Generale, TD Bank Group, UniCredit, U.S. Bank, Wells Fargo and Westpac Banking Corporation (Allison, 2016). However, Banco Santander, Morgan Stanley and National Australian Bank also left the project in 2016 along with Goldman Sachs (Martin, 2016).

[19] Bitcoin core developer Peter Todd has also been hired to help build Corda.

In a technical Corda whitepaper, Mike Hearn (2016b) explains the technical solution offered by blockchains "trade performance and usability for security and global acceptance". This makes sense for a cryptocurrency but for an interbank management system such an operational database is far from optimal. Rather than using a standardised blockchain architecture as a one-size fits all solution the Corda team designed it "from the ground up to address the specific needs of the financial services industry" (Rutter, 2017). As such, Corda is a system that looks to share the management of financial agreements across firms that "record the agreement consistently and identically," is "visible to the appropriate regulators," and is "built on industry-standard tools, with a focus on interoperability and incremental deployment" without "leak[ing] confidential information to third parties" (ibid.). And so Corda directly applies "the 'authentication', 'immutability' and 'uniqueness service' features of blockchains" but radically departs "when it comes to the scope of 'consensus' (parties to individual deals rather than all participants) and 'validation' (the legitimate stakeholders to a deal rather the whole universe or some arbitrary set of 'validators')" (ibid.). Crucially, then, Corda "restricts access to data within an agreement to only those explicitly entitled to it, rather than the entire network… [while] linking business logic and data to associated legal prose in order to ensure that the financial agreements on the platform are firmly rooted in law" (ibid.).

State Cryptocurrencies

R3 is also involved in an exploit called 'FedCoin'. The term started being used in the blogosphere during 2013 to describe the possibility of pegged (to reduce volatility) central bank cryptocurrencies specific to particular nation states (Koning, 2013a, 2014; Motamedi, 2014; Sams, 2015; Andolfatto, 2015). In a discussion paper released in 2015, the Bank of England put forth a surprisingly forward-thinking approach towards the benefits and challenges of adopting a form of national digital currency similar to Bitcoin; at the time, this was very much against the grain in terms of typical central bank responses. Andreas Antonopoulos famously addressed the Canadian Committee on Banking, Trade, and Commerce in 2014 and was received with great interest and appreciation (Senate of Canada, 2014). The Bank of Canada has since shown extremely progressive thinking towards cryptocurrencies and blockchain technology in their subsequent publications (Bank of Canada, 2014; Weber, 2016; Fung & Halaburda, 2016) and is working closely with R3 on central bank digital currency related projects, as is the Monetary Authority of Singapore (Swanson, 2017b). The motive is to reduce cryptocurrency volatility by reintroducing "one central point of control to the monetary system by granting a central bank the ability to set the supply of tokens on a Fedcoin blockchain" (Koning, 2016). Fedcoin could be treated as an extra component of the cash compartment of the monetary supply which would include a degree of anonymity, censorship resistance, reusability of tokens and provide central banks with the monetary control feature of negative interest rates (ibid.). More radically Fedcoin could compete directly with private bank deposits reducing the need for some of the services that commercial banks provide (ibid.).

These forms of permissioned blockchains are designed to "fulfil requirements such as the need to comply with regulations and allow for faster payments, transaction throughput and settlement speed" (ibid.). Yet while "permissioned blockchains provide superior speed, oversight and finality, permissionless blockchains are better at recreating some of the unique qualities of coins and banknotes, particularly their ability to provide anonymity and censorship resistance" (ibid.). In short, "the more cashlike a government digital currency is to be, the stronger are the arguments for implementing a blockchain solution" (ibid.). This blockchain solution can offer a number of benefits:

> 1) the population would get a safe form of fixed-price electronic money that is pegged to the existing unit of account 2) the central bank maintains an independent monetary policy with negative rates as a tool 3) cash, an old technology, is replaced (or complimented) by a cheaper and faster form of fixed-price payment that can be used over long distances 4) and society continues to enjoy a form of anonymous and censorship-resistance payments (sic.). (ibid.)

Meanwhile other global powerhouses have been investing time and money into understanding blockchains potential impact upon the world economy. For example, while I was working out of Europe's largest FinTech accelerator (Level39, One Canada Square, Canary Wharf), UBS, Switzerland's largest bank, had set up a Blockchain Innovation Lab there to keep a finger on the pulse of the emerging industry (Level39, 2015; Irrera, 2015; Prisco, 2015a). Likewise, I interviewed employees of London companies who were situated in accelerators set up by banks, for example, Barclays provided free office space to Bitcoin and blockchain companies in Notting Hill so they could keep tabs on the industry and provide an entry point into the emerging 'world of blockchains'. A co-founder of a blockchain start-up situated in one of these spaces recalled to me how a member of the bank had told him: "you're our tentacles out there". He explained that banks, financial firms, and other big companies were realising they were going to have to work more closely with these new start-ups because they themselves were bereft of ideas and moved at a snails pace of innovation due to their bureaucratic structures. Similarly, back in Silicon Valley, at a Retail and FinTech Expo located at Plug and Play, hordes of investors like this were present looking to take advantage of ideas emerging in the technology industry.

As a response to their dated and time-intensive communication structure (see Appendix 12), SWIFT have also begun including blockchain technology in its global payments innovation initiative (Prisco, 2015b) and later stepped up its exploration of distributed ledger technologies by designing a proof of concept to reconcile bank nostro databases in real time (SWIFT, 2017; Finextra, 2017). To do this, SWIFT has started building a blockchain application leveraging the open source Hyperledger codebase to simplify cross-border payments by synchronising databases and optimize the global liquidity of banks (del Castillo, 2017). Here, "only authorized members will be able to access the POC, which will be integrated with Swift's own identity management platform and its public key infrastructure" (ibid.). SWIFT claim that distributed ledger technologies can generate trust in a disseminated system, efficiency in broadcasting information, complete traceability of transactions, simplified reconciliation, and high resiliency (SWIFT, 2016). Elsewhere, Hyperledger acts as an open umbrella project initiated by the Linux Foundation collating open source blockchains and related tools such as Digital Asset Holdings, Blocksteam's libconsensus, and IBM's OpenBlockchain. Blockchains are partly, but clearly, moving from an anarchist tool of economic dissent towards the potential tools of embedded centralised powers in existing financial empires. They are also becoming powerful mechanisms for organising the operations of nation states such as Estonia (see Appendix 17).

Conclusion

This chapter highlights how blockchains are being co-opted from the beloved disruptive product of anarchist hackers to the management tool of technology enterprises such as Arcade City, multinational corporations like SWIFT, global banks consortiums such as R3. Perhaps more surprisingly, blockchains are being reimagined by nation state central banks to create their own territorial cryptocurrencies that could help create a cashless (in terms of physical coins and bank notes) society. By examining how algorithmic decentralisation via blockchains is administered contrastingly amongst a myriad of stakeholders, the incredible contradictions at play in crypto economies become apparent. Not only is decentralisation imagined and practised in different ways, but all instantiations are now becoming commingled in an interdependent web; in other words, tangled up. Blockchains show that it no longer makes sense (if it ever did) to think about centralisation and decentralisation as a binary system: a small number of large actors act as oligoptical obligatory passage points in blockchain networks. This is not dualistic but a complex spatial form of actors jostling for control (and means of accruing capital) by constructing the next big thing/blockchain. Consequently, calling something centralised or decentralised is meaningless without tracing the contextual, relational, spatial, and contingent patterns of sociotechnical practice that shape (and are shaped by) economic practice.

The phrase "put it on the blockchain" has been used in the industry to mean to decentralise a certain phenomenon (land assets, stocks, health records, votes). I have always found this "the" to be a frustrating misnomer. Although they may share things in common, there is no such thing as a singular or universal blockchain standard. The colloquialism, therefore, always begs the question "which one?" With this in mind, there is often a "homologous spectrum of support" for political-technological modes of organisation "ranging from liberal capitalists to an assortment of anti-capitalist positions" (Taffel, 2015c, 57). The politics of every individual chains, therefore, are complex and vary according to their design and uptake. Consequently, new and contingent subtleties of power emerge through their architectures. More often than not, blockchains are being repurposed, quoting a venture capitalist mentioned in Chapter 6, "to change the world and make a lot of money doing it". This is true in both realms of FinTech: the gregarious start-up economy and traditional finance industry. As Jill Carlson (2017) says, "[w]e may think that we are down the crypto rabbit hole, but really we are through the Wall Street looking glass".

This melting pot is seeing money, code, and space combined in new ways. Projects built on top of blockchains, depending on how they are coded, can become the gatekeepers of great swaths of data about their users and with KYC regulations that insist on companies holding customer identities their role in de-anonymising blockchains grows. As Carlson argues, the "intent was to give people direct control of their funds, free from seizure from banks and governments. Instead, people are handing over that control to a new class of actors—who are frequently even less accountable than their old school counterparts" (ibid.). Meanwhile, blockchain knowledge is being carried forward into different infrastructures (central bank settlement systems, global supply chains, nation state voting, etc.) and developed into other distributed ledger technologies. Here, there are competing ideologies and practices that highlight practical and theoretical limitations to distributed economies. As the technology is normalised it is subject to bureaucratic routines that include "diligence on investors, book-building, addressing compliance concerns and handling the legal process. On the one hand, this marks an important initiative in maturing the market. On the other, it is recreating Wall Street's system around this new asset class" (ibid.). There are, of course, exceptions to the rule but they are increasingly marginalised. That being said, there are certain modes of resistance to this form of co-option by traditional oligopolies: "decentralised exchange is one of the most compelling areas of research in the space. Rather than rebuild the legacy exchanges, decentralized exchange seeks to enable a new way of transacting that is truer to the value proposition of the technology" (ibid.). Ultimately, proponents of decentralisation must be aware of how the desire for capital accumulation in platforms bends distributed software systems around particular centralised business models. It is they who must ensure that blockchain capitalism sheds the limitations of platform capitalism, if that is indeed possible.

Conclusion

Geographies of Algorithmic (De)Centralisation

Drawing from a diverse set of literatures, the aim of this thesis has been to trace diligently the cultural, political, material, economic, and spatial networks of Bitcoin and other blockchains to understand how power is manifested across the protocol between humans and non-humans. The five empirical chapters deal with different theoretical strands that represent overlapping but distinct component parts of the Bitcoin/blockchain cultural economy. The main focus has been to explore how Bitcoin's apparently distributed network infrastructure becomes materialised, socialised, and centralised on different levels.

Thus far, the price of Bitcoin has largely remained beyond the analytical scope of this thesis for the reason that it can become extremely distracting to academics and other commentators: hysteria fills the rhetoric of proponents and sceptics alike as the value fluctuates between highs and lows. In other words, for pundits, a rising price often reflects success and a falling price reflects failure. I first became involved with Bitcoin in the summer of 2013, at the foot of its third bubble as a single bitcoin rocketed from around $68 to $1163 USD. When the price began to fall slowly towards a low of $151 in 2015 many of my peers would confidently tell me that "Bitcoin is dead". Most members of the Bitcoin community (or, rather, communities) are often used to these pessimistic accounts to the point of amusement. This is represented by the webpage and cultural meme of Bitcoin Obituaries at 99bitcoins.com that lists accounts of its death—at the time of writing, Bitcoin had apparently been declared dead 269 times by varying journalists/pundits, the first being in 2010 when the currency was valued at just 23 US cents. The price of Bitcoin is not necessarily indicative of, and certainly not directly proportional to, its success as a decentralising phenomenon. In many cases the stability of currencies, for example, is preferable to volatility or even an increase in value (see Chapter 1).

However, the price remains important and intersects with other geopolitical events. For example, the value of a bitcoin often spikes during times of geographically specific uncertainty—the Cypriot financial bail in, the UK Brexit vote, and the United States presidential election of Donald Trump—as the protocol is used as a tool for capital flight.[1] This is a realisation of a core tenet for Bitcoin's development: providing the power/option for individual citizens to opt out of fiat currencies in times of crisis. Yet it also means that external speculators can profit from the flow of other people's capital flight, piggybacking profits from those crises. While some would argue this is nothing new, Bitcoin is a novel means for doing so. The point of this thesis has been to stress that while blockchains may offer

[1] However, how much of this is speculation and how much is the moving of value outside of fiat currency is unclear.

more distributed modes of money and finance, it is important to trace the contours of power between its actor-networks. Upon closer examination, the role of centralised obligatory passage points in blockchain architectures is significant and often necessary for their formation/maintenance. Even the price of Bitcoin is not a given but is 'discovered' and changed via market mechanisms that are assembled in centralised exchanges via bids and asks—themselves constituted by a range of social factors (capital flight, speculation, remittances, etc.). It is these bottlenecks that 'collect' aggregated speculation as "centres of calculation" (Latour, 1987).

This echoes depictions of nomadic global monetary flows (Leyshon & Thrift, 1997). As value materialises and circulates through different intermediaries—bank notes, digital balances, derivatives, stocks, property—it is only temporarily tied to particular things, people, and places but forcefully participates in assembling their cultural and economic geographies (ibid.). As time goes on, these money/spaces are increasingly mediated by code that also plays a powerful role in modulating "the conditions under which sociospatial processes operate" (Kitchin & Dodge, 2011, 65). Consequently, it is appropriate to understand these contemporary economic geographies as money/code/spaces. This theoretical understanding required a methodology that involved tracing the material-semiotic connections between the things and people that enact and sustain the codified data structures of Bitcoin and other blockchains.

Traditionally, transaction processors within monetary networks have elevated themselves into positions of power not only by accumulating capital (shaving value from the flows of money) but by becoming the gatekeepers of information and centres of calculation where data can be interpreted to make informed economic actions or monetised itself (Leyshon & Thrift, 1997). Cryptographic code/money, as offered by blockchains, is administered by the actor-network of a public distributed ledger that reflects an ideology of the separation of money from centralised institutions. I showed in Chapter 5 that the networked protocol of Bitcoin on a technical level—in terms of node dissolution and the logic of its algorithmic architecture—is certainly distributed: there is no hierarchy amongst peers and any node is free to join any other (see Figure 1). However, the different cultural-economic practices of actors intersecting/interacting with the protocol work to centralise it into a decentralised network state: the senatorial governance of code development, the concentration of private key management under start-up companies, and the coalescence of miners in pools. So while the technical architecture may be (perfectly) distributed, the economy and monetary policy are decentralised (that is, working through many centres).

Following geographies of algorithmic (de)centralisation not only empirically pulls to the surface cultural, economic, material, and political relationships of money/code/space, but also makes advances to its conceptual terrain. Bitcoin's attempt to homogenise and flatten monetary networks with its blockchain architecture only shows how there will always be multiple incantations and hierarchies of money as they fill different political spaces. The fragmentation of the Bitcoin project personifies this: altcoins, hard forks, private blockchains, government blockchains. Now with open source blueprints for cryptographic code/money at everyone's fingertips—with many ideas for how they should be tweaked in order to function correctly, satisfy applications, or fulfil political agendas—the amount of world currencies is growing. So while money homogenises everything else under its quantifiable scale (Marx, 1867; Simmel, 1900), not everything is homogenised under the same money.

This thesis has made bare the political conditions of algorithmic decentralisation as it is manifested by blockchains. As Alexander Galloway (2004) uncovered hierarchy and power through the Internet, and as Nathanial Tkacz (2015) exposed bureaucracy and closure in Wikipedia, through empirical analysis and theoretical critique this thesis finds centralisation in Bitcoin. Tracing the material-semiotic connections between the things and people that enact and sustain the codified data structures of blockchains has demonstrated how their geographies are never isotropic. In other words, while blockchains certainly work to (re)distribute practices on some level, examining their networks from different social, spatial, and material angles reveals subtleties of uneven power. Framing obligatory passage points as socio-spatial 'structures' or 'zones' through which certain cultural-economic practices are enrolled works to redefine centralisation (currently a term used far too ambiguously to carry any real potency) into a relational and contingent process. Multiplications of passage points represent (de)centralised systems but these bottlenecks do not always afford the same control to all actors—as outlined by senatorial governance and the material infrastructure of Bitcoin. To arrive at such conclusions, the socio-spatial trajectories of networked practice must be traced in order to uncover their cohesion in different places. There, the many centres of Bitcoin shape (and are shaped by) the network in distinctive fashions. The politics of centralised coding practices, for example, differs to the politics of centralised start-up companies.

In other words, blockchains will not become ubiquitous modes of democratisation but will equally not disappear from societal organisation. Instead, they will become complex patterns of centralised networked practice (funnelled through obligatory passage points) and multiplied connectivity (distribution) like the Internet before it because they live in the same cultural-economic world. The Bitcoin governance structure can be called centralised, under the obligatory passage point definition, when looking at the practices of the Core developers, but appears decentralised when observing the many clients that can be built on top of the network with the possibility of forking their own rules (see Chapter 4). To do this miners must be relied upon for voting on these decisions, who seem distributed until the cohesion of mining pools are observed, yet the fact that individual miners can move between pools provides another (de)centralised pattern of governance (see Chapter 5). Start-up companies build centralised bottlenecks of control over private keys (see Chapter 6) but the option still remains for individuals to download a Bitcoin client software themselves and become their own self-regulating node in a financial network. I have shown how algorithmic (de)centralisation is piecemealed ideologically and operationally among a mismatch of stakeholders so that it becomes a cultural-economic multiplication (see Chapter 7).

For the most part, radical decentralisation appears to be a stark impossibility on both a technical and capitalistic level: platforms need to be built under some form of centralised governance whereas the quest for capital accumulation demands some degree of conglomeration in economic systems. This is put poignantly by Steve Wilson, Vice President and Principal Analyst of Constellation Research: "[t]here is no utopia in blockchain. The harsh truth is that when we fold real world management, permissions, authorities and trust, back on top of the blockchain, we undo the decentralisation at the heart of the design" (Wilson, 2016). The same was true for the Internet as different entities enrolled its new spatial connectivity into hierarchal channels of capital accumulation.

Blockchain Tensions

The differing roles of Bitcoin arose in opposition to centralised forms of monetary policy and posed challenges to established norms of international financial transactions. In Chapter 1, I described the growth of Bitcoin and developed the concepts of money, code, and space as they are (re)defined through the organisational lens of the Bitcoin blockchain. Here, money/code/space was used as an analytical framework for understanding the geographies of blockchains and approaching the concept of the algorithmic decentralisation of (crypto)currency. Taking inspiration from actor-network theory, it is here that I started to shed the centralisation-decentralisation dualism by adapting obligatory passage points (Callon, 1986) as a way of understanding centralised control in 'distributed' networks. Throughout, the specific practices that constitute money/code/spaces were articulated so that understandings of Bitcoin and blockchain technology would encapsulate their complex cultural relationships.

The investigation, set out in Chapter 2, was designed to carve through the imaginaries of blockchain decentralisation as they intersect with the materialities of infrastructure and high technology cultural economies. This involved redefining a follow the thing methodology around the spatial traces of blockchains, with specific attention paid to Bitcoin, to interrogate their algorithmic architectures as socioeconomic organisational mechanisms. Throughout, the definition of the Bitcoin blockchain as a *thing* has been altered to offer an array of perspectives and help reveal varying modes of (de)centralisation: Chapter 3 as ideology; Chapter 4 as open source code; Chapter 5 as infrastructure; Chapter 6 as entrepreneurial enterprise, and; Chapter 7 as precursor for a range of decentralised forms. Harnessing an ethnographic sensitivity, I traced certain spatial trajectories to illuminate the (dis)connections that are formed through emerging practices as they coalesced at different geographical points.

Blockchains, as management systems, are (generally) designed to obscure their users' identities through public key cryptography and so pursuing certain connections proved to be a challenging endeavour. It seems quite fitting, then, given the community's references to *Alice in Wonderland* in terms of 'going down the Bitcoin rabbit hole', that this task, at times, felt like I was 'following the white rabbit': a frenetic pursuit of an alluring, allusive, and illusive entity into strange places. This is a common feeling for thing-followers: "[t]his kind of research can involve exciting but risky ventures. And it can do your head in. So many things that aren't supposed to go together in theory come together in practice" (Cook et al., 2006, 657). These methodological exasperations are only exaggerated in this case by the slipperiness of digital things and the dead ends provided by cryptographic concealment. But these spatial disconnections are just as important to blockchain ontologies as are the connections that can be more easily followed. Severed ties and gaping chasms *make* space as much as connected paths that align and converge (Massey, 2005): the resilience and deterioration, welding and breaking of trajectories are the enactments and characteristics of overlapping (blockchain) geographies. So the spatial disconnections presented by blockchains are not only methodological hurdles but also an important part of their very being —stumbling across impasses says something about their character. Blockchains, then, simultaneously expose and mask their own spatial connections by cryptographic design: their transactional spatiality is inherently one of (dis)connection.

Follow the thing work opens up more boxes than it closes but this is precisely the point. As a tool for locating uneven political relationships through space it illuminates points of interest for future researchers. By debunking imaginaries of blockchains as homogenising platforms that can flatten all power in monetary (and other) networks, and instead revealing them as complex and contingent digital-material architectures that bind humans and non-humans together in asymmetrical ways, my follow the thing work has attempted to cut through the Bitcoin (and blockchain) cultural economies; in doing so, it has been like looking at a cross-section of bedrock to determine the strata of a geological system. The ethnographer, "renegotiating identities in different sites[…] learns more about a *slice* of the world system (Marcus, 1995, 113, my emphasis). This is both a strength and a limit of all ethnographic research: it is not necessarily representative but also helps reject overarching theoretical generalisations that shroud complexity and, in this case, power. Blockchains, then, should not succumb to overarching investigations but become subject to more detailed and nuanced cultural studies that unpick and unpack their algorithmic fabrics (made up of people, places, and machines) to reveal unique and inherent spatial arrangements.

This attentiveness helped reveal the different worldviews surrounding the algorithmic architectures of blockchains from varying stakeholders (venture capitalists, governments, libertarians, regulators, hackers, etc.). Interestingly, these visions proved to be in a state of political tension and friction. This resonates with the point that "what an algorithm is designed to do in theory and what it actually does in practice do not always correspond due to a lack of refinement, miscodings, errors and bugs" (Kitchin, 2017, 25). From my own analysis, I would also add political struggle to this list. The research process I laid out fully encompassed this understanding and looked to debunk the ideological claims of decentralisation that saturated online discourse pertaining to blockchains. The manner in which algorithms do work in the world cannot be

> …simply denoted from an examination of the algorithm/code alone... [because] algorithms perform in context—in collaboration with data, technologies, people, etc. under varying conditions—and therefore their effects unfold in contingent and relational ways, producing localised and situated outcomes. (Kitchin, 2017, 25)

It was with similar intentions that I did not only rely on the Bitcoin code to tell its own story but allowed different narratives to emerge by following the spatial trajectories of a host of other actors that propel it into being.

The historical and perpetuating ideologies that fuelled the creation of Bitcoin outlined in Chapter 3 demonstrated how the idea of decentralisation has been welded to that of technological determinism/development and perpetuated as an optimal model for economic organisation. Similarly, David Golumbia (2015, 2016b) tars Bitcoin with one political brush by calling it "software as right-wing extremism". Yet this thesis showed that claiming code/infrastructure purely encompasses the politics of their (original) makers is to mask their complexity. Instead, they become wrapped up in a storm of competing trajectories that carry them off in different directions. Bitcoin infrastructure represents a struggle between different groups of people that wish to subvert or control points in its architecture for different cultural, political, ideological, or economic reasons: start-ups to accumulate capital or coin tumblers to enhance anonymity.[2] As such Bitcoin is torn at the algorithmic seams: a reminder that architectures are politically polysemous in their becoming carrying multiple affordances and destinies. This makes any future alignments of money/code/space (not limited to blockchains) poignant foci of research as they collide in different ways and present spatio-political struggles amongst various stakeholders that perform (and profit from) economic practices.

---

[2] Coin tumblers are services that mix different cryptocurrency funds together in order to disguise the movement of money through the network and further obscure potentially trackable and identifiable coins. This represents the continued presence of an 'anarchist' or 'hacker' strand in Bitcoin/blockchain culture where anonymity is preferred.

The plurality of identities that saturated Bitcoin communities was once fairly cohesive because members were bound by the unified goal of developing and normalising the protocol within the global economy. However, as the network has scaled it has become clear that a singular open source codebase, and its centralised mode of governance, cannot fulfil the desires for all of its diverse proponents/ components. The growing stasis of Bitcoin code development with its increasing number of stakeholders, followed by numerous forks, reflects this while the diversity of altcoins, blockchains, start-ups, mining pools, and meet-up groups exhibits fragmentation. This demonstrates that there is no singular blockchain worldview yet the quest for (some level of) decentralisation unites them all, whether this is to increase efficiency (central bank blockchains) or to disrupt the entire economic order (Bitcoin). The main lesson in Chapter 4 is that code builders retain a certain degree of power over the digital infrastructures that they create, even under open source models and a 'decentralised' miner-voting governance mechanism. While there are avenues for dissent, these must come in the form of competing centralised parties that can only hope to hijack the system for themselves. This is not necessarily a problem for decentralised governance, as it generates a new organisational model where power to make decisions for change can be jostled for amongst different actors, but the presence of centralised governors should not be overlooked.

In Chapter 5, I demonstrated how Bitcoin unavoidably has a material and spatial fabric despite popular ethereal imaginaries of the digital. At the same time, however, I showed how cryptography and peer-to-peer architecture are employed to veil Bitcoin's material and spatial processes. The cryptographic techniques shroud the specificity of space in mathematical obscurity. Money under the Bitcoin blockchain, in *effect*, appears dematerialised and despatialised as it enters a 'foggy' and 'intangible' digital nebula that negates the possibility of following some of its footprints. In other words, the material and spatial processes are still whirring away under the hood but the inability to trace them across space renders the Bitcoin network an impalpable entity because transactions enter a cryptographically sealed black box.

By following a bitcoin 'through space' it became evident that technically distributed blockchains rely on centralised cultural-economic components as information is bottlenecked into certain infrastructural spaces (undersea network cables, data centres, ISPs, etc.). The builder(s) of Bitcoin attempt(s) to overcome these material limitations by polyfurcating its database capability across many nodes and obscuring certain data metrics behind cryptographic algorithms. However, when looking at individual wallet services or exchanges in the industrial economy that have been built up around Bitcoin, information and practices are concentrated in centralised locations and become subject to internal weaknesses and hacks as with any other financial system. While cryptography exists to mask transactions, technical barriers to entry push user practices through these bottlenecks that can then act as centres of calculation emerging, by this very process, as the gatekeepers of information and the administrators of transactions. These centres are consequently enrolled as powerful actors within the money/code/space(s) of blockchains. I argue here that start-up companies play a role in reattaching some of the 'ethereal' algorithmic processes of Bitcoin back to locatable space; while the Bitcoin blockchain may be distributed and opaque, for start-ups the Bitcoin economy of transactions is anything but.

Similarly, the process of cryptoeconomics necessitates 'built in' competition that gives rise to centralised mining practices. The scaling of operations by people all over the world investing in more efficient machines raises the difficulty of receiving block rewards. This competition has given rise to mining pools: centralised bottlenecks where miners separated through space can collectively funnel their power through to increase the likelihood of a block reward that will be shared among participants proportionally to their contributions of hashing power. With an oligopoly of large mining pools, miner voting is consolidated among a few small parties (effectively being raised as political representatives for individual miners). Such activities are within the codified rules of the Bitcoin blockchain demonstrating that centralisation certainly lingers within their modes of operational governance. The material logic of code, then, is essential for pinpointing control in any digital infrastructure including the subtle hierarchies of distributed cryptographic protocols.

Bitcoin has provided an opportunity for pioneers to carve out different business models from its distributed architecture creating a vibrant industry in technology hubs like Silicon Valley. In these spaces, the axioms are of a forthcoming and democratising disruption marching forward under the banner of technological decentralisation. In Chapter 6, I argued that the production of Bitcoin and blockchain companies encapsulates a plurality of desires but is ultimately underpinned by a relentless faith in technological determinism, that simultaneously caters for disruption and profit—sometimes by different actors but often by the same. That is, (blockchain) technology becomes the tool that can satisfy the dreams of all stakeholders from hackers to venture capitalists, the left and the right. The internal wrestle of worldviews entrapped in blockchains can be seen, in many cases, as the Californian Ideology in practice. As start-up companies scale, they are enrolled into an embedding and centralising process exposing themselves to external pressures like venture capitalists, legal firms, nation state governments, and hackers. This turns start-ups from small disruptive projects run by a select few technocrats into larger political melting pots that succumb to bureaucracy. The cultures of these different players, far from being irrelevant, are extremely important to cryptocurrency and blockchain economies, especially when so many private keys are centralised within start-up companies. Promises of human disintermediation are again shown to be a fantasy and certain parts of Bitcoin become susceptible to hacks, manipulation, incompetencies, insider trading, and other 'faults' that are supposedly antithetical to cryptosystems but creep back in through their centralised pieces. The overall trend is that the capitalistic best interests of centralised proprietary software companies wins out over anarchist philosophies in a pattern of normalisation.

Finally, Chapter 7 started to unpack the branching out of blockchain projects from Bitcoin while ensuring that their political mutuality was not lost entirely. This focuses predominantly on the contradiction of how blockchains are set up as a tool for both radical decentralisation *and* capital accumulation. In many ways, this chapter acted as an overview but also pinpointed the varying money/code/spaces emerging from algorithmic decentralisation as blockchains are further co-opted among a myriad of stakeholders. So while code certainly transduces the spaces of everyday life (Kitchin & Dodge, 2011), it is also remoulded by cultural practice that is not limited to updates made by programmers. Code/spaces, then, are continually mutating and processual so that power achieved through their digital-material architectures evolve over time. As such, the money/spaces of blockchains are not fixed, but are continually unfolding and splintering.

Value creation and transference via blockchains may continue to be performed through dense social networks (Leyshon & Thrift, 1997), but the transformational relationship with code deeply affects their layered and connective spatial make-up. Consequently, the cultural-economic busyness of money/code/space must be paid attention to: while political monetarist desires can be embedded in software, these rules are not necessarily set in stone. The algorithmic configuration of Bitcoin may on the surface appear to be perfectly distributed but, in practice, it becomes socialised and materialised around specific centres. So on one level code "does what it says" (Galloway, 2004, 193) in the sense that software materially executes what is written in its programming language, but on another it does not because its rules can be manipulated or bent around cultural-economic practice. Future theorisations of money/code/space should be aware of these differences as value is transacted across ever-changing algorithmic geographies.

Appendices

Appendix 1: Imperfect Monies

Today the Gross Domestic Product of the United Kingdom is at 1.8% whereas the inflation rate for the Great British Pound (GBP) is set at 2.9% (BBC, 2017). To put it crudely, this means that GBP loses 1.1% of its value annually, represented by the rise in prices of goods and services.[1] A small amount of inflation in capitalist economies is widely regarded as a positive attribute because it stops money being hoarded as a *store of value* and encourages it being spent as a *medium of exchange*, which, in turn, boosts economic growth. While the British pound continues to be used as a *unit of account*, its buying power decreases when more money is injected into the nation's economy than is spent by its citizens. This reinforces the notion that the functional triad of money is unstable.

When merchants, such as Microsoft, Expedia, Gyft, and Overstock.com, accept bitcoin the value of goods is pegged to fiat money. Yet in Argentina the same is true for the inflationary peso. Legally citizens must pay with 'state-printed' currency but because the Central Bank of the Argentine Republic has broken fiduciary trust with its citizens (and 'globalised' currency markets) by printing more and more pesos to pay for the country's debts, the value has constantly fallen.[2] Consequently, Argentinians usually store their wealth with US dollars giving rise to the occupation of currency traders who stand outside shops to swap US dollars (as a store of wealth) for pesos (as a medium of exchange) at the time of purchase. Yet despite the Argentine peso's inability to hold steady value or act as a decent unit of account, economists still call it money—merely referring to it as a 'failing' or 'poor' example.

Hyperinflation is the name given to the phenomenon when monetary value drops at an extortionate rate. This occurred in post-World War I Germany as the government printed vast amounts of German marks to pay for the country's war debt: by 1923 the US dollar was the equivalent to 4,210,500,000,000 marks (Pollard & Holmes, 1973). Historical photographs (in)famously depict Germans collecting wages with wheelbarrows, children playing with bundles of banknotes as substitutes for building blocks, and people using marks as wallpaper or kindling—an example where a money's 'material use value' as paper overrides its value as a store of wealth. More recently the hyperinflationary Zimbabwean dollar, that soared to an inflation rate of up to 79.6 billion percent in 2008 (Hanke & Kwok, 2009), experienced

---

[1] To reinforce this point British currency is still referred to as 'pound sterling', a terminological hangover from 775AD when 240 silver Saxon pennies would weigh a pound (lbs)—the same weight in silver today would be worth roughly £155 GBP. The pound coin was first introduced in 1489 by Henry II.

[2] It is worth saying at this point that less and less of global money is actually 'printed' in the paper-and-ink sense but rather the supply is increased through digital bank balances.

such a downward spiral of value that citizens were pictured holding cardboard signs that read "Starving Billionaire" and the Central Bank of Zimbabwe ended up issuing bank notes for one hundred trillion dollars. These case studies describe situations where the functions and, by proxy, definitions of money become difficult to discern at the same time as alluding to the different geographical contextualisations of money in varying time-spaces.

To reject Bitcoin as money because it refuses to align with existing, disjointed definitional frameworks seems like an early judgement call to make. That is not to say that I do not take these critiques on board, merely that Bitcoin's "moneyness" (Ingham, 2004) should not be immediately dismissed; while it may still be too early to call cryptocurrencies an evolution of money it is also too early to reject them as such. After all, the definition of money has historically evolved with its (im)material transformations through time (Zelizer, 1989; Davies, 1994; Weatherford, 1997; Leyshon & Thrift, 1997). Some cases have been a result of gradations in cultural practice whereas others, such as the colonial imposition of the French Guinea in West Africa to replace the native cowrie shell as described by Appendix 5, have, understandably, been nothing short of culture shocks (Johnson, 1970; Gregory, 1996; Werthmann, 2003; Şaul, 2004). At this point in time, with such a rapid and dynamic shifting of currencies and payment technologies (Castronova, 2014; Lovink et al., 2015; Maurer & Swartz, 2015; Maurer, 2016), it seems wiser (even if only temporarily) to widen the definition of money and encompass such developments as opposed to confining it to a traditionally and institutionally closed box.

With this in mind, I place a conceptual stake in the ground: I treat Bitcoin first and foremost as a cryptocurrency. In other words, instead of attempting to label Bitcoin with pre-definitions, I treat it as a newfangled entity that sometimes acts like money and at other times like a speculative asset, stock, share, payment network, or digital gold (of course other monies can act like some of these things as well). To use an analogy, in science, under some empirical tests, light acts like a wave and in others more like a particle. I find this a useful parallel for Bitcoin that acts like so many other 'things' depending on the way, or direction from which, it is looked at. Consequently, I posit that it is conceptually advantageous to treat Bitcoin as something new entirely, possessing the qualities of the different 'assets' outlined above—which can be seen as monetary extensions themselves (Leyshon & Thrift, 1997). Cryptocurrencies, I argue, should be researched and understood in and of themselves to reveal their inherent complexity. In the case of Bitcoin, it could be said that I set out to explore its moneyness as well as the powers that reside in the algorithmic decentralisation that it installs/instills through its architecture. In other words, I look at how Bitcoin and blockchain technology connect people and value through spatial and cultural practice.

Appendix 2: A Brief History of Monetary Control

According to archeology, forms of debt management and reciprocation predate currency exchange in local communities throughout history (Graeber, 2011). The earliest records of financial technology date back to 3100 BC in Uruk, Mesopotamia, where royal palaces and temples used stone tablets as accountancy ledgers for marking deposits of commodities such as grain (Oates, 1986).[3] Throughout history, various apparatuses like this have been used in different cultures to organise economic transactions (Davies, 1994; Weatherford, 1997). Alongside such inscriptions used for settling ownership emerged different tokens used as forms of money, like precious metals that were later tied to nation state sovereignty through coinage. To maintain trust in these material-economic systems, and thus allowing their value to carry into the future as socialised forms of reciprocation, they often demanded some form of 'overseer'. Of course, supervisors can act corruptly which originally gave rise to the philosophical question pertaining to tyranny posed by Roman poet, Juvenal: "who will guard the guards themselves?"—a problem that blockchains look to solve.

The first commercial banks emerged in Renaissance Italy with the invention of an innovative financial instrument: the bank note. It was a tool used by pioneering goldsmiths: what "started out simply as paper records of credit transactions and transfer payments gradually became transformed into a significant extension of the metallic money supply" (Davies, 1994, 251). This would eventually have extreme impacts on the economy as the "invention of banking and the paper money system destroyed feudalism, changed the basis of organization from heredity to money, and it changed the basis of economic power from owning land to owning stocks, bonds, and corporations" (Weatherford, 1997, xii-xiii). This demonstrates how material networks of money are deeply connected to the spatialisation of economies. Bills of exchange freed the value of money from the confines of precious metals or singular currencies that could be deposited at the bank (for a fee) while their value was readily exchangeable with issued paper credits (ibid.). Bank notes were effectively as 'good as gold' and remained so until privatised institutions discovered the art of money creation through a paper-based form of debasement that pushed money "beyond the limits of minting" (Davies, 1994, 149).[4] By issuing more bank notes than they had gold in reserves, banks had produced an early form of fractional reserve banking: in effect, creating money from nothing.

Money creation "provoked a boom in the European markets by helping to overcome the vastly

---

[3] The first forms of writing found in archeology have been allocated to economic transactions.

[4] Debasement is a form of inflation personified by Roman Emperors who, faced with rising government expenses, increased coffers by reducing the precious metal content of coinage, which had the effect of increasing the price of goods relative to currency units (Weatherford, 1997).

insufficient supplies of gold and silver coins. By making the system work much faster and more efficiently, they increased the amount of money in circulation" (Weatherford, 1997, 77). Yet, with it came a systemic obligation for depositors to trust their banks not to inflate the money supply. In this kind of system, monetary policy was 'decentralised' as no single entity has a monopoly on the creation or regulation of currency—although individual deposit control remained centralised because institutions were trusted to hold money. In a sense, this free banking model self-regulates itself through reputation-based self-preservation in a competitive market that reduces moral hazard for individual banks who are only as strong as the overall whole and therefore each other (Bagehot, 1873). The Scottish model of free banking between 1716 and 1845 is often given as evidence for its potentially positive competitiveness and stability (White, 1992; 1995; Kroszner, 1995). Naturally, then, free banking adheres to a trust in market forces to create a functioning banking system with no outside interference or regulation; it similarly represents an inherent distrust in the ability of government bodies to make decisions for the good of the economy (Goodhart, 1991). Free banking resonates somewhat here with the Bitcoin movement in terms of a rejection of overarching authorities who some see as guilty of defrauding or plundering the people (Hayek, 1937; 1976). Free banking advocates further argue authoritative regulation is too conservative or restrictive on competition and innovation in financial markets (Smith, 1936). This cohort of advocates calls for a theoretical re-adoption of free banking and includes Smith (1936), Hayek (1976), Bagehot (1873), Friedman (1982), Rolnick and Weber (1983; 1984; 1988), White (1984; 1992; 1995), Horwitz (1992), Timberlake (1978; see also Dowd and Timberlake, 1998), and Foldvary (2008).[5]

On the other hand, it is argued that in terms of practice, the absence of a centralised governing body, a laissez-faire free banking system invokes instability (Thornton, 1802); if faith in a bank dwindles, too many withdrawals could soak up its liquidity and the paper money it printed 'out of thin air' would be worthless. Here, trust in currency reflects trust in commercial banks. Numerous bank runs occurred in the United States during the early 19th century where various forms of free banking models were in operation (Gorton, 1985; Markham, 2002).[6] Lack of capital, or fraudulent procedures led to distrust in, and failure of, certain banks; this, in turn, caused contagious panic across the industry (ibid).[7] It would

---

[5] For a deeper discussion of free banking and its evolution see Goodhart (1991), especially Chapter 2.

[6] It should be noted that the period in the United States from 1837 to 1864 known as the Free Banking Era is somewhat of a misnomer as the country was based on various state banking systems that practised "free banking" laws so that government restricted certain operational procedures (Kenneth, 1988; Rockoff, 1989; Bodenhorn, 1990; Economopoulous & O'Neill, 1995). In this sense bank failures have also been attributed to regulation procedures as opposed to the systematic failure of free banking itself (Calomiris, 2010). The relationship between governments and banks in the nineteenth century is therefore much more complicated than this thesis has room for. For greater discussion see Rolnick and Weber, (1983; 1984; 1988).

[7] Michigan banks notoriously practised fraudulent banking operations and were known for depicting animals on their issued bank notes which gave rise to the term "wildcat" banks that were "marked by their lack of stability and suspect notes" (Markham, 2002).

later become the role of the central bank, or the banker's bank, to undo the risk associated with decentralised free banking systems through the introduction of government monitoring and control via centralised monetary policy.

The first central banks, however, were private commercial banks, not regulators. The Bank of England, for example, was formed by an Act of Parliament in 1694 to raise £1,200,000 from wealthy Englishmen (who would become private shareholders of the bank) to finance the Nine Years' War with France fought by King William III (Andreadēs, 1966: Bank of England, 1970; Bagehot, 1873; Goodman, 2009). The Bank of England, and many other emerging central banks, would develop and adopt the modern functions of central banking slowly (Capie et al., 1994). As Charles Goodhart (1991) puts it: "Central Banks have evolved naturally over time" (vii-viii).

Early European central banks were not initially formed to occupy a supervisory role to the commercial banks that conducted business within the nation state (Goodhart, 1991): the Bank of England operated as a "private joint-stock commercial organisation, trading and seeking profit on its own capital resources" (Elgie & Thompson, 1998, 36). While depending on the Bank of England as a "money-raising machine" ministers used the renewal of the Bank's charter as a "bargaining counter" to establish some control over its operations and "keep at lest a minimal grip on the terms of credit which they received" (Elgie & Thompson, 1998, 36). In the two centuries following 1694, as the Bank of England "developed the modern techniques of central banking, it continued, under certain formal and informal constraints imposed by different governments, to exhibit substantial levels of economic and political independence" (Elgie & Thompson, 1998, 35).

In 1847, as the bank was looked to increasingly as a public authority, the Bank Charter Act was passed by government, restricting the authorisation of new bank notes to the Bank of England and leading to its monopolistic control over the British money supply (Capie et al., 1994).[8] It had, through legislation, become an obligatory passage point for the issuance of bank notes (see Chapter 1). The Bank of England's "privileged legal position, as banker to the government and in note issue, then brought about consequently, and, naturally, a degree of centralization of reserves within the banking system in the Central Bank, so it became a bankers' bank" (Goodhart, 1991, 5). Holding the bulk of the nation's metallic reserve (from the government, commercial banks, and its own depositors) gave the central bank a certain degree of power and responsibility: it would become dependable for providing extra liquidity in times of economic difficulty (ibid.). Still a private institution, albeit with tight formal (and informal) ties with the government, the Bank first acted as the lender of last resort during the widespread panic caused by the credit crunch of 1866 (Fischer, 1999; Flandreau & Ugolini, 2011). This

---

[8] As new banks could not issue bank notes and existing banks could not expand their issue, private bank notes were eventually phased out.

was something that economist Walter Bagehot (1873) advocated strongly and The Bank of England would later adopt this role as one of its core functions (Goodfriend & King, 1988; Goodhart, 2011). Gradually, the Bank became a "noncompetitive, non-profit-maximizing body" until it was officially nationalised in 1946 (Goodhart, 1991, 45).

Ever since 1914, with the massive amounts of expenditure needed to finance the First World War, ministers had slowly begun to exercise more control over the Bank of England to direct monetary policy towards their own economic visions (Elgie & Thompson, 1998). After it was nationalised, the Bank of England continued to be marginalised in both decision-making and administrative controls being positioned in more of an advisory role to government who brandished a new hands-on Keynesian economic philosophy of cheap money (Fforde, 1992): expanding money supply with low interest rates to stimulate lending, employment, and economic growth (Keynes, 1936). In doing so, politicians backed themselves into a corner. With increased inflation and unemployment the nation's economic state became increasingly a government product and therefore problem. By the 1980's the central bank had become an instrument of parliament and politicians were feared as an inflation-creating machine (ibid.). Monetary policy became a tool for influencing short-term electoral decisions at the expense of long-term economic stability and so "debate about the value of central bank independence gathered momentum" (Elgie & Thompson, 1998, 66). During the 1990's the Bank of England slowly clawed back greater responsibility and autonomy from the government until Prime Minister Gordon Brown gave it operational independence in 1997. Today, the UK government sets the inflation target for the Bank of England to reach with its own monetary policy.

Many countries have modelled their central banks on the Bank of England yet all have evolved in unique circumstances. The United States Federal Reserve, for example, was formed in 1913 as a direct response to calls for central governmental control of the monetary system to quench the flames of reoccurring financial crises (Warburg, 1930; Hetzel, 2008). President Woodrow Wilson offered the solution of "a public-private partnership with semiautonomous, privately funded reserve banks supervised by a public board. The directors of the twelve reserve banks, representing commercial, agricultural, industrial, and financial interests within each region, controlled each bank's portfolio" (Meltzer, 2003, 3). Ultimately, a "central bank's authority and scope of action depends on the government" who grants laws to give them autonomy (or not) on pursuing price stability (Cukierman, 1992, 354). Naturally, different central banks enjoy varying degrees of independence (Parkin, 1978, 1987; Banaian et al., 1983; Cukierman, 1992; Burdekin et al., 1992).[9] The typical paradoxical or schizophrenic situation of central banks—publicly owned yet an independent institution (Meltzer, 2003)—has evolved over time as a position to reflect both private and public interests. Indeed, with

[9] The staggering hyperinflation in Zimbabwe of 471 billion percent in 2008, caused by the masses amount of fiat currency printing orchestrated through the overarching dominance of the Zimbabwean government over its central bank, shows how dangerous these relationships can be for a country's people (Coltart, 2008; Hanke, 2008; Hanke & Kwok, 2009).

private and public components, central banks necessarily adopt a unique structural situation in an attempt to decrease any single body profiting from interference and to increase economic efficiency (Johnson et al., 1998). However, many commentators on the 2008 global financial crisis, including the early builders of Bitcoin, see the private-public ties of central banks, and their consequential influence, as a dangerous centre of control with its own points of corruption (i.e. bailing out private banks).

Appendix 3: Decentralism

The etymology of decentralisation is deeply rooted in the French Revolution of the late 18th century and usually promotes secession and separatism from large overruling governments (Schmidt, 1990; Leroux, 2012). It is often used in opposition to centralised forms of control—structures that decentralists see as closed, hierarchal, oppressive, and unequal. Decentralisation, as both a political vision and tool, has become increasingly popular since the 1970's following a prior post-war trend that saw the increased centralisation of governmental power and resources (Manor, 1999). This pattern led to massive economic gains for certain nation states but did little to reduce poverty and inequality for their citizens (ibid).

Slowly, Western scholars and policymakers alike began championing and experimenting with the notion of decentralisation that could be used to bring about fiscal efficiency and participatory citizenship at a local scale (Rodden et al., 2003). This framework of decentralisation is traditionally used to describe a "mechanism designed to devolve decision-making powers to the lowest levels of government authority and to promote democracy and participation, such that local people are directly involved in decisions and developments which affect them personally" (Nel & Binns, 2003, 108-109). The term 'geography' in relation to decentralisation is only ever really used in this context or its wider practice within nation states (Burns et al., 1994, 6). Here, it has become a popular model for democratising what the West calls (post-colonially) developing countries (Bardhan & Mookherjee, 2006; World Bank, 2004, 2009; Cheema & Rondinelli, 2007).

Appendix 4: The Demonetisation of India

The vulnerability of citizens to centralised institutions was personified in India at 8.00pm on the 8th November 2016 when the country's Prime Minister, Narendra Modi, suddenly announced the demonetisation of all 500 and 1000 rupee banknote denominations with the aim of reducing counterfeiting, discouraging tax avoidance, and curtailing the operations of black markets. At midnight that same day, the invalid notes would no longer be accepted nationwide but citizens had until the 26th December to exchange their old notes (with an initial limit of 4500 rupees). Subsequently, citizens queued at banks all over the country in order to redeem expired banknotes for government-sanctioned money. This had a significant effect on rural areas where people had to travel to the nearest town to exchange their currency (Doshi & Allen, 2016). A number of deaths were linked with the crowds that gathered outside banks (Dhupkar, 2016), as well as the non-acceptance of demonetised denominations at hospitals (Rajeevan & Ganapatye, 2016). But the withdrawal 87% of India's cash also had a staggering effect on the nation's economy (Reddy, 2017). Poorer citizens were accustomed to using the revoked notes as a store of wealth and, with no record validating their income source, they were unable to exchange them for legitimate currency. Instead, the largely illiterate populations living in rural villages had no other choice but to open bank accounts with no prior knowledge of the associated procedures nor the money to bear the costs of maintaining one. Demonetisation had forced the poorer population to embrace more modern forms of financial exchange and divorce traditional means but at severe private economic cost. Former Indian Prime Minster, Manmohan Singh, called it "organised loot and legalised plunder" (Quartz India, 2016).

Appendix 5: The West African Cowrie Shell

I cannot walk into my local café and buy a coffee with a handful of cowrie shells. Historically, however, this was a common medium of low-cost exchange in West Africa for centuries (Johnson, 1970; Gregory, 1996; Werthmann, 2003). The reason that I must use Australian dollars as a means of exchange in Sydney but would have been able to trade with cowrie shells in West Africa 200 years ago, is because money is constrained to cultural-economic practices in space-time. This is personified by the struggle of French colonialists from 1897 to impose their imperial and, from their point of view, more progressive franc upon Burkina Faso (then West Volta) economies for four decades (Şaul, 2004). For a time both currencies operated with some independence, overlay, and friction with each other. The cowrie shell stuck thanks to the cultural values placed in the item (including religious significance, protection, medicine, ritual payment, fertility, divination and burial) and the embedded networks of control where native leaders managed markets and currency (sometimes as a form of calculative independence from and cultural resistance to colonial sovereignty) which were eventually disrupted by a number of methods imposed by the French settlers (ibid.). These included banning imports of cowries, including them as tax payments in an endeavour to exhaust supplies, and later through confiscation and destruction where the French would seize and then burn piles of shells under the cover of darkness to strengthen the position of the franc (ibid.). Acceptance of the franc over the cowrie found most progress, however, from the changing of cultural practice over time. Eventually, after 40 years of struggle, subsequent generations of the indigenous population, who had grown up under colonial rule, no longer saw the cowrie shell as valuable as their ancestors once did (ibid.). In other words, the cultural-economic networks of practice in Burkina Faso had changed to start excluding the cowrie shell as a thing-of-economic-value and it was mostly eradicated from monetary circulation. This case study beautifully captures the social relations intertwined with money and the power that can come from its control (Simmel, 1900; Baker & Jimerson 1992; Maurer, 2006; Dodd, 2014) and also shows how it is performed through specific networks that, if broken down, no longer suspend that thing as a monetary form (see also Appendix 6).

Appendix 6: The (Swiss-printed) Iraqi Dinar

A case study that epitomises the cultural-economic suspension of things-as-money across space through practice is that of the 'Swiss-printed' Iraqi dinar. Following the 1990-1991 Gulf War, Iraq was effectively divided into two areas that were "politically, militarily and economically separate from each other" (King, 2004, 7): southern Iraq fell under the control of Saddam Hussein and northern Iraq became "a *de facto* Kurdish protectorate" (ibid.) known as Iraqi Kurdistan. As a result of embargoes under Hussein's rule, the Central Bank of Iraq (CBI) began printing large amounts of low-quality Iraqi dinar using Chinese-manufactured plates that depicted Hussein's image. The currency subsequently underwent a period of hyperinflation: the circulation of new notes "jumped from 22 billion dinars at the end of 1991 to 584 billion only four years later" (ibid.). Formerly, Iraqi dinar had been printed in the UK by the British banknote manufacturer De La Rue using Swiss-engraved plates (Koning, 2013b). When the new government-backed 'Saddam dinars' were introduced Hussein revoked the legitimacy of 'Swiss dinars' and offered a six-day period from the 5th May 1993 where citizens could exchange Swiss for Saddam dinars, after which the CBI would cease to honour their liability (ibid.). Over the same six days Hussein closed the border between northern and southern Iraq cutting the northern population off from repatriating their currency (Coats, 2005). This left a large proportion of Swiss dinar stranded in Iraqi Kurdistan (Koning, 2013b), backed by "no formal government, central bank, nor any law of legal tender" (King, 2004, 13). The "Kurdish governorates did not have access to the printing plates for the Swiss dinars… [and refused] to print low-quality notes of their own" (Foote et al., 2004, 19). This left the population with supposedly 'worthless' pieces of paper backed by nothing. Yet from such an insidious and isolating incision came a compelling and emancipatory tale of the power of money that I cite here to demonstrate the necessary cultural-economic networks required for its performativity.

Despite being cut off from any associated government, the population of Iraqi Kurdistan (with no other option) continued to practise economic exchange with the limited supply of Swiss Iraqi dinar available to them. Amazingly, the unsanctioned, illegitimate, and disendorsed bank notes maintained their economic value over a ten-year period as they continued to be used as money. In a twist of fate the heavily printed Saddam dinars that bore the full weight of government backing devalued tremendously over the same amount of time so that one Swiss dinar eventually had an exchange rate of three-hundred Saddam dinars. With "regard to viability, the episode shows that 'intrinsically useless' notes can continue to function as money, even though their use as such is, not only officially unrecognized, but officially condemned" (Selgin, 2015, 96). To add further intrigue to this story, as the invasion of Iraq by coalition forces in 2003 became ever more likely, the Swiss dinar actually rose in value relative to the US dollar (Varian, 2004). Financial derivatives played a significant role in this elevation: for example, a particular futures contract "paid out 100 cents if Saddam was deposed by the end of June 2003 and nothing otherwise" (King, 2004, 9). This outside force meant the Swiss dinar became more valuable the more likely the currency would be valued by a subsequent government following a takeover (Varian, 2004).

On one hand, this case study points to the irrelevance of government-backing if cultural-economic networks exist between people to keep money suspended in a state of agreed-upon value (consensus). On the other hand, it proves expected future value, based on the actions of nation states, plays a very real role in the forming or dismantling of monetary value. What is consistent here is the necessary trust, belief, or faith present in the humanised geographic spaces that perform money: shifting networks and the withdrawal or introduction of new actors fixed and fluctuated the value of the Iraqi Swiss dinar. In other words, cultural-economic networks contribute to the value of money thanks to a 'suspension of disbelief'. When these relationships change, so does the value of the money they suspend.

Appendix 7: The Value of Monopoly Money

The phrase "Monopoly money" references the banknotes used in the popular board game and is sometimes used to describe currencies that have no value or are treated as worthless (Boise, 2005). Yet, within the 'networked economy' of the Monopoly board these notes are imbued with a particular potency. Interior to the game, such 'banknotes' can be used to buy plastic hotels or pay rent to another player: they are powerful within the context of the game and, indeed, the game could not function without them. As the notes are passed around they become their own form of money inside the small spatial-temporal network that is created. The performance of this network is exemplified (and destroyed) when a cheater enters the game's economic system: if someone steals extra notes from the bank, and others notice, then the trust in the currency breaks down. The performance of money is broken and the notes become worthless bits of paper (again) that can no longer be used to make purchases or payments. While the networks of fiat currency and other monies may be more spatially far-reaching and complex, the networked practice by which value is suspended acts, and/or reacts, in the same way.

Appendix 8: A Constantly Evolving Space-Time

Modern societies are defined by their complex mobilities (Urry, 2007). Countries, regions, states, and borders, for example, are not stationary entities but shifting, semi-permeable, and dynamic with countless flows of people, commodities, and ideas traversing (or inducing) their spaces (Massey, 1991; Macleod & Jones, 2001; Terlouw, 2001; Mezzadra & Neilson, 2013). Cities are not stable in and of themselves but are continually *made* through an array of complementary and competing processes (Hermant & Latour, 1998; McNeill, 2017). The obelisk, Cleopatra's Needle, in Charing Cross Embankment, London, is far from motionless. It is part of a dynamic transitory or "continual differing" (Anderson & Harrison, 2010, 20): "a physicist who looks on part of the life of nature as a dance of electrons, will tell you daily it has lost some molecules and gained others" (Whitehead, 1920, 167). Meanwhile, the earth is spinning rapidly on its axis, swinging around the sun, and being flung outwardly through the galaxy at 1,300,000 miles per hour. There is always a "background 'hum' of on-going activity" (Anderson & Harrison, 2010, 6). Mobility, according to Hayden Lorimer, can even include "the continual flux of sitting still" (Merriman et al., 2008, 206). Space, then, is constantly busy: a vortex of trajectories, alive with movement (Massey, 2005). Even things that appear to be static are in a constant state of change: co-contributors to a perpetual movement and patrons of space.

Appendix 9: Losing my Religion

When I first 'went down the Bitcoin rabbit hole' I was engrossed by the compelling and pioneering visionaries working on the political fringes to neutralise monetary control by submitting it to a distributed network. Fascinated by Bitcoin's unique mode of value formation and the plethora of social practices that blockchains promised to decentralise, I quickly became a follower and a proponent. My enthusiasm was heightened upon entering Silicon Valley in 2015 where I felt like I was at the forefront of something world-changing and emancipating: the next technological revolution (see Chapter 6).

'Going native' is a term that suffers from the colonial hangover of anthropology's history. It was originally used to depict 'white' anthropologists getting too close to the 'natives' that they were researching and losing critical detachment. While the term carries this historical weight that, if not used carefully, could reinforce fallacious binaries—between stranger and native, white and black, West and East, and culture and nature—it is useful for describing the difficulties experienced by the ethnographer when researching any group of people that they try to understand. Despite my best efforts, I had gone somewhat 'native' as a participant observer working for Bitcoin/blockchain companies, attending meet-ups, and interviewing members of the community. By carrying such optimism for algorithmic decentralisation I, in part, absorbed parts of the mindset described as the

Californian Ideology. I had read Richard Barbrook and Andy Cameron's (1996) article that first presented this term before I had started my research, taking it with a pinch of salt and brushing it off as a poetic exaggeration of high technology culture with loose analytical comparisons to Jeffersonian democracy and the West Coast expansion of the United States—highlighting its many paradoxes. It was only upon returning to Sydney, and analysing my collected empirical data, that I began to recognise the philosophical contradictions emanating from different actors within the Bitcoin and blockchain cultural economies as well as my own way of thinking. This is something also recognised by Nigel Dodd (2017):

> When I asked a Bitcoin trader about the theory of money underlying his understanding of cryptocurrency, he compared Bitcoin to gold; indeed he suggested that the currency was superior to gold because its supply could be absolutely fixed (at 21 million coins) by the underlying software. At the same time, he conceded that it is possible for the chief scientist at Bitcoin to remove the cap on Bitcoin production, for example by doubling the total number of Bitcoins that will eventually be mined to 42 million… [S]uch a move would undermine the techno-utopian ideals that are so important to Bitcoin, which hinge on the argument that the supply of Bitcoin can never be altered. When I put this point to the trader in a question, he suggested that the belief that the total number of Bitcoins would never exceed 21 million acts like a socially necessary fiction that holds the network together. In other words, while the chief scientist at Bitcoin could indeed raise the cap, he was highly unlikely to do so because such an action would shatter the belief-system that sustains the network itself. In other words, the trader I was speaking to appears to behave like a gold bug, while thinking like a social constructionist. He saw no contradiction in his position. (8-9)

Similarly, I would assert that Bitcoin was distributed, willingly ignoring the holes in this argument even though I knew they existed; probably because they disproved the fantastical imaginary of a distributed world with, at the time, an unwelcome complexity. With this form of confirmation bias, I was, to a degree, fulfilling my own role as a Californian Ideologue. From subsequent analyses, particularly by creating a more relational and spatial lens through which to understand (de)centralisation, different and uneven patterns of power became increasingly evident to me.

Today I stand somewhere between a proponent and a sceptic. This, I find (or, rather, hope), helps me stay critical when the majority of pundits stray into the camps of complete proponent or complete naysayer, thus succumbing to sensationalist narratives. The inherent contradictions I experienced in my own way of thinking led me to create the term algorithmic (de)centralisation to pull out/apart the centralised and distributed pieces of blockchains. But to ignore my early partial swaying to the hype of Silicon Valley would be intellectually dishonest and an analytical limitation. The builders of blockchains are, in some cases, right to be excited about the impact of algorithmic decentralisation, but they should also be wary of slipping into tropes of radical disruption—a sensationalism that echoes older narratives surrounding the Internet and the New Economy. Blockchains will certainly change the world to some degree (they already have as all things do in their own way), but not in the radical manner many early proponents espoused.

Appendix 10: Screen Essentialism and High Frequency Trading

Software now saturates daily practices to the extent it has become part of the epistemic wallpaper of everyday life (Thrift, 2004): it is assiduously active yet blends into the background noise of the normal and mundane. Digital data appears to float around as a metaphysical phenomenon—especially since the rise of the Internet and cloud computing both of which conjure up imaginary (almost fourth dimensional) space sequestered from the corporeal. Here, software becomes a "visibly invisible" essence (Chun, 2008) with the "visible code written by the programmer… made invisible at the moment the code is compiled" (Galloway, 2004, 65).

The Bitcoin blockchain is an algorithmic protocol. Algorithms, composed of the commands facilitated by computer code, are largely ignored despite their inextricability to the hyperconnected data-driven global economy (Kemp-Robertson, 2013):

> Once we become habituated to infrastructures, we are likely to take them for granted. They become transparent, as it were. But there is something distinctive about the invisibility of algorithms. To an unprecedented degree, they are embedded in the world we inhabit. This has to do with their liminal, elusive materiality. In sociological parlance, we could say that algorithms are easily black-boxed. (Mazzotti, 2017)

Disregarding code and the material infrastructures that support it, however, can have profound implications. This was exemplified by the exposure of Wall Street to High Frequency Trading (HFT), a practice that secretly and parasitically attached itself to the world economy in the form of algorithms that purchased stocks from electronic exchanges. Since the demise of the trading pit in lieu of automated technologies, traders now rely on computer terminals to access the market (Zaloom, 2006). Michael Lewis's (2014) bestseller *Flash Boys* describes the formation of an industrial ignorance surrounding this new technology where traders remained oblivious to the physical processes by which algorithms and routers worked. Behind the click of a button is a material meshwork of wires, cables, and circuit boards that help perform the global stock market. Lewis explains how the "world clings to its old memorial picture of the stock market because its comforting; because it's hard to draw a picture of what has replaced it; and because the few people able to draw it for you have no interest in doing so" (4). Screen essentialism obscures the simple fact that information takes time to travel across distances in different forms (radio waves, electricity, light) through varying mediums to enact the digital. So data not only governs time-space but is also mobile through it, no matter how unfathomably small the timeframes of movement appear to be.

The infrastructural ignorance to algorithmic geographies presented an opportunity for HFT firms to set up hardware in close proximity to the data centres that feed information to traders on Wall Street. This allowed coders to 'cheat' the system by sending and receiving data quicker than any stockbroker in the city. Programmers designed algorithms to intercept and read buy orders for stocks—when a buyer made a bid to an exchange the algorithm beat that order and purchased it. Then with ownership of the stock, the algorithm sold it to the same buyer who made the initial order for a fractionally higher price. Here, traders fell victim to an extremely costly form of screen essentialism as HFT firms sapped billions of dollars from the economy. Even as early as 2012 algorithms administered 70 per cent of public stock market trades (Steiner, 2012), so that pensions, mortgages, shares, stock and individual retirement accounts have become increasingly left in the hands of code; the story of *Flash Boys* emphatically shows understandings should not neglect the actions of humans pulling some of the algorithmic strings in the background. In "order to work, algorithms must exist as part of assemblages that include hardware, data, data structures (such as lists, databases, memory, etc.), and bodies' behaviours and actions" (Terranova, 2014).

Like many infrastructures, algorithms often go unnoticed until they break and systems seize up (Star, 1999; Jackson, 2014).[10] Events like the 2010 Flash Crash, where nine per cent of the world's market value briefly disappeared thanks to malfunctioning HFT algorithms, personify this. Such a reliance on code has created a degree of anxiety surrounding the growing dependency on machines in an increasingly automated society (Stiegler, 2016). Other accounts, however, are more sobering: Beverungen and Lange (2017) describe financial markets as "human-machine ecologies" recognising that the relative simplicity of HFT algorithms demands consistent attention from programmers. This perspective ensures markets "do not resemble the bleakest visions of cybernetic control" (ibid.). It is important for algorithmic geographies to recognise these human-machine ecologies where even climate can become a notable factor—in London, microwave transmissions are used to send market data through the air because they work particularly well in drizzle (Mackenzie, 2014b).

---

[10] Brain Larkin (2013), however, suggests that this quality of infrastructures is a "partial truth": "[i]nvisibility is certainly one aspect of infrastructure, but it is only one and at the extreme edge of a range of visibilities that move from unseen to grand spectacles and everything in between" (336). For example, people who work on infrastructures are constantly aware of their existence.

Appendix 11: The History of Open Source

The specific investigation of Bitcoin's political history in Chapter 3 demonstrates how its code is a repository of social norms and values (Berry, 2011). The cypherpunks I outlined often held similar values to those associated with the open source software movement and these intellectual groups largely overlapped. As a means of production, open source grew out of what was initially referred to as "free software" and emerged as a "genuine grass roots revolution" (ibid.):

> Free Software's roots stretch back to the 1970s and crisscross the histories of the personal computer and the Internet, the peaks and troughs of the information-technology and software industries, the transformation of intellectual property law, the innovation of organizations and 'virtual' collaboration, and the rise of networked social movements. (Kelty, 2008, X)

The movement positioned itself against the increasing control of propriety software utilised by corporations in order to create an ecosystem in code development that resembled that of the intellectual style of science (Deek & McHugh, 2008): an open, experimental, and consensual form of knowledge production (Berry, 2004). Practitioners initially existed in dislocated dribs and drabs but became formalised by Richard Stallman with the Free Software Foundation in 1985 that emerged as a rallying cry to make software free from both constraints and cost (Deek & McHugh, 2008; Kelty, 2008). Producing this proprietary system provided a form of 'commoning'—exemplified in open access—for technological development (Raymond, 1998). The political premise regarded code as a public good harnessing a discourse surrounding "code, freedom, power, progress, community and rights" (Berry, 2004, 71). To ensure the best quality of code and for advancements to become most beneficial to society, it was based on the premise that software should be accessible to an open, cooperative community (Kuhn & Stallman, 2001).

Free software groups first began to align with the Advanced Research Projects Agency Network (ARPANET): an early packet-switching network that used the TCP/IP protocol and later became the foundation of the Internet. ARPANET's "electronic highways brought together hackers [from] all over the U.S. in a critical mass; instead of remaining in isolated small groups each developing their own ephemeral local cultures, they discovered (or re-invented) themselves as a networked tribe" (Raymond, 1998, 16). Gradually, free software gained traction exemplifying a "considerable reorientation of knowledge and power in contemporary society… with respect to the creation, dissemination, and authorization of knowledge in the era of the Internet" (Kelty 2008, 2). Yet some ideological friction occurred; this was instigated by Eric Raymond in 1997 and resulted in a divergence (or forking) between free software and open source software.

Raymond "was concerned that conservative business people were put off by Stallman's freedom pitch, which was, in contrast, very popular among the more liberal programmers" (Perens, 1999, 80). Opposing the anti-government and anti-centralist rhetoric (Berry, 2004), open source was conceived to "market the free software concept to people who wore ties" (Perens, 1999). The countercultural New Left and the entrepreneurial New Right of the Californian Ideology locked horns again here. David Berry (2004) explains that the Free Software foundation used a discourse of ethics and a discourse of freedom (Stallman, 1999), whereas the open source movement draws more from discourses of neoliberalism and technical efficiency (Raymond, 1999). Both strands helped create projects like the Linux Kernel (an operating system assembled under free and open source software development and distribution) grow into the business world to become the most widely ported operating system in global computer hardware platforms—here the "neoliberal tinge" (Tkacz, 2015) of openness is relatively clear as capital accumulation becomes a driving force behind the open source model under laissez-faire markets. Although there are distinctions between the free and open source software movements they have often shared a similar trajectory, as well as the same authors and coders (Berry, 2004). Looking past the differences, both have contributed to the "increased visibility of code as an object of economic, legal, political, artistic and academic interest" (Mackenzie, 2006, 21).

Appendix 12: A Fragmented Global Monetary System

In Chapter 1, and following in the footsteps of economic geographers, I outlined how money is raised through dense networks of practice between specific people so that its different forms are patchworked across the world in an independent yet interconnected manner. Different financial services utilise strategies and technologies to streamline the gateways between them, profiting in the process by taking a fee. Almost serendipitously I experienced this monetary fragmentation when I first landed in San Francisco in early 2015 to begin my research within the Bitcoin start-up economy. On arrival, I immediately needed to transfer $5000 AUD to an American bank account so I could start paying rent to my new landlord—this would be done with the financial tool of a bank cheque sent monthly to their home address via the postal system or 'snail mail' (a system that remains the primary method for rental payments in the United States).

I made my way to Market Street and opened an account with Wells Fargo before returning to my apartment to log onto the online banking service of my Australian bank, Bankwest. Half way through the transfer procedure I was met with error messages due to my international payment limit being set to zero (something my bank had failed to tell me needed changing when I had let them know of my intentions the week before). To change this limit I had to type in a code sent via SMS to my Australian mobile telephone number—something that I no longer had—in order to authenticate my identity. To solve this problem I topped up my credit on my Skype account and made a long distance telephone call to Australia. After an arduous time period filled with efforts to prove my identity I was directed to an International Money Transfer (IMT) form to fill out and, as the advisor told me, "fax back". As a researcher in my mid-twenties, I neither knew where I would find a fax machine or, indeed, how to operate one. We finally agreed that scanning the document and emailing it to Bankwest would work just as well. I do not carry a digital copy of my Bank State Brach (BSB) and Account Number and so I had to call a friend in Australia who was looking after my things in storage to send me these details. I then filled in, scanned, and sent the IMT form to Bankwest via email. I had been informed my bank would attempt to call me three times to confirm the transaction and if they could not get through it would be cancelled.

No call came. Meanwhile I was withdrawing $400 USD from ATMs per day (the limit for daily withdrawals) with my Bankwest debit card and depositing the cash into my Wells Fargo account in person (taking the transaction fee hit each time). A few days later I received an email from Bankwest saying my transaction had been cancelled because the telephone number I provided did not match the number they had for me in their database. A stern email and a telephone call (consisting of a rigorous identity check) later, Bankwest finally agreed to process the transaction. A few business days went past and the money appeared in my account—11 days, plus many banking fees, after I had first tried to make the money transfer. This anecdote will for many Bitcoin proponents personify the problems existing with centralised systems of banking and finance: a reliance on third parties that use traditional means for proving identity and require permission to transfer.

The process by which Australian dollars vanished from my Bankwest account and reappeared as US dollars in my Wells Fargo account relies heavily on the SWIFT (Society for Worldwide Interbank Financial Telecommunication) network that was formed in 1977 and whose name may be gathering a degree of irony in the light of quicker modern financial technology developments. SWIFT is simply a standardised messaging system: its "primary role [is] to carry the messages containing the payment instructions between financial institutions involved in a transaction" (Scott & Zachariadia, 2013, 43). Bankwest uses the SWIFT interface to communicate with Wells Fargo initiating a "sequence of events that involves a number of financial institutions and technologies such as banks, clearinghouses, data transmission links, and electronic accounting systems" (Scott & Zachariadis, 2013, 41). SWIFT essentially sends out payment orders to the required parties needed to complete the transaction which must be settled by the corresponding accounts institutions have with each other; it caters for a flow between these different centralised pools of money. Depending on the web of banking relationships this can involve up to four intermediary banks (who all take a fee), underpinned by clearing houses (that authorise end-of-day transfers between banks in bulk) all of which to delays and costs of international money transfers (Wilson, 2014).

This brief narrative describes the interlocking yet somewhat bordered and separated global monetary systems that are, at times, brimming with friction. It was with a degree of irony that I was visiting California to explore a digital currency designed to make this convoluted system obsolete and yet I was nonetheless caught in the fractured monetary networks that reside in the sticky webs of bordered territories. This experience seemed to epitomise the "dated" and "broken" global financial system that Bitcoin proponents like Andreas Antonopoulos (2014) had been preaching. Meanwhile, a host of start-up companies were gathering in the San Francisco Bay Area around me, poised to subvert the banking operations that had caused me so much grief. Many of their solutions shared one thing in common: the utilisation of a distributed algorithmic protocol, the (Bitcoin) blockchain.

Appendix 13: The Regional Economy of Silicon Valley

Popular stories of Silicon Valley's birth hail to the legends of William Hewlett and David Packard who started ITC company Hewlett Packard in Hewlett's parent's garage in Palo Alto during 1938 (Lowen, 1992; Leslie, 1993; Kenney, 2000) or William Shockley's foundation of Shockley Transistor Company in 1955 who's spinoff Fairchild Semiconductor for a time dominated the regions silicon chip productivity (Kenney, 2000). However, these accounts truncate the historical economic geography of Silicon Valley; this dates back to the turn of the twentieth century where a small scale but vibrant electronics industry emerged in the larger San Francisco Bay Area experimenting and innovating with radio, television and military electronics (Sturgeon, 2000). Other smaller electronics firms were also established in the Bay Area during World War II (Sturgeon, 2000; Kenney & von Burg, 2001). It was not until the post-war period, however, in a relatively localised rural area of Santa Clara Valley, California – north and west of San Jose – that the real industrial prowess of Silicon Valley first took root (Saxenian, 1981; Gershon, 2014). From 1944 to 1949 the fields and orchards of tomatoes, peas, prunes, apricots and pears synonymous with the area were uprooted to increase industrial diversification and make way for tract housing, industrial plants, shopping centres and 80 new industries (Scott, 1985). The previously rural area became known as Silicon Valley, from the silicon chips that it produced (Hoefler, 1971), and grew into a sprawling suburbia whose seemingly endless interconnecting grid of roads and rectangular buildings took on the look of the integrated circuits it came to produce (Johnston, 1982).

The federal funding of nearby electronic equipment laboratories, the large local market of the war-related semiconductor-hungry aerospace and electronics enterprises, and the skilled scientific and engineering labour emerging from local universities such as Stanford allowed the industry to thrive

(Saxenian, 1983).[11] Accumulated capital from semiconductor firms such as Fairchild and their subsequent reinvestments in new ventures, in tandem with the proximity to the West Coast financial centre of San Francisco for added capital, created a fertile environment for these technologically related start-up companies (Saxenian, 1983). In the latter part of the 1980s however, semiconductor production dwindled in the area with increased competition from overseas. By 1993 Silicon Valley had begun haemorrhaging jobs and losing its cultural edge for attracting talent worldwide (Khanna, 1997). In the semiconductor industry many manufacturers, who were predominantly ethnic minorities, were laid off and by 1993, Silicon Valley had begun haemorrhaging jobs and losing its cultural edge for attracting talent worldwide (Khanna, 1997).[12]

Software development proved to be a more opportunistic and profitable sector and the local economy began to shift in part because of a fresh injection of venture capital (ibid.) that followed a moving trajectory from hardware production to companies that facilitated computer systems and application software (Burnham, 2007). A subsequent shift towards new media companies that sought to capitalise from business models built around the Internet left the primary sector of semiconductor production in decline (although headquarters often remained in the valley). Whilst hardware manufacturing dwindled, the opportunity to work on new software services dragged world class programmers to the valley from across the world and the infrastructural capacity to cater for high tech firms grew up around them. The rise of software based innovation led to a resurgence of Silicon Valley productivity (Arora et al., 2010) and the commercialisation of the Internet from 1995 to 1998 reversed the region's economic decline (Kenney, 2000). Production would no longer come from manufacturers on the assembly line but programmers lined up at rows of computers that were increasingly built outside of Silicon Valley and the United States.

From 1995 to 2000 roughly $65 billion USD of venture capital was pumped into the area (mainly within the New Economy) creating a secondary wave of growth that included 172,000 high tech jobs (Mann & Luo, 2010). When the dotcom "boom" proved to be a bubble a few companies like Yahoo! (Sunnyvale) and eBay (San Jose) survived the wreckage (The Economist, 2001). A third wave of venture capital came in 2004 with the development of Web 2.0 companies (GlobeNewswire, 2007; Mann & Luo, 2010) and a few years later Silicon Valley added a plethora of social networking sites to its repertoire including Facebook, Twitter and LinkedIn. Its economy even remained strong enough so

---

[11] Stimulated "after the Second World War by military contracts awarded to electronic plants, the burgeoning industrial chain grew rapidly in the 1960's when the National Aeronautics and Space Administration established its Ames Laboratory at Moffet Field and the Atomic Energy Commission supported the construction of a giant linear accelerator at Stanford University" (Scott, 1985).

[12] Although semiconductor productivity decreased, a degree of hardware manufacturing remains in Silicon Valley today although this tends to be limited to more specialised products such as prototype production (Caulfield, 2012).

it was barely touched by the 2008 Global Financial Crisis (Miller, 2008; Williams, 2013) – although some cuts in spending were made in anticipation of a downturn (Tam et al., 2008).

As the technology industry's production diversified from hardware to software Silicon Valley began to occupy a vast geographic and mental space up the San Francisco peninsular and around the Bay Area (Kenney & von Burg, 2001). Therefore, although it is a technopole on an international level (Saxenian, 1996; Sotarauta & Spinivas, 2005; Woodward et al., 2006), it is more of a technosprawl on a local one. In fact, the valley now pulls more commuters from San Francisco than the other way around; the city has been suburbanised by its own suburbs—epitomised by the iconic Google and Facebook shuttle busses carrying young professionals from the city to the Mountain View head offices (Schafran & Walker, 2015). Meanwhile, tech companies like Twitter, Airbnb, Dropbox and Uber have moved into the city to areas such as SoMa (South of Market) making San Francisco a locational and metaphorical extension of Silicon Valley (McNeill, 2016).

Appendix 14: The Politics of Social Networking Sites

On one hand, the libertarian vision of technology as means to free people from politics has some empirical grounding. For example, it has been argued that the communication facilitated by online social media during the Arab Spring allowed for the cohesion and mobilisation of political protests (Khondker, 2011; Howard et al., 2011; Wolfsfeld et al., 2013). However, dissent is itself a deeply political action so that technological emancipation from politics is nonsensical. For example, social media platforms are not just an avenue of dissent but can also act as modes of control: while Israel continues to occupy and colonise Palestinian land illegally, its government uses Facebook—of which Peter Thiel was an early investor—as a surveillance tool over its population (McKernan, 2016; Nashif, 2017). Facebook has also been complicit in silencing Palestinian voices through the censorship of online content and the permanent suspension of journalists' accounts (Alareer, 2016; Al Jazeera, 2017). To suggest, then, that digital environments constitute new worlds or spaces, and that the technological is somehow in opposition to the political, is both a fantasy and a fallacy; this brief example alone demonstrates how Facebook can be tied tightly to the spatial control of sovereignty and colonial rule. Technology, then, is not as neutralising and/or innocent as the Californian Ideology would suggest.

Appendix 15: "Death by Gentrification"

Anyone who has lived in San Francisco will know that it is relatively difficult to meet someone that was actually born there; it is an incredibly xenolothic space assembled through national and international migration. The topography is therefore littered with competing and overlapping San Franciscan territorial identities that have contributed to its long historic morphogenesis (Godfrey, 1985). Perhaps the most tumultuous addition to the melting pot has been the rapid intrusion of well paid technology company employees who have had a tremendous impact on the city's physical and cultural urban morphology.

In the later 1990s San Francisco became awash with dotcommers: a new type of "young, moneyed, hip, professional" striving to profit from Internet businesses whose spatial practices and consumption changed the urban landscape in the form of "chic bars and electric boutiques, postindustrial apartments, and sleek office spaces" (Centner, 2008). In the Mission District, a bizarre colonisation of street space occurred in the form of illegal parking practices conducted by dot-commers who would leave their sports cars "bumper to bumper" along Valencia Street—the parking fines meaning little to the "new economy revellers [who] sipped unorthodox martinis and made new connections with other internet workers in the overflowing bars of the district" (207). The Mission became a heated site of cultural backlash towards these new patterns of consumption (Nieves, 2000) that continues to this day. For example, in 2016, San Francisco-based author Rebecca Solnit's article titled "Death by Gentrification" told the story of a local 28-year-old Mexican man killed by police who were called for by "white newcomers" because they saw him as a "menacing outsider" (Solnit, 2016b). The tale emanates disconnection as a rich techie monoculture sweeps through the poor local mulitculture of the Mission so that the title holds a duplicity of meaning: to Solnit, Alejandro Nieto's death is a literal and tragic consequence of a wider metaphorical necrosis of San Francisco's cultural soul via gentrification fuelled by the technological industry. This "violent" process, Solnit argues, turns a complex urban environment into a homogenous and exclusionary place (Solnit, 2014a, 2014b, 2016a).

Appendix 16: The Libertarian Aspirations of PayPal

When Peter Thiel returned to his old university, Stanford, to "deliver a guest lecture on the link between market globalization and political freedom" (Jackson, 2004, 8), he met 24 year old programmer Max Levchin who had recently sold his start-up NetMeridian to Microsoft. The pair began meeting in Palo Alto before forming Fieldlink, which would later become Confinity, X.com, and finally PayPal. The company secured funding from Nokia Ventures and Deutsche Bank and began rapidly pulling in talent (largely from Thiel's Stanford alumni network) to their office 165 University Avenue in Palo Alto, which had previously housed Google and Logitech (ibid.). The company's 27th Employee, Eric Jackson, in his book *The PayPal Wars*, recalls a speech made by Thiel during his second week of employment:

> Everyone wants to invest in this company! And why not? We're definitely onto something big. The need PayPal answers is monumental. Everyone in the world needs money – to get paid, to trade, to love. Paper money is an ancient technology and an inconvenient means

> of payment. You can run out of it. It wears out. It can get lost or stolen. In the twenty-first century, people need a form of money that's more convenient and secure, something that can be accessed from anywhere with a PDA or an Internet connection.
>
> Of course what we're calling "convenient" for American users will be revolutionary in the developing world. Many of these countries' governments play fast and loose with their currencies. They use inflation and sometimes wholesale currency devaluations, like we saw in Russia and several Southeast countries last year, to take wealth away from their citizens. Most of the ordinary people there never have an opportunity to open an offshore account or to get their hands on more than a few bills of stable currency like U.S. dollars.
>
> Eventually PayPal will be able to change this. In the future, when we make our service available to outside the U.S. and as Internet penetration continues to expand to all economic tiers of people, PayPal will give citizens worldwide more direct control over their currencies than they ever had before. It will be nearly impossible for corrupt governments to steal wealth from their people through their old means because if they try the people will switch to dollars or Pounds or Yen, in effect dumping the worthless currency for something more secure.
>
> (2004, 25-26)

The libertarian and decentralist rhetoric in this passage is extremely clear: PayPal is elevated as an enterprising saviour of citizens from the evils of centralised governments.

Appendix 17: Estonian Blockchain Governance

Nathan Heller's (2017) poetic and comprehensive article in *The New Yorker*, 'Estonia, the Digital Republic', explains how the country has used blockchain technology to revolutionise its governmental services from "legislation, voting, education, justice, health care, banking, taxes, policing, and so on… across one platform, wiring up the nation" (ibid.). Chipped ID cards and a password allows citizens access to the online platform X-Road, supported by the Guardtime's Keyless Signatures Infrastructure 'blockchain', where data is not centrally held but instead "links individual servers through end-to-end encrypted pathways, letting information live locally. Your dentist's practice holds its own data; so does your high school and your bank. When a user requests a piece of information, it is delivered like a boat crossing a canal via locks" (ibid.). As other countries like Finland, Moldova, and Panama begin to use platforms like X-Road, interoperability between them is achieved by channeling secure information across borders, like prescriptions from pharmacies, facilitating a 'global' flow of information (ibid.). But, simultaneously, individuals own their own data: "[e]very time a doctor (or a border guard, a police officer, a banker, or a minister) glances at any… secure data online, that look is recorded and reported. Peeping at another person's secure data for no reason is a criminal offense" (ibid.). Additionally, a digital 'residency' program allows "logged-in foreigners to partake of some Estonian services, such as banking, as if they were living in the country" (ibid.). Here, "heat is taken off immigration because, in a borderless society, a resident need not even have visited Estonia in order to work and pay taxes under its dominion" (ibid.).

Evidently, in Estonia the algorithmic privatisation/decentralisation of personal data is creating new modes of governance that enact space in new ways. For venture capitalist Tim Draper, who is heavily involved in Estonia's start-up scene—"[w]ith so many businesses abroad, Estonia's startup-ism hardly leaves an urban trace" (ibid.)—the country's progressive stance to decentralism was a revelation: he "recognized a new market for élite tech brainpower and capital. 'I thought, Wow! Governments are going to have to compete with each other for us'"(ibid.). This envisioned form of nationalist free market competition for labour is an intriguing new hypothesis. Yet it does not eradicate the state, but rather evolves its spatial arrangements, reinforcing sovereignty in new ways. The Estonian government remains in control of the money, borders, and laws by which its citizens live, it merely now employs new methods for administrating them that can operate outside of its geographic territory. The geographies of power mutate but remain. While citizens are in control of their own data, the issues raised in this thesis expound/explicate the requisite levels of critical awareness researchers need to bring to following connections of such platforms to understand the control that is gained through obligatory passage points like developer teams and block mining.

References

Accenture (2014) The rise of fintech: New York's opportunity for tech leadership. The Partnership Fund for New York City.

Accenture (2016) Fintech and the evolving landscape: landing points for the industry. Accenture.

Al Jazeera (2017, January 29) How Israel polices Palestinian voices online. *Al Jazeera* <https://www.aljazeera.com/programmes/listeningpost/2017/01/israel-polices-palestinian-voices-online-170128120614211.html>

Alareer, R. (2016, October 21) Why is Facebook targeting Palestinian accounts again? *Al Jazeera* <https://www.aljazeera.com/news/2016/10/facebook-targeting-palestinian-accounts-161019063930119.html>

Allison, I. (2015, September 18) Blockchain expert Tim Swanson talks about R3 partnership of Goldman Sachs, JP Morgan, UBS, Barclays et al. *International Business Times* <http://www.ibtimes.co.uk/blockchain-expert-tim-swanson-talks-about-r3-partnership-goldman-sachs-jp-morgan-ubs-barclays-1519905>

Allison, I. (2016, March 3) R3 completes trial of five cloud-based blockchain technologies with 40 banks. *International Business Times* <http://www.ibtimes.co.uk/r3-completes-trial-five-cloud-based-blockchain-technologies-40-banks-1547260>

Altschuler, J., Judge, M., and Krinsky, D. (2014) Silicon Valley. HBO. 3 Arts Entertainment. Altschuler Krinsky Works. Judgemental Films Inc.

Alvarez-Torrez, R. (1986, September 28) More companies rent workers to fill gaps. *San Jose Mercury News*.

Amin, A., and Thrift, N. (1994) Living in the global. In Amin, A., and Thrift, N. (eds) *Globalization, Institutions and Regional Development*. Oxford University Press.

Amin, A., and Thrift, N. (2002) *Cities: Reimagining the Urban*. Polity Press.

Amin, A., and Thrift, N. (2004) *Cultural Economy Reader*. Blackwell.

Amsterdamska, O. (1990) 'Surely You're Joking, Mr Latour!'. *Science, Technology, Human Values* 15 (4) 495-504.

Anand, N. (2011) Pressure: The politechnics of water supply in Mumbai. *Cultural Anthropology* 26 (4) 542-564.

Anderson, J., and Dash, E. (2008, August 28) For Lehman, more cuts and anxiety. *New York Times* <http://www.nytimes.com/2008/08/29/business/29wall.html>

Anderson, B. (2008) For Space (2005): Doreen Massey. In Hubbard, P., Kitchin, R., and Valentine, G. (eds) *Key Texts in Human Geography*. Sage.

Anderson, B., Cook, I., and Maddern, J. (2006) Geography and matter/materiality. RGS Social and Cultural Geography Group.

Anderson, B., and Harrison, P. (2010) *Taking Place: Non-Representational Theories and Geography*. Ashgate Publishing Company.

Anderson, B., and Wylie, J. (2009) On geography and materiality. *Environment and Planning A* 41 (2): 318-335.

Andolfatto, D. (2015) Fedcoin: On the desirability of a government cryptocurrency. *MacroMania* <http://andolfatto.blogspot.co.uk/2015/02/fedcoin-on-desirability-of-government.html>

Andreadēs, A. (1966) *History of the Bank of England: 1640 to 1903*. Cass.

Andreessen, M. (2014a, January 21) Why Bitcoin matters. *New York Times* <https://dealbook.nytimes.com/2014/01/21/why-bitcoin-matters/>

Andreessen, M. (2014b, March 26) Video—Bitcoin fireside chat with Marc Andreessen and Balaji Srinivasan. *Weusecoins* <https://www.weusecoins.com/video-fireside-chat-about-bitcoin/>

Androulaki E., Karame G., Roeschlin M., Scherer T., and Capkun S. (2013) Evaluating user privacy in Bitcoin. In Sadeghi, A. (ed) *Financial Cryptography and Data Security*. LNCS 7859: 34-51. Springer.

Angel, D. (1991) High-technology agglomeration and the labor market: The case of Silicon Valley. *Environment and Planning A* 23: 1501-1516.

Angel, D. (2000) High-technology agglomeration and the labor market: The case of Silicon Valley. In Kenney, M. (ed.) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press.

AngelList (2016) Coinbase <https://angel.co/coinbase>

Antenucci, I., and Pollio, A. (2017) The technopolitics of Ubuntu: City and citizen-making in post-apartheid Cape Town. Institute for Culture and Society (Western Sydney University) Seminar Series.

Antonopoulos, A. (2014) *Mastering Bitcoin: Unlocking Digital Cryptocurrencies*. O'Rielly Media.

Antonopoulos, A. (2015a) Mastering Bitcoin. *WIRED MONEY* <https://www.youtube.com/watch?v=A6kJfvuNqtg>

Antonopoulos, A. (2015b) Consensus algorithms, blockchain technology and Bitcoin (University College London). *Satoshi Pollen* <https://www.youtube.com/watch?v=sE7998qfjgk&t=151s>

Antonopoulos, A. (2016) The Internet of Money. *Merkle Bloom LLC.*

Aoyama, Y., Dodge, M., Townsend, A., and Zook, M. (2004) New digital geographies: Information, communication, and place. In Brunn, S., Cutter, S., and Harrington, S. (eds) *Geography and Technology*. Springer.

Appadurai, A. (1986) *The Social Life of Things: Commodities in Cultural Perspective*. Cambridge University Press.

Arcade City (2018) Arcade City homepage <https://arcade.city>

Arcade City Hall (2016) Decentralization and the future of ridesharing. Arcade City Blog <https://blog.arcade.city/decentralization-and-the-future-of-ridesharing-29d8f84a4ea7>

Arora, A., Branstetter, L., and Drev, M. (2010) Going soft: how the rise of software based innovation led to the decline of Japan's IT industry and the resurgence of Silicon Valley. National Bureau of Economic Research.

Arthur, C., and Topping, A. (2014, September 2) Gang of hackers behind nude celebrity photo leak routinely attacked iCloud. *The Guardian* <https://www.theguardian.com/technology/2014/sep/02/gang-hackers-naked-celebrity-photos-routinely-attacked-icloud>

Arthur, W. (1994) *Increasing Returns and Path Dependency in the Economy*. University of Michigan Press.

Ash, J., Kitchin, R., and Leszczynski, A. (2016) Digital turn, digital geographies?. *Progress in Human Geography* 42 (1) 1-19.

Assange, J., Appelbaum, J., Muller-Maguhn, A., and Zimmerman, J. (2012) *Cypherpunks: Freedom and the Future of the Internet*. OR BOOKS.

Atkinson, T., Luttrell, D., and Rosenblum, H. (2013) How bad was it? The costs and consequences of the 2007-2009 financial crisis. Federal Reserve Bank of Dallas.

Atlassian (2017) What is version control?. *Atlassian Tutorials* <https://www.atlassian.com/git/tutorials/what-is-version-control>

Audretsch, D., and Feldman, M. (2003) Knowledge spillovers and the geography of innovation. In Henderson, J., and Thisse, J. (eds) *Handbook of Urban and Regional Economics*. North Holland Publishing.

Auletta, K. (2009) *Googled: The End of the World as We Know It*. Penguin.

Australian Tax Office (2014, December 18) Tax treatment of crypto-currencies in Australia—specifically bitcoin <https://www.ato.gov.au/General/Gen/Tax-treatment-of-crypto-currencies-in-Australia---specifically-bitcoin/>

Babbie, E. (2008) *The Basics of Social Research*. Thomson Wadsworth.

Back, A. (2002) Hashcash—A denial of service counter-measure. <http://www.hashcash.org/hashcash.pdf>

BaFin (2014) Bitcoins: Supervisory assessment and risk to users. *Federal Financial Supervisory Authority* <https://www.bafin.de/SharedDocs/Veroeffentlichungen/EN/Fachartikel/2014/fa_bj_1401_bitcoins_en.html>

Bagehot, W. (1873) *Lombard Street: A Description of the Money Market*. Henry S. King and Co.

Baichwal, J. (2006) Manufactured Landscapes. Zeitgeist Films.

Baker, W., and Jimerson, J. (1992) The Sociology of Money. *American Behavioural Scientist* 35 (6) 678-693

Balea, J. (2014, December 12) Bitcoin remittances to the Philippines have gone up. Here's why. *Tech in Asia* <https://www.techinasia.com/bitcoin-remittances-rebit-philippines>

Ball, J., Arthur, C., and Gabbatt, A. (2013) FBI claims largest Bitcoin seizure after arrest of alleged Silk Road founder. *The Guardian* <https://www.theguardian.com/technology/2013/oct/02/alleged-silk-road-website-founder-arrested-bitcoin>

Balmès, T. (2005) A Decent Factory. Margot Films. Making Movies Oy. France 2. BBC—Storyville & YLE.

Banaian, K., Laney, L., and Willett, T. (1983) Central Bank Independence: An International Comparison. Federal Reserve Bank of Dallas Economic Review, March 1–13.

Bank of Canada (2014) Decentralized E-Money (Bitcoin) *Backgrounders* <http://www.bankofcanada.ca/wp-content/uploads/2014/04/Decentralize-E-Money.pdf>

Bank of England (1970) The Bank of England: History and Functions. Gordon Chalmers Fortin at The Bank of England Printing Works.

Banse, T. (2014, April 7) Central Wshington home to nation's biggest Bitcoin 'mine,' more coming, *nwnewsnetwork.org* <http://nwnewsnetwork.org/post/central-washington-home-nations-biggest-bitcoin-mine-more-coming>

Baran, P. (1962) On Distributed Communications Networks. The RAND Corporation.

Barber, S., Boyen, X., Shi, E., and Uzun, E. (2012) Bitter to better—How to make Bitcoin a better currency. In Keromytis, A. (ed) *Financial Cryptography and Data Security*. LNCS 7397: 399-414. Springer.

Barboza, D. (2005, December 9) Boring game? Hire a player. *New York Times* <http://www.nytimes.com/2005/12/09/technology/boring-game-hire-a-player.html>

Barbrook, R. (2001) Hypermedia freedom. In Ludlow, P. (ed.) *Crypto Anarchy, Cyberstates, and Pirate Utopias*. MIT Press.

Barbrook, R. (2015) *The Internet Revolution*. Network Books.

Barbrook, R., and Cameron, A. (1995) The Californian ideology. *Mute* 1 (3) <http://www.metamute.org/editorial/articles/californian-ideology>

Barbrook, R., and Cameron, A. (1996) The Californian ideology. *Science as Culture* (6) 1: 44-72.

Bardhan, P., and Mookherjee, D. (2006) *Decentralization and Local Governance in Developing Countries: A Comparative Perspective*. MIT Press.

Barlow, J. (1996) The declaration of the independence of cyberspace. *Electronic Frontier Foundation* <https://www.eff.org/cyberspace-independence>

Barndt, D. (2002) *Tangled Routes: Women, Work and Globalization on the Tomato Trail*. Lanham: Rowman & Littlefield.

Barok, D. (2011) Bitcoin: censorship-resistant currency and domain system for the people. Forum America Bar Association.

Barratt, M. (2012) Silk Road: eBay for drugs. *Addiction* 107 (3): 683–684.

Bartley, B., Fuller, D., Hubbard, P., and Kitchin, R. (2002) *Thinking Geographically: Space, Theory and Contemporary Human Geography*. Bloomsbury.

Bartos, J. (2015) Does Bitcoin follow the hypothesis of efficient market? *International Journal of Economic Sciences* 4 (2): 10-23.

Bashir, M., Strickland, B., and Bohr, J. (2016) What motivates people to use Bitcoin?. In Spiro, E., and Ahn, Y. (eds) *Social Informatics*. Springer.

Bateson, G. (1972) *Steps to an Ecology of Mind*. The University of Chicago Press.

Baumann, A., Fabian, B., and Lischke, M. (2014) Exploring the Bitcoin Network. 10th International Conference on Web Information Systems and Technologies (WEBIST). Barcelona, Spain.

Baur, D., Hong, K., and Lee, A. (2015) Bitcoin: Medium of Exchange or Speculative Assets?. SSRN.

BBC (2016, May 2) Australian Craig Wright claims to be Bitcoin creator. *BBC Technology* <http://www.bbc.co.uk/news/technology-36168863>

BBC (2017, September 12) UK inflation rate rises to 2.9%. *BBC Business* <http://www.bbc.co.uk/news/business-41238822>

Becker, J., Breuker, D., Heide, T., Holler, J., Rauer, H., and Böhme, R. (2013) Can we afford integrity by proof-of-work? Scenarios inspired by the Bitcoin currency. In Böhme, R. (ed) *The Economics of Information Security and Privacy*. Springer.

Becker, W. (1997) Teaching economics to undergraduates. *Journal of Economic Literature* 43: 1247-1362.

Begel, A. (2013) Social networking meets software development: Perespectives from GitHub, MSDN, Stack Exchange, and TopCoder. IEE Software 20 (1): 52-66.

Bek-Thomsen, J., Jacobsen, S., and Christiansen, C. (2014) Virtual money. *Distinktion: Journal of Social Theory* 15 (1): 1-5.

Benedikt, M. (1991) *Cyberspace: first steps*. MIT Press.

Benkler, Y (2006) *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. Yale University Press.

Benner, C. (2003) Learning communities in a learning region: the soft infrastructure of cross-firm learning networks in Silicon Valley. *Environment and Planning A* 35: 1809-1830.

Berger, A., (2002) *Video Games: A Popular Culture Phenomenon*. Transaction Publishers.

Bergstra, J., and de Leeuw, K. (2013) Bitcoin and Beyond: Exclusively Informational Money. Informatics Institute, University of Amsterdam.

Bergstra, J., and Weijland, P., (2014) Bitcoin: a money-like informational commodity. <http://arxiv.org/pdf/1402.4778.pdf>

Bernard, R. (1998) *The Corporate Intranet*. John Wiley and Sons.

Berry, D. (2004) Internet research: privacy, ethics and alienation: an open source approach. *Internet Research* 14 (4): 323-332.

Berry, D. (2011) *The Philosophy of Software*. Palgrave Macmillan.

Bershidsky, L. (2014, July 17) Trust will kill Bitcoin. *Bloomberg* <https://www.bloomberg.com/view/articles/2014-07-17/trust-will-kill-bitcoin>

Bestor, T. (2000) How sushi went global. *Foreign Policy* 121: 54-63.

Beutelspacher, A. (1994) *Cryptology*. The Mathematical Association of America.

Beverungen, A. (2016, June 16) DCRL questions: Armin Beverungen. Leuphana University: Centre for Digital Cultures <https://vimeo.com/170938966>

Beverungen, A., and Lange, C. (2017) High-frequency trading and the cost of consciousness. Institute for Culture and Society (Western Sydney University) Seminar Series.

Biddle, S., and Cush, A. (2015, December 8) This Australian says he and his dead friend invented Bitcoin. *Gizmondo* <https://gizmodo.com/this-australian-says-he-and-his-dead-friend-invented-bi-1746958692>

Bilham, P. (1998) Internet payment systems. *PJB Computing* <http://www.pjb.com.au/comp/ingrestalk.html>

Biryukov, A., Khovratovich, D., and Pustogarov, I. (2014) Deanonymisation of clients in Bitcoin P2P network. ACM SIGSAC Conference on Computer and Communications Security.

Bissessar, S. (2013) Analysis of Bitcoin transaction flows to reveal usage and geographic patterns. University College London. Masters Thesis.

Bitcoin Foundation (2012) Bylaws of the Bitcoin Foundation Inc. GitHub <https://github.com/pmlaw/The-Bitcoin-Foundation-Legal-Repo/blob/master/Bylaws/Bylaws_of_The_Bitcoin_Foundation.md>

Bitcoin Project (2017) How does Bitcoin work?. bitcoin.org <https://bitcoin.org/en/how-it-works>

Bitcoin Wiki (2016, April 11) Block size limit controversy. en.bitcoin.it <https://en.bitcoin.it/wiki/Block_size_limit_controversy>

Black, R., Bollands, T., Davies, W., Charlton, K., Christie-Miller, C., Redfern, M., Stevens, J., Swan, M., Webber, L., Wheatley, M., Woolford, B. (2010) Our new commemorative £2 coin. followthethings.com <http://www.followthethings.com/commemorativecoin.shtml>

Blanchard, O. (2011, March 14) The future of macroeconomic policy: Nine tentative conclusions. IMF Blog <https://blogs.imf.org/2011/03/13/future-of-macroeconomic-policy/>

Blackwell, M. (2007) *The Secret Life of Things: Animals, Objects and It-narratives in Eighteenth-century England*. Bucknell University Press.

Blanchette, J. (2011) A material history of bits. *Journal of the American Society for Information Science and Technology* 62 (6): 1042–1057.

Blanchette, J. (2012) *Burdens of Proof*. MIT Press.

Blankenship, J. (2017) Forging blockchains: Spatial production and political economy of decentralised cryptocurrency code/spaces. *University of South Florida*. Masters Thesis.

BlockchainHub (2017) Types of blockchains. Learning Resources <https://blockchainhub.net/blockchains-in-general/>

Blockchain University (2015) Homepage. <http://blockchainu.co>

Bloemen, S. (2001) T-shirt travels. Grassroot Pictures.

Bodenhorn, H. (1990) Entry, rivalry and free banking in the Antebellum period. *Journal of Money, Credit and Banking* 72 (4): 682–686.

Boellstorff, T. (2008) *Coming of Age in Second Life: An Anthropologist Explores the Virtually Human*. Princeton University Press.

Böhme, R., Christin, N., Edelman, B., Moore, T. (2015) Bitcoin: Economics, Technology, and Governance. *Journal of Economic Perspectives* 29 (2): 231-238.

Boise, C. (2005) Playing with 'monopoly money': Phony profits, fraud penalties and equity. *Minnesota Law Review* 90: 144-212.

Bolici, F., Howison, J., and Crowston, K. (2009) Coordination without discussion? Socio-technical congruence and stigmergy in free and open source software projects. Conference: 2nd International Workshop on Socio-Technical Congruence, ICSE <https://crowston.syr.edu/content/coordination-without-discussion-socio-technical-congruence-and-stigmergy-free-and-open-sourc>

Bonabeau, E., Theraulaz, G., Deneubourg, J., Aron, S., and Camazine, S. (1997). Self-organization in social insects. *Trends in Ecology & Evolution* 12 (5): 188-193.

Borsook, P. (2000) *Cyberselfish: A Critical Romp Through the Terribly Libertarian Culture of High Tech*. PublicAffairs.

Borsook, P. (2001) Cyberselfish: Ravers, guilders, cyberpunks, and other Silicon Valley lifeforms. *Yale Journal of Law and Technology* 3 (1): 1-10.

Bovaird, C. (2016, May 27) Was Ether's loss Bitcoin's gain? Traders wonder after wild week <http://www.coindesk.com/was-ethers-loss-bitcoins-gain/>

Bowker, G., and Star, S. (1999) *Sorting Thins Out: Classifications and its Consequences*. MIT Press.

Boyd, A. (2011) San Francisco's Castro district: from gay liberation to tourist destination. *Journal of Tourism and Cultural Change* 9 (3): 237-248.

Braunstein, P., and Doyle, M. (2002) *Imagine Nation: The American Counterculture of the 1960s and '70s*. Routledge.

Brewer, J. (2000) Ethnography. In Bryman, A. (ed.) *Understanding Social Research*. Policy Press.

Bridges, T. (1772) *The Adventures of a Bank-Note*. Printed for T. Davies.

Brikman, Y. (2014, April 24) Bitcoin by analogy. *ybrikman.com* <http://www.ybrikman.com/writing/2014/04/24/bitcoin-by-analogy/>

Brito, J. (2011, April 4) Online cash Bitcoin could challenge governments. *Time Magazine* <http://techland.time.com/2011/04/16/online-cash-bitcoin-could-challenge-governments>

Broderick, R. (2011) Bitcoin, used to purchase illegal things, has been illegally stolen. *Motherboard* <https://motherboard.vice.com/en_us/article/gvv8kj/bitcoin-currency-used-for-illegal-things-illegally-stolen>

Brown, R., Carlyle, J., Grigg, I, and Hearn, M. (2016) Corda: An introduction. <https://docs.corda.net/_static/corda-introductory-whitepaper.pdf>

Brown, J., and Duguid, P. (2000) *The Social Life of Information*. Harvard Business Review Press.

Brown, M. (2014, September 19) Peter Thiel: the billionaire tech entrepreneur on a mission to cheat death. *The Telegraph* <http://www.telegraph.co.uk/technology/11098971/Peter-Thiel-the-billionaire-tech-entrepreneur-on-a-mission-to-cheat-death.html>

Brown, R. (2016, April 5) Introducing R3 Corda™: A Distributed Ledger Designed for Financial Services. The R3 Report <http://www.r3cev.com/blog/2016/4/4/introducing-r3-corda-a-distributed-ledger-designed-for-financial-services>

Bruns, A. (2008) *Blogs, Wikipedia, Second Life and Beyond: From Production to Produsage*. Peter Lang.

Bryant, S., Forte, A., and Bruckman, A. (2005) Becoming Wikipedian: Transformation of participation in a collaborative online encyclopedia. Group'05 <https://www.cc.gatech.edu/~asb/papers/bryant-forte-bruckman-group05.pdf>

Brynjolfsson, E., and Mcafee, A. (2014) *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W. W. Norton & Company.

Buckingham, D., Willett, R. (2006) *Digital generations: Children, Young People, and New Media*. Lawrence Erlbaum Associates Inc. Publishers.

Burdekin, R., Wihlborg, C., and Willet, T. (1992) A monetary constitution case for an independent European Central Bank. *The World Economy* 15 (2): 231-249.

Burnham, B. (2007, January 2007) 'What's next?'. *Union Square Ventures* <https://www.usv.com/blog/whats-next>

Burns, D., Hambleton, R., and Hogget, P. (1994) *The Politics of Decentralisation: Revitalising Local Democracy*. The MacMillan Press Ltd.

Burrows, R., and Featherstone, M. (1995) *Cyberspace, Cyberbodies, Cyberpunk: Cultures of Technological Embodiment*. Sage.

Burrows, R. (2014) Living by Numbers? Metrics, Algorithms and the Sociology of Everyday Life. Digital Life Research (Western Sydney University) Seminar.

Busk, O. (2009) £20 banknote. followthethings.com <http://www.followthethings.com/banknote.shtml>

Bustillos, M. (2015 December 11) The bizarre sage of Craig Wright, the latest 'inventor of Bitcoin'. *New Yorker* <https://www.newyorker.com/business/currency/bizarre-saga-craig-wright-latest-inventor-bitcoin>

Buterin, V. (2012a, February 28) The wasted electricity objection to Bitcoin. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/the-wasted-electricity-objection-to-bitcoin-1330409176/>

Buterin, V. (2012b, December 1) BitMessage: A model for a new web 2.0?. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/bitmessage-a-model-for-a-new-web-2-0-1354411679/>

Buterin, V. (2013a, March 12) Bitcoin network shaken by Bitcoin fork. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/bitcoin-network-shaken-by-blockchain-fork-1363144448/>

Buterin, V. (2013b) Ethereum: A Next-Generation Smart Contract and Decentralized Application Platform. GitHub <https://github.com/ethereum/wiki/wiki/White-Paper>

Buterin, V. (2015) On public and private blockchains. Ethereum Blog <https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/>

Buterin, V. (2016, June 17) CRITICAL UPDATE Re: DAO Vulnerability. Ethereum Blog <https://blog.ethereum.org/2016/06/17/critical-update-re-dao-vulnerability/>

Buterin, V. (2017, February 23) Introduction to Cryptoeconomics. Ethereum Foundation <https://www.youtube.com/watch?v=pKqdjaH1dRo>

Buzzard, J. (2011, March 15) Silicon Valley map. justinbuzzard.net <http://www.justinbuzzard.net/2011/03/15/silicon-valley-map/>

Caffyn, G. (2015, August 21) What is the Bitcoin block size debate and why does it matter?. *CoinDesk* <https://www.coindesk.com/what-is-the-bitcoin-block-size-debate-and-why-does-it-matter/>

Caincrross, F. (1997) *The Death of Distance: How the Communications Revolution Will Change Our Lives*. Orion Business Books.

Calhoun, C. (2013) What threatens capitalism now?. In Wallerstein, I., Collins, R., Mann, M., Drerluguian, G., and Calhoun, C. (eds) *Does Capitalism Have a Future?*. Oxford University Press.

Callaway, A. (2016) Apploitation in a city of instaserfs: How the 'sharing economy' has turned San Francisco into a dystopia for the working class. *Canadian Centre for Policy Alternatives* <https://www.policyalternatives.ca/publications/monitor/apploitation-city-instaserfs>

Callon, M. (1986) Some elements of a sociology of translation: domestication of the scallops and the shermen of St Brieuc Bay. In Law, J. (ed.) *Power, Action, Belief: A New Sociology of Knowledge?*. Routledge.

Callon, M. (1998a) *Laws of the Market*. Wiley.

Callon, M. (1998b) An essay on framing and overflowing: Economic externalities revisited by sociology. *The Sociological Review* 46 (1): 244-269.

Callon, M. (1999) Actor-network theory—The market test. In Law, J., and Hassard, J. (eds.) *Actor Network Theory and After*. Blackwell Publishers.

Callon, M. (2007) What does it mean to say that economics is performative?. In Mackenzie, D., Muniesa, F., and Siu, L. (eds) *Do Economists Make Markets? On the Performativity of Economics*. Princeton University Press.

Callon, M., and Muniesa, F. (2005) Peripheral Vision: Economic Markets as Calculative Collective Devices. *Organization Studies* 26 (8) 1229-1250.

Calloway, A. (2016) Apploitation in a city of instaserfs: How the 'sharing economy' has turned San Francisco into a dystopia for the working class. *Canadian Centre for Policy Alternatives* <https://www.policyalternatives.ca/publications/monitor/monitor-januaryfebruary-2016/>

Calomiris, C. (2010) The great depression and other contagious events. In Berger, A., Molyneux, P., and Wilson, J. (eds) *The Oxford Handbook of Banking*. Oxford University Press.

Calomiris, C., and Wallison, P. (2008) The last trillion-dollar commitment: The destruction of Fannie Mae and Freddie Mac. *The American Enterprise Institute* <http://www.aei.org/publication/the-last-trillion-dollar-commitment/>

Canada Revenue Agency (2015) What you should known about digital currency. *Government of Canada* < http://www.cra-arc.gc.ca/nwsrm/fctshts/2015/m03/fs150317-eng.html>

Capie, F., Fischer, S., Goodhart, C., and Schnadt, N. (1994) *The future of central banking: the tercentenary symposium of the Bank of England*. Cambridge University Press.

Carlson, J. (2017) Why crypto looks a lot like Wall Street. *CoinDesk* <https://www.coindesk.com/growing-greed-crypto-looks-lot-like-wall-street/>

Carmody, B. (2014, December 2) Why CoinJar really relocated to the UK. Smart Company <https://www.smartcompany.com.au/startupsmart/advice/startupsmart-legal/why-coinjar-really-relocated-to-the-uk-2/>

Carmona, A. (2015) The Bitcoin: The currency of the future, fuel of terror. In Blowers, M. (ed) *Evolution of Cyber Technologies and Operations to 2035*. Springer.

Castells, M. (1993) The informational economy and the new international division of labor. In Carnoy, M., Castells, M., Cohen, S., and Cardoso, F. (eds) *The New Global Economy in the Information Age: Reflections on our Changing World*. Pennsylvania State University Press.

Castells, M. (1989) *The Informational City: Economic Restructuring and Urban Development*. Blackwell.

Castronova, E. (2014) *Wildcat Currency: How the Virtual Money Revolution Is Transforming the Economy*. Yale University Press.

Caulfield, B. (2012, June 20) Made in Silicon Valley. *Forbes* <http://www.forbes.com/global/2012/0716/technology-manufacturing-flextronics-made-in-silicon-valley.html>

Cawrey, D. (2014) Boost VC to Accelerate 100 Bitcoin Companies Over Next Three Years. *CoinDesk* < http://www.coindesk.com/boost-vc-accelerate-100-bitcoin-companies-next-three-years/>

CB Insights (2017) What is Blockchain Technology?. CB Insights.

Centner, R. (2008) Places of privileged consumption practices: Spatial capital, the dot-com habits, and San Francisco's Internet boom. *City & Community* 7 (3): 193-223.

Chadwick, A. (2013) *The Hybrid Media System: Politics and Power*. Oxford University Press.

Champagne, P. (2014) *The Book of Satoshi: The Collected Writings of Bitcoin Creator Satoshi Nakamoto*. e53 Publishing LLC.

Chaparro, F. (2018, January 11) 97% of all bitcoins are held by 4% of addresses. *Business Insider* <http://uk.businessinsider.com/bitcoin-97-are-held-by-4-of-addresses-2018-1>

Charters, A. (2001) *Beat Down to Your Soul*. Penguin Books.

Chaum, D. (1983) Blind signatures for untraceable payments. In Chaum, D., Rivest, R., Sherman, A. (eds) *Advances in Cryptology*. Springer.

Chaum, D. (1985) Security without identification: Transaction systems to make Big Brother obsolete. *Communications of the ACM* 28 (10): 1030-1044.

Cheema, S., and Rondinelli, D. (2007) *Decentralizing Governance: Emerging Concepts and Practices*. Brookings Institution Press.

Chen, P. (2010). *Economic Complexity and Equilibrium Illusion: Essays on Market Instability and Macro Vitality*. Routledge.

Cheney, I., and Ellis, C. (2007) King Corn: you are what you eat. Mosaic Films (US).

Chown, J. (1994) *A History of Money: From AD 800*. Routledge.

Christie-Miller, J. (2009) Blood, Sweat & Takeways. Ricochet.

Christophers, B. (2011a) Follow the thing: money. *Environment and Planning D* 29: 1068-1084.

Christophers, B. (2011b) Credit, where credit's due. Response to 'Follow the thing: credit'. *Environment and Planning D* 29: 1089-1091.

Christopherson, S. (1993) Market rules and territorial outcomes: the case of the United States. *International Journal of Urban and Regional Research* 17: 274-288.

Chun, W. (1999) *Sexuality in the Age of Fiber Optics*. Princeton University Press.

Chun, W. (2008) On 'sourcery,' or code as fetish. *Configurations* 16 (3): 299-324.

Chun, W. (2006) *Control and Freedom: Power and Paranoia in the Age of Fiber Optics*. MIT Press.

Chun, W. (2011) *Programmed Visions: Software and Memory*. MIT Press.

Clark, G. (2000) *Pension Fund Capitalism*. Oxford University Press.

Clark, G. (2005) Money flows like mercury: The geography of global finance. *Geografiska Annaler B* 87 (2): 99-112.

Clark, G., and Hebb, T. (2004) Corporate engagement: the fifth stage of capitalism, *Relations Industrielles/Industrial Relations* 59: 54–79.

Clark, G., and Thrift, N. (2005) FX risk in time and space: managing dispersed knowledge in global finance. In Knorr Cetina, K., and Preda, A. (eds) *The Sociology of Financial Markets*. Oxford University Press.

Clark, G., and Wojcik, D. (2007) *The Geography of Finance: Corporate Governance in the Global Marketplace*. Oxford University Press.

Clayton, R., Murdoch, S., Watson, R. (2006) Ignoring the Great Firewall of China. In Danezis, G., and Golle, P. (eds) *Privacy Enhancing Technologies*. Springer.

Cllon, M., Meadel, C., and Rabeharisoa, (2004) The economy of qualities. In Amin, A., and Thrift, N. (eds) *Cultural Economy Reader*. Blackwell.

Coats, W. (2005) My Travels to Baghdad. Warren Coats, Bethesda.

CoinDesk (2014) Is Bitcoin legal? <http://www.coindesk.com/information/is-bitcoin-legal/>

CoinDesk (2015) Q1 2016 State of Blockchain. *CoinDesk*.

CoinDesk (2016a, February 19) Who is Satoshi Nakamoto? <http://www.coindesk.com/information/who-is-satoshi-nakamoto/>

CoinDesk (2016b) Bitcoin Venture Capital <http://www.coindesk.com/bitcoin-venture-capital/>

CoinDesk (2016c) Q1 2016 State of Blockchain. *CoinDesk*.

Coinjar (2015, May 24) UK relocation. Coinjar Support <https://support.coinjar.com/hc/en-us/articles/202504025-UK-Relocation>

Coleman, E. (2012) *Coding Freedom: The Ethics and Aesthetics of Hacking*. Princeton University Press.

Collins, H., and Yearly, S. (1992) Epistemological Chicken. In Pickering, A. (ed) *Science as Practice and Culture*. University of Chicago Press.

Collins, R. (2013) The end of middle class work: No more escapes. In Wallerstein, I., Collins, R., Mann, M., Drerluguian, G., and Calhoun, C. (2013) *Does Capitalism Have a Future?*. Oxford University Press.

Coltart, D. (2008) A decade of suffering in Zimbabwe: Economic collapse and political repression under Robert Mugabe. Cato Institute: Center for Global Liberty & Prosperity.

Cook et al. (2004) Follow the thing: Papaya. *Antipode* 36 (4): 642-664.

Cook et al. (2006) Geographies of food: Following. *Progress in human geography* 30 (5): 655-666.

Cook et al. (2008) Geographies of food: Following. In Tucker L (ed) *Bioneering: hybrid investigations of food*. University of California, Irvine.

Cook, I. (2011) Frequently asked questions. followthethings.com <http://www.followthethings.com/faq.shtml>

Cook et al. (2014) Fabrication critique et web 2.0: Les géographies matérielles de followthethings.com. *Géographie et cultures* 91-92: 23-48.

Cook et al. (2017) From 'follow the thing: Papaya' to followthethings.com. *Journal of Consumer Ethics* 1(1): 22-29.

Cook, I., and Crang, M. (1995) *Doing Ethnographies*. Sage.

Cook, I., and Harrison, M. (2007) Follow the thing: 'West Indian hot pepper sauce'. *Space and culture* 10 (1): 40-63.

Coppola, F. (2016, November 26) Ethereum's latest hard fork shows it has a very long way to go. *Forbes* <https://www.forbes.com/sites/francescoppola/2016/11/26/ethereums-latest-hard-fork-shows-it-has-a-very-long-way-to-go/#3c7e9e60443a>

Corbridge, S. (1993) Colonialism, post-colonialism and the political geography of the Third World. In Taylor, P. (ed.), *Political Geography of the Twentieth Century: A Global Analysis*. John Wylie & Sons.

Corea, F. (2017, December 1) The convergence of AI and Blockchain: what's the deal?. Medium.com <https://medium.com/@Francesco_AI/the-convergence-of-ai-and-blockchain-whats-the-deal-60c618e3accc>

Corrigan-Gibbs, H. (2015) Cryptography in the open: Public-key, crypto and the NSA. Silicon Valley Ethereum Meetup <https://www.youtube.com/watch?v=GvWG4jAen8I>

Cormen, T., Leirson, C., Rivest, R., and Stein, C. (1990) *Introduction to Algorithms*. MIT Press.

Courtois, N., and Bahak, L. (2014) On subversive miner strategies and block withholding attack in Bitcoin digital currency. CoRR: Computing Research Repository.

Courtois, N., Grajek, M., and Naik, R. (2013) The unreasonable fundamental incertitudes behind Bitcoin mining <https://arxiv.org/pdf/1310.7935.pdf>

Craig, M. (2015, February 5) The Race to Replace Bitcoin. *The Observer* <http://observer.com/2015/02/the-race-to-replace-bitcoin/>

Crang, M. (2003) Qualitative methods: touchy, feely, look-see?. *Progress in Human Geography* 27 (4): 494-504.

Crang, P. (2005) The geographies of material culture. In Cloke, P., Crang, P., and Goodwin, M. (eds) *Introducing Human Geographies*. Routledge.

Crofton, I. (2015) *Crypto Anarchy*. LULU Press.

Crouch, C. (2004) *Post-democracy*. Polity Press.

Crump T. (1978) Money and number: the Trojan horse of language. *Man* 13 (4): 503–518.

Crunchbase (2018) Coinbase <https://www.crunchbase.com/organization/coinbase#/entity>

CryptoNinjas (2017, April 21) MGTI now mining 100 bitcoins per month, ranking as one of the largest U.S. miners. cyrptoninjas.net <https://www.cryptoninjas.net/2017/04/21/mgti-now-mining-100-bitcoins-per-month-ranking-one-largest-u-s-miners/>

Cukierman, A., Webb, S., and Neyapti, B. (1992) Measuring the independence of Central Banks and its effect on policy outcomes. *The World Bank Economic Review* 6 (3): 353-398.

Cuthbertson, A. (2014, October 7) Geothermal gold: Why Bitcoin mines are moving to Iceland. *International Business Times* <http://www.ibtimes.co.uk/geothermal-gold-why-bitcoin-mines-are-moving-iceland-1468295>

Curtis, A. (2011) All watched over by machines of love and grace. *BBC.*

Cusumano, M. (2014) The Bitcoin ecosystem: Speculating on how the Bitcoin economy might evolve. *Communications of the ACM* 57 (10): 22-24

Dabbish, L., Stuart, C., Tsay, J., and Herbsleb, J. (2012) Social coding in GitHub: Transparency and collaboration in an open software repository. CSCW.

Dai, W. (1998) b-money. <http://www.weidai.com/bmoney.txt>

Dalal, N. (2014) Exploring the Bitcoin system: A complex econo-sociotechnical systems (CEST) perspective. Saïd Business School, University of Oxford.

Dale, B. (2016, September 27) A second Internet, coming soon, courtesy of the blockchain. *The Observer* <http://observer.com/2016/09/a-second-internet-coming-soon-courtesy-of-the-blockchain/>

Dale, B. (2017, December 20) $300 million lockup: Storj clarifies token economics in surprise reveal. *CoinDesk* <https://www.coindesk.com/300-million-lockup-storj-clarifies-token-economics-surprise-reveal/>

Dallyn, S. (2017) Cryptocurrencies as market singularities: The strange case of Bitcoin. *Journal of Cultural Economy* 10 (5): 462-473.

David, C. (2016, December 29) In the spirit of transparency. Medium.com <https://christopherdavid.co/in-the-spirit-of-transparency-e8037d9a0bfd>

David, C. (2017) Introducing the Arcade Token ($ARCD) — and why you probably shouldn't buy any. Arcade City Blog <https://blog.arcade.city/introducing-the-arcade-token-atx-and-why-you-probably-shouldnt-buy-any-f32f40900b1e>

David, C., Ponnet, S., De Wachter, K., Adriaenssen, B., and Thuy, M. (2016) Whitepaper and Token Plan. Arcade City <https://bravenewcoin.com/assets/Whitepapers/AC-whitepaper.pdf>

Davidson, J., and Milligan, C. (2004) Embodying emotion sensing space: introducing emotion geographies. *Social and Cultural Geography* 5 (4): 523-532.

Davies, G. (1994) *A History of Money: From Ancient Times to the Present Day*. University of Wales Press.

Davis, J. (2011, October 10) The crypto-currency: Bitcoin and its mysterious inventor. *The New Yorker* <http://www.newyorker.com/magazine/2011/10/10/the-crypto-currency>

Davis, M. (1992) Who killed LA? A political autopsy. *New Left Review* 197: 3-28.

de Filippi, P. (2014) Bitcoin: A regulatory nightmare to a libertarian dream. *Internet Policy Review* 3 (2): 1-12.

de Filippi, P. (2015) The interplay between decentralization and privacy: The case of blockchain technologies. *Journal of Peer Production* 7.

de Jong, E., Lovink, G., and Riemans, P. (2015) 10 Bitcoin myths. *Institute of Network Cultures* <http://networkcultures.org/moneylab/2015/11/30/10-bitcoin-myths/>

de Vera, B. (2017, October 4) World Bank sees PH remittances hitting $33 billion in 2017. *Philippine Daily Inquirer* <http://business.inquirer.net/237974/world-bank-sees-ph-remittances-hitting-33-billion-2017-remittance-dollars-peso-world-bank>

Decker, C., and Wattenhofer, R. (2013) Information propagation in the Bitcoin network. Thirteenth IEEE International Conference on Peer-to-Peer Computing.

Decker, C., and Wattenhofer, R. (2014) Bitcoin transaction malleability and MtGox. In Kutyłowski, M., and Vaidya, J. (eds) *Computer Security*. Springer.

Deek, F., and McHugh, J. (2008) *Open Source: Technology and Policy*. Cambridge University Press.

del Castillo, M. (2014, July 8) "Paypal Mafia" pals welcome hot bitcoin startup to the family. *The Business Journals* <http://www.bizjournals.com/bizjournals/news/2014/07/08/old-paypal-mafia-<pals-welcome-hot-bitcoin-startup.html>

del Castillo, M. (2015, August 12) The "Great Bitcoin Exodus" has totally changed New York's bitcoin ecosystem. *New York Business Journal* <http://www.bizjournals.com/newyork/news/2015/08/12/the-great-bitcoin-exodus-has-totally-changed-new.html>

del Castillo, M. (2017, January 12) Swift is building a blockchain to optimize global cash liquidity. *CoinDesk* <http://www.coindesk.com/swift-building-blockchain-app-optimize-global-cash-liquidity/>

Demartino, I. (2015, September 2) Who asked Wlad? What does Bitcoin's Lead Developer say about the scaling debate? (Exclusive). *CoinJournal* <https://coinjournal.net/who-asked-wlad-what-does-bitcoins-lead-developer-say-about-scaling-debate-exclusive/>

Demeritt, D. (2002) What is the 'social construction of nature'? A typology and sympathetic critique. *Progress in Human Geography* 26 (6) 767-790.

Department of Justice (2013, February 8) Combating transnational organized crime: International money laundering as a threat to our financial systems. Statement for the Record Before the Subcommittee on Crime, Terrorism, and Homeland Security of the House Committee on the Judiciary <**Error! Hyperlink reference not valid.**>

Delbecq, A., and Weiss, J. (1990) A regional culture perspective of high technology management. In Lawless, M., and Gomez-Meija, L. (eds) *Strategic Management in High Technology Firms*. JAI Press.

Derluguian, G. (2013) What communism was. In Wallerstein, I., Collins, R., Mann, M., Drerluguian, G., and Calhoun, C. (eds) *Does Capitalism Have a Future?*. Oxford University Press.

Derrida, J. (1967) *Of Grammatology*. Les Éditions de Minuit.

Derthick, M., and Quirk, P. (1985) *The Politics of Deregulation*. Brookings Institution.

Dhupkar, A. (2016, November 12) Doc says no to deposit in RS 500 notes, baby dies awaiting help. *Mumbai Mirror* <https://mumbaimirror.indiatimes.com/mumbai/cover-story/Doc-says-no-to-deposit-in-Rs-500-notes-baby-dies-awaiting-help/articleshow/55380976.cms>

Dibbell, J. (2003) Serfing the Web: Black Snow Interactive and the world's first virtual sweat shop. juliandibbell.com <http://www.juliandibbell.com/texts/blacksnow.html>

Dibbell, J. (2006) *Play Money, or, How I Quit my Day Job and Made Millions Trading Virtual Loot*. Basic Books.

Dibbell, J. (2007, June 17) The life of the Chinese gold farmer. *New York Times* <http://www.nytimes.com/2007/06/17/magazine/17lootfarmers-t.html>

DiBona, C., Ockman, S., and Stone, M. (1999) *Open Sources: Voices from the Open Source Revolution*. O'Reilly.

Dicken, P. (2015) *Global Shift: Mapping the Changing Contours of the World Economy*. Sage.

Dicken, P., and Lloyd, P. (1990) *Location in Space: Theoretical Perspectives in Economic Geography*. Harper Collins.

Dicken, P., and Thrift, N. (1992) The organization of production and the production of organization: why business enterprises matter in the study of geographical industrialization. *Transactions of the Institute of British Geographers* 17: 279-291.

Diffie, W., and Hellman, M. (1976) New directions in cryptography. *IEEE Transactions on Information Theory* (22) 6: 644-654.

Dodd, N. (1994) *The Sociology of Money: Economics, Reason and Contemporary Society*. Cambridge: Polity Press.

Dodd, N. (1995) Money and the nation-state: contested boundaries of monetary sovereignty in geopolitics. *International Sociology* 10: 139-54.

Dodd, N. (2014) *The Social Life of Money*. Princeton University Press.

Dodd, N. (2017) The social life of Bitcoin. *Theory, Culture & Society: Technologies of Relational Finance* 0 (0): 1-22.

Donet, J., Pérez-Solà, C., Herrera Joancomartí, J. (2014) The Bitcoin P2P network. In Böhme, R., Brenner, M., Moore, T., Smith, M. (eds) *Financial Cryptography and Data Security*. Springer.

Donnelly, J. (2014, December 28) Bitcoin 2014: Bitcoin's biggest nightmare, the collapse of Mt. Gox. *Inside Bitcoins* http://insidebitcoins.com/news/bitcoin-2014-bitcoins-biggest-nightmare-the-collapse-of-mt-gox/28074>

Doshi, V., and Allen, K. (2016, November 10) Your money's no good: Rupee note cancellation plunges India into panic. *The Guardian* <https://www.theguardian.com/world/2016/nov/10/rupee-note-cancellation-panic-in-india-banks-500-1000>

Dovey, M. (2016, July 12) Blockchain & bureaucracy. Institute of Network Cultures <http://networkcultures.org/moneylab/2016/07/12/%C2%ADblockchain-bureaucracy/>

Dowd, K. (2014) New Private Monies: A Bit-Part Player. Institute of Economic Affairs.

Dowd, K., and Timberlake, R. (1998) *Money and the Nation State*. Transaction Publishers.

Downey, G., and Fisher, M. (2006) Introduction: The anthropology of capital and the frontiers of ethnography. In Downey, G., Fisher, M. (eds) *Frontiers of Capital: Ethnographic Reflections on the New Economy*. Duke University Press.

Draper University (2014) Adam Draper: Bitcoin as a utility for financial markets. *Zapchain Interview* <https://www.youtube.com/watch?v=kRwVWPDdYH8>

Draper, W. (2011) *The Startup Game: Inside the Partnership Between Venture Capitalists and Entrepreneurs*. Palgrave Macmillan.

Dubé, L., Bourhis, A., and Jacob, R. (2005) The impact of structuring characteristics on the launching of virtual communities of practice. *Journal of Organizational Change Management* 18 (2): 145-166.

Ducheneaut, N. (2005) Socialization in an open source software community: A socio-technical analysis. *Computer Supported Cooperative Work* 14: 323–368. Springer.

Dwyer, G. (2014) The economics of Bitcoin and similar private digital currencies. *Journal of Financial Stability* 17: 81-91.

Dyson, E., Gilder, G., Keyworth, G., and Toffler, A. (1994) Cyberspace and the American Dream: A Magna Carta for the Knowledge Age. *The Information Society* 12 (3): 295-308.

du Sautoy, M. (2015) The Secret Rules of Modern Living: Algorithms. *BBC.*

Easterling, K. (2014) *Extrastatecraft: The Power of Infrastructure Space*. Verso.

ECLAC (2014) Report of the expert group meeting on opportunities and risks associated with the advent of digital currency in the Caribbean. United Nations.

Economopoulous, A., and O'Neill, H. (1995) Bank entry during the Antebellum era. *Journal of Money Credit and Banking* 27 (4): 1071-1085.

Eha, B. (2013, November 15) Bitcoin startups get their own Silicon Valley accelerator. *Entrepreneur* <https://www.entrepreneur.com/article/229960>

Ekelund, L., and Bjurling, K. (2004) Santa's workshop: inside China's slave labour toy factories. Fair Trade Center & Lotta Films.

Eggimann, S., Truffer, B., and Maurer, M. (2015) To connect or not to connect? Modelling the optimal degree of centralisation for wastewater infrastructures. *Water Research*. 84: 218–231.

Elgie, R., and Thompson, H. (1998) *The Politics of Central Banks*. Routledge.

Elliot, M. (2006) Stigmergic collaboration: The evolution of group work, *MC Journal: A Journal of Media and Culture* 9 (2).

Elliott, F. (2009, January 3) Chancellor Alistair Darling on brink of second bailout for banks, *The Times* <http://www.thetimes.co.uk/tto/business/industries/banking/article2160028.ece>

Elliott, L. (2012, August 6) Three myths that sustain the economic crisis. *The Guardian* <https://www.theguardian.com/business/economics-blog/2012/aug/05/economic-crisis-myths-sustain>

Ellis, J. (1970) The possibility of secure non-secret digital encryption. GCHQ <http://cryptocellar.org/cesg/possnse.pdf>

Endert, J. (2014, September 2) From the sharing lie and other internet fairy tales. JBlog <https://navigarenecesseest.wordpress.com/2014/09/02/von-der-sharing-luge-und-anderen-internet-marchen/>

England, K. (2003) Producing feminist geographies: Theory, methodologies and research strategies. In Aitken, S., and Valentine, G. (eds) *Approaches to Human Geography*. Sage.

Epicenter Bitcoin (2015) Adam Draper: Accelerating 100 Bitcoin companies with Boost VC. *Epienter Bitcoin* <https://www.youtube.com/watch?v=qD88IRVLM3s>

Ethereum (2016) Homepage. <https://www.ethereum.org>

Evans, D. (2014) Economic aspects of Bitcoin and other decentralized public-ledger currency platforms. Coase-Sandor Working Paper Series 685.

Evans, D. (2014) Flash file systems. University of Virginia <https://www.youtube.com/watch?v=qXjuVxlVyfc>

Eyal, I., and Sirer, E. (2014) Majority is not enough: Bitcoin mining is vulnerable. In Böhme, R., Brenner, M., Moore, T., Smith, M. (eds) *Financial Cryptography and Data Security*. Springer.

Farlie, R., and Chatterji, A. (2013) High-technology entrepreneurship in Silicon Valley. *Journal of Economic Strategy* 22 (2) 365-389.

Farmer, J. (2003) The spector of srypto-anarchy: Regulating anonymity-protecting peer-to-peer networks. *Fordham Law Review* 72 (3): 725-784.

Ferguson, C. (2010) Inside Job. Sony Pictures Classics. Representational Pictures and Screen Pass Pictures.

Fernando, L. (2002) Theoretical approach to decentralization: An introduction. *Vidyodaya: Journal of Management Science* 1 (1-2): 117-141.

Ferraiolo, D., Berkley, J., and Kuhn, R. (1999) A role-based access control model and reference implementation within a corporate intranet. *ACM Transactions on Information and System Security* 2 (1): 34-64.

Ferrary, M., and Granovetter, M. (2009) The role of venture capital firms in Silicon Valley's complex innovation network. *Economy & Society* 38 (2) 326-359.

Fforde, J. (1992) *The Role of the Bank of England, 1941-1958*. Cambridge University Press.

FinCEN (2013, March 18) Application of FinCEN's regulations to persons administering, exchanging, or using virtual currencies. US Department of the Treasury, FIN-2013-G001, Washington, DC <http://fincen.gov/statutes_regs%20/guidance/html/FIN-2013-G001.html.>

Finextra (2017, January 12) Swift goes deeper into the blockchain. Finextrea Research <https://www.finextra.com/newsarticle/29974/swift-goes-deeper-into-the-blockchain>

Finney, H. (2004) RPOW—Reusable proofs of work. <https://cryptome.org/rpow.htm>

Fintech News (2016, August 29) 27 most valued world fintech unicorns, 8 From China. *Fintech News Singapore* <http://fintechnews.sg/4915/fintech-ipo/world-fintech-unicorns/>

Fisch, M. (2013) Tokyo's commuter train suicides and the society of emergence. *Cultural Anthropology* 28 (2) 320-343.

Fischer, E., and Benson, P. (2006) *Broccoli and Desire: Global Connections and Maya Struggles in Postwar Guatemala*. Stanford University Press.

Fischer, S. (1999) On the need for an international lender of last resort. *The Journal of Economic Perspectives* 13 (4): 85–104.

Fisher, M. (2006) Navigating Wall Street women's gendered networks in the New Economy. In Downey, G., and Fisher, M. (eds) *Frontiers of Capital: Ethnographic Reflections on the New Economy.* Duke University Press.

Flandreau, M., and Ugolini, S. (2011) Where it all began: Lending of last resort and the Bank of England during the Overend-Gurney panic of 1866. Norges Bank Working Paper.

Fletcher, J. (2013) Currency in transition: An ethnographic enquiry of Bitcoin adherents. *University of Central Florida*. Masters Thesis.

Florida, R., and Kenney, M. (1988) Venture capital-financed innovation and technological change in the USA. *Research Policy* 17 (3): 119-137.

Florida, R., and Kenney, M. (2000) Venture capital in Silicon Valley: Fuelling new firm formation. In Kenney, M. (eds) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press.

Foldvary, F. (2008) Free Banking Explained. The Progress Report.

Foote, C., Block, W., Crane, K., and Gray, S. (2004) Economic policy and prospects in Iraq. *Federal Reserve Bank of Boston*. Public Policy Discussion papers 04 (1)

Forbes (2017, February 4) Peter Thiel. *Forbes* <https://www.forbes.com/profile/peter-thiel/>

Forbes, S. (2013) Bitcoin: Whatever it is, it's not money!. *Forbes* <https://www.forbes.com>

Forde, B. (2016, March 28) Announcing a $900,000 Bitcoin developer fund. Medium.com https://medium.com/mit-media-lab-digital-currency-initiative/announcing-a-900-000-bitcoin-developer-fund-6e8b7e8b0861>

Foster, R. (2006) Tracking globalization: commodities and value in motion. In Tilley, C., Keane, W., Kuchler, S., Rowlands, M., and Spyer, P. (eds) *Handbook of material culture*. Sage.

Francis, M., and Francis, N. (2006) Black Gold. Speak-It Films and Fulcrum Productions.

Franklin, S. (2011) 11 Digital Media. *Year's Work Critical and Cultural Theory*, 21 (1): 219-227.

Frauenfelder, M. (2016, February 19) Bitcoin is the Sewer Rat of Currencies. Medium.com <https://medium.com/institute-for-the-future/bitcoin-is-the-sewer-rat-of-currencies-b89819cdf036#.1z0qwloag>

French, S., Leyshon, A., and Signoretta, P. (2008) 'All gone now': The material, discursive and political erasure of bank and building society branches in Britain. *Antipode* 40: 79–101.

Friedman, D. (1982) Gold, Paper, Or… Is There a Better Money?. *Cato Policy Analysis* 17.

Friedman, M. (1962) Capitalism and Freedom. *University of Chicago Press.*

Friedman, M. (1993) *Why Government is the Problem*. Hoover Institution Press.

Frisby, D. (2014) *Bitcoin: The Future of Money?*. Unbound.

Frisch, W., Meschede, M., and Blakey, R. (2010) *Plate Tectonics: Continental Driftand Mountain Building*. Springer Heidelberg Dordrecht.

Freud, S. (1950) Fetishism. In Strachey, J. (ed) *Sigmund Freud Collected Papers: Volume 5*. The Hogarth Press.

Fujita, M., Krugman, P., and Venables, A. (2001) *The Spatial Economy: Cities, Regions and International Trade*. MIT Press.

Fuller, M. (2003) *Behind the Blip: Essays on the Culture of Software*. Autonomedia.

Fuller, M. (2008) *Software Studies: A Lexicon*. MIT Press.

Fung, B., and Halaburda, H. (2016) Central Bank digital currencies: A framework for assessing why and how. Bank of Canada <http://www.bankofcanada.ca/wp-content/uploads/2016/11/sdp2016-22.pdf>

Galloway, A. (2004) *Protocol: How Control Exists After Decentralization*. MIT Press.

Galloway, A. (2006) Language wants to be overlooked: Software and ideology. *Journal of Visual Culture* 5 (3): 315–331.

Galt, J. (2015, December 18) 'Companies will not bring FinTech to the Third World'—Andreas Antonopoulos. Bitcoin.com <https://news.bitcoin.com/companies-will-not-bring-fintech-third-world-andreas-antonopoulos/>

GAO (2013) Financial regulatory reform: Financial crisis losses and potential impacts of the Dodd-Frank Act. Report to Congressional Requesters.

GAO (2013) Virtual economies and currencies: Additional IRS guidance could reduce compliance risks. Report to the Senate Committee on Finance, GAO-13-516 <http://www.gao.gov/assets/660/654620.pdf.>

Garcia, D., Tessone, C., Mavrodiev, P., and Perony, N. (2014) The digital traces of bubbles: Feedback cycles between socio-economic signals in the bitcoin economy. Computing Research Repository.

Garfinkel, S. (1995) *PGP: Pretty Good Privacy*. O'Reilly.

Gatecoin (2017) Bitcoin: What is this 'bitcoin'? <https://gatecoin.com/bitcoin/>

Geiger, S. (1986) Women's life histories: Method & content. *Signs: a Journal of Women in Culture & Society* 11 (20): 334-351.

Gellman, B. and Poitras, L. (2013, June 7) U.S., British intelligence mining data from nine U.S. Internet companies in broad secret program. *The Washington Post*.

Gershon, L. (2014, September 13) The Origins of Silicon Valley. JSTOR Daily <https://daily.jstor.org/how-did-silicon-valley-happen/>

Gervais, A., Karame, G., Capkun, V., and Capkun, S. (2014) Is Bitcoin a decentralized currency?. *IEEE Security & Privacy* 12 (3): 54–60.

Gervais, A., Ritzdorf, H., Karame, G., and Capkun, S. (2015) Tampering with the delivery of blocks and transactions in bitcoin. *Cryptology ePrint Archive* <https://eprint.iacr.org/2015/578.pdf>

Geyh, P. (2009) *Cities, Citizens and Technologies: Urban Life and Postmodernity*. Routledge.

Gibson-Graham, J.K. (1996) *The End of Capitalism (as we knew it): A Feminist Critique of Political Economy*. Oxford: Blackwell.

Giddens, A. 1990. *The Consequences of Modernity*. Stanford, CA: Stanford University Press.

Gilbert, E. (2011) Follow the thing: credit. Response to 'Follow the thing: money'. *Environment and Planning D* 29: 1085-1088.

Gilbertson, A. (2015, July 14) A week inside a hacker hostel. *Bloomberg* <https://www.bloomberg.com/news/features/2015-07-14/a-week-inside-a-hacker-hostel>

Gill, R. (2014, June 13) CEX.IO slow to respond as fears of 51% attack spread. *CoinDesk* <https://www.coindesk.com/cex-io-response-fears-of-51-attack-spread/>

Gill, S. (1992) Economic globalization and the internationalization of authority: limits and contradictions. *Geoforum* 23: 269-283.

Gill, S. (1993) Global finance, monetary policy and cooperation among the group of seven, 1944—92. In Cerny, P. (ed.) *Finance and World Politics: Markets, Regimes and States in the PostHegemonic*. E. Elgar.

Gillespie, T. (2010) The politics of "platforms". *New Media & Society* 12 (3): 347-364.

Girard, M., and Stark, D. (2005) Heterarchies of value: Distributing intelligence and organizing diversity in a New Media startup. In Ong, A., and Collier, S. (eds) *Global Assemblages: Technology, Politics and Ethics as Anthropological* Problems. Blackwell.

Giridharadas, A. (2013, October 28) Silicon Valley roused by secession call. *New York Times* <http://www.nytimes.com/2013/10/29/us/silicon-valley-roused-by-secession-call.html>

GitHub (2017a) The state of the Octoverse 2017. GitHub <https://octoverse.github.com>

GitHub (2017b) Differences between user and organization accounts. GitHub <https://help.github.com/articles/differences-between-user-and-organization-accounts/>

Giuseppe, L., Sartori, L., Paolo, D., and Panayotis, A. (2014) From an idea to a scalable working model: merging economic benefits with social values in Sardex. Inaugural WINIR Conference, 11-14 September 2014, Greenwich, London, UK.

Glaser, F., Zimmermann, K., Haferkorn, M., Weber, M., and Siering, M. (2014) Bitcoin—Asset or currency? Revealing users' hidden intentions. Twenty Second European Conference on Information Systems.

GlobeNewswire (2007, March 21) Global Venture Capital Investment in Web 2.0 Companies on the Rise. Dow Jones Financial Information Services <http://globenewswire.com/news-release/2007/03/21/356905/115876/en/Global-Venture-Capital-Investment-in-Web-2-0-Companies-On-the-Rise.html>

Godfrey, B. (1985) Ethnic identities and ethnic enclaves: The morphogenesis of San Francisco's Hispanic "Barrio". *Yearbook: Conference of Latin Americanist Geographers* 11: 45-53.

Goffman, E. (1959) *The Presentation of Self in Everyday Life*. Random House.

Gold, R. (1958) Roles in sociological field observations. *Social Forces* 36 (3): 217-223.

Goldstein, D. (2016, February 23) San Francisco real estate looking like it did before dot-com crash in 2000, MarketWatch <http://www.marketwatch.com/story/san-francisco-real-estate-looking-like-it-did-before-dotcom-crash-in-2000-2015-11-20>

Golumbia, D. (2009) *The Cultural Logic of Computation*. Harvard University Press.

Golumbia, D. (2015) Bitcoin as politics: Distributed right-wing extremism. In Lovink, G., Tkacz, N., and de Vries, P. (eds) *MoneyLab Reader: An Intervention in Digital Economy*. Institute for Network Cultures.

Golumbia, D. (2016a) Computerization always promotes centralization even as it promotes decentralization. In Simanowski, R. (ed) *Digital Humanities and Digital Media: Conversations on Politics, Culture, Aesthetics and Literacy*. Open Humanities Press.

Golumbia, D. (2016b) *The Politics of Bitcoin: Software as Right-Wing Extremism*. University of Minnesota Press.

Goodfriend, M., and King, R. (1988) Financial Deregulation, Monetary Policy, and Central Banking. Federal Reserve Bank of Richmond: Economic Review.

Goodhart, C. (1991) *The Evolution of Central Banks*. MIT Press.

Goodhart, C. (2011) The past mirror: Notes, surveys, debates—The changing role of central banks. *Financial History Review* 18 (2): 135-154.

Goodman, H. (2009) The formation of the Bank of England: A response to changing political and economic climate, 1694. *Penn History Review* 17 (1): 10-30.

Goodman, I. (2017, June 20) Bitcoin: The ascent of a borderless currency. Das Netz <http://dasnetz.online/en/bitcoin-the-ascent-of-a-borderless-currency/>

Goodwin, T. (2015, March 3) The Battle Is For The Customer Interface. *TechCrunch* <https://techcrunch.com/2015/03/03/in-the-age-of-disintermediation-the-battle-is-all-for-the-customer-interface/>

Gordon, R. (2000) Does the 'New Economy' measure up to the great inventions of the past?. *Journal of Economic Perspectives* 14 (4): 49-74.

Gordon, R. (2001) State, milieu, network: Systems of innovation in Silicon Valley. Centrer for Global, International, and Regional Studies, University of California.

Gorton, G. (1985) Clearinghouses and the origin of Central Banking in the United States. *The Journal of Economic History* 45 (2): 277-283.

Gousios, G., Vasilescu, B., Serebenik, A., and Zaidman, A. (2014) Lean GHTorrent: GitHub data on demand. Conference on Mining Software 384-387.

GQ Magazine (2016, May 2) Dr Craig Wright outs himself as Bitcoin creator Satoshi Nakamoto. *GQ Magazine* <http://www.gq-magazine.co.uk/article/bitcoin-creator-satoshi-nakamoto-craig-wright>

Graeber, D. (2011) *Debt: The First 5000 Years*. Melville House Publications.

Graeber, D. (2015) *The Utopia of Rules: On Technology, Stupidity and the Secret Joys of Bureaucracy*. Melville House.

Graf, K. (2013) On the origins of Bitcoin: Stages of monetary evolution. Creative Commons <http://nakamotoinstitute.org/static/docs/origins-of-bitcoin.pdf>

Graham, M., De Sabbata, S., and Zook, M. (2015) Towards a study of information geographies: (Im) Mutable augmentations and a mapping of the geographies of information. *Geo: Geography and environment* 2 (1): 88-105.

Graham, S., and Marvin, S. (1996) *Telecommunications and the City: Electronic Spaces, Urban Places*. Routledge.

Graham, S. (1998) The end of geography or the explosion of place? Conceptualising space, place and information technology. *Progress in Human Geography* 22 (2): 164-185.

Graham, S. (2005) Software-sorted geographies. *Progress in Human Geography* 29 (5): 562-580.

Graham, S., and Thrift, N. (2007) Out of order: Understanding repair and maintenance. *Theory, Culture and Society* 24 (3): 1-25.

Granovetter, M. (1985) Economic action and social structure: the problem of embeddedness. *American Journal of Sociology* 91: 481-510.

Green, E. (2015, October 29). S.F. Mayor Ed Lee's career arc from activist to politician. *San Francisco Chronicle* <http://www.sfchronicle.com/bayarea/article/S-F-Mayor-Ed-Lee-s-career-arc-from-activist-to-6599763.php>

Green, M. (1974, May 26) Deciding on utilities: Public or private?. *New York Times* <http://www.nytimes.com/1974/05/26/archives/deciding-on-utilities-public-or-private-con-ed-has-taken-a-step.html>

Greenberg, A. (2013, October 25) FBI says it's seized $28.5 million in bitcoins from Ross Ulbricht, alleged owner of Silk Road. *Forbes* <https://www.forbes.com/sites/andygreenberg/2013/10/25/fbi-says-its-seized-20-million-in-bitcoins-from-ross-ulbricht-alleged-owner-of-silk-road/#73e5068d2765>

Greenberg, A. (2014, March 25) Nakamoto's neighbor: My hint for Bitcoin's creator led to a paralyzed crypto genius. *Forbes* <http://www.forbes.com/sites/andygreenberg/2014/03/25/satoshi-nakamotos-neighbor-the-bitcoin-ghostwriter-who-wasnt/#54178cbd2639>

Greenberg, A., and Branwen, G. (2015, December 12) Bitcoin's creator Satoshi Nakamoto is probably this unknown Australian genius. *WIRED* <https://www.wired.com/2015/12/bitcoins-creator-satoshi-nakamoto-is-probably-this-unknown-australian-genius/>

Greenfield A. (2006) *Everyware: The Dawning Age of Ubiquitous Computing*. New Riders.

Greenspan, G. (2015, November 22) Avoiding the pointless blockchain project. MultiChain Blog <http://www.multichain.com/blog/2015/11/avoiding-pointless-blockchain-project/>

Greenspan, G. (2016) Four genuine blockchain use cases. MultiChain Blog <http://www.multichain.com/blog/2016/05/four-genuine-blockchain-use-cases/>

Greenwald, G. (2013, June 7) NSA Prism program taps into user data of Apple, Google and others. *The Guardian* <https://www.theguardian.com/world/2013/jun/06/us-tech-giants-nsa-data>

Greenwald, G. (2014) *No Place to Hide: Edward Snowden, the NSA and the Surveillance State*. Penguin UK.

Gregory, C. (1996) Cowries and conquest: towards a subalternate quality theory of money, *Comparative Studies in Society and History* 38 (2): 195-217.

Grigg, I. (2011) Bitcoin—the bad news. *Financial Cryptography* <http://financialcryptography.com/mt/archives/001327.html>

Grinberg, R. (2011) Bitcoin: An Innovative Alternative Digital Currency. *Hastings Science & Technology Law Journal* 4: 159-207.

Grove, A. (1987) The Future of Silicon Valley. *California Management Review* 29 (3): 154-160.

Gruber, S. (2013) Trust, identity, and disclosure: Are Bitcoin exchanges the next virtual havens for money laundering and tax evasion. *Quinnipiac Law Review* 32 (1): 135-208.

Güring, P., and Grigg, I. (2011) Bitcoin & Gresham's Law—The economic inevitability of collapse. Mimeo.

Hacker News (2013) Why would a government have created bitcoin?. <https://news.ycombinator.com/item?id=5547423>

Hackett, R. (2016, November 22) Why Goldman Sachs and Santander are bailing on R3's blockchain group. *Fortune* <http://fortune.com/2016/11/21/goldman-sachs-r3-blockchain-consortium/>

Haejin (2018) VERGE (XVG) is following Bitcoin (BTC). Steemit <https://steemit.com/verge/@haejin/verge-xvg-is-following-bitcoin-btc >

Haigh, T. (2009). How data got its base: Information storage software in the 1950s and 1960s. IEEE Annals of the History of Computing 6–25.

Hajdarbegovic, N. (2014, April 16) Linguistic researchers name Nick Szabo as author of Bitcoin Whitepaper, *CoinDesk* <http://www.coindesk.com/linguistic-researchers-name-nick-szabo-author-bitcoin-whitepaper/>

Hall, P., and Markusen, A. (1985) *Silicon Landscapes*. Allen & Unwin.

Hall, S. (2007) Knowledge makes the money go round: Conflicts of interest and corporate finance in London's financial district. *Geoforum* 38: 710–19.

Hall, S. (2011) Geographies of money and finance I: Cultural economy, politics and place. *Progress in Human Geography* 35 (2) 234-245.

Hall, S. (2012) Geographies of money and finance II: Financialization and financial subject. *Progress in Human Geography* 36 (3) 403-411.

Hall, S. (2012) Geographies of money and finance III: Financial circuits and the 'real economy'. *Progress in Human Geography* 37 (2) 285-292.

Hall, S., and Appleyard, L. (2009) 'City of London, City of Learning?' Placing business education within the geographies of finance. *Journal of Economic Geography* 9: 597–617.

Han, E. (2014, August 20) Australian Tax Office decides bitcoins are assets, not currency. *The Sydney Morning Herald* <https://www.smh.com.au/technology/australian-tax-office-decides-bitcoins-are-assets-not-currency-20140820-1063gq.html>

Hanke, S. (2008) Zimbabwe: From hyperinflation to growth. Cato Institute: Center for Global Liberty & Prosperity.

Hanke, S., and Kwok, A. (2009) On the measurement of Zimbabwe's hyperinflation, *Cato Journal* 29 (2) :353-364.

Hanson, C. (2011) Too Big to Fail. Duece Three Productions. HBO and Spring Creek Productions

Haraway, D. (1991) *Simians, Cyborgs and Women: The Reinvention of Nature*. Free Association Books.

Harris, J., and Junglas, I. (2013) Decoding the contradictory culture of Silicon Valley. Accenture.

Hartwick, E. (2000) Towards a geographical politics of consumption. *Environment and Planning A* 32 1177-1192.

Harvey, D. (1989) *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change*. Blackwell.

Harvey, D. (1990) Between space and time: Reflections on the geographical imagination. *Annals of the Association of American Geographers* 80 (3) 418-434.

Harvey, D. (2010) *A Companion to Marx's Capital: Volume 1*. Verso.

Harvey, C. (2014) Bitcoin myths and facts. SSRN.

Harvey, C., and Tymoigne, E. (2015, March 1) Do Cryptocurrencies Such as Bitcoin Have a Future?. *Wall Street Journal* <https://www.wsj.com/articles/do-cryptocurrencies-such-as-bitcoin-have-a-future-1425269375>

Harvey, P. (2012) The topological quality of infrastructural relation: An ethnographic approach. *Theory, Culture & Society* 29 (4/5): 76-92.

Haun, K. (2016) How the US government is using blockchain to fight fraud. TED Talks < https://www.youtube.com/watch?v=507wn9VcSAE&t=1145s>

Hawcroft, J. (2012) How computers work: Computation (Part II) <https://www.youtube.com/watch?v=9a7XQmEBK5Q>

Hawkins, G., Potter, E., and Race, K. (2015) *Plastic Water: The Social and Material Life of Bottled Water*. MIT Press.

Hayek, F. (1937) *Monetary Nationalism and International Stability*. Longmans Green.

Hayek, F. (1944) *The Road to Serfdom*. Routledge & University of Chicago Press.

Hayek, F. (1976) *The Denationalisation of Money*. Coronet Books.

Hayes, D. (1989) *Behind the Silicon Curtain: The Seductions of Work in a Lonely Era*. Black Rose Books.

Haylighen, F. (2007) Why is open access Development so succesful? Stigmergic economics of information. in Lutterbeck, B., Baerwolff, M., and Gehring, R. (eds) *Open Source Jahrbuch 2007*. Lehmanns Media <https://arxiv.org/abs/cs/0612071>

Hearn, M. (2015, November 2) On block sizes. medium.com <https://medium.com/@octskyward/on-block-sizes-e047bc9f830>

Hearn, M. (2016a, January 14) The Resolution of the Bitcoin Experiment. Mike Hearn: Collected Essays <https://blog.plan99.net/the-resolution-of-the-bitcoin-experiment-dabb30201f7>

Hearn, M. (2016b) Corda: A distributed ledger. R3 <https://www.corda.net/content/corda-technical-whitepaper.pdf>

Heber, A. (2014, December 1) Australian startup CoinJar has picked up and moved to the UK to take advantage of better tax policies. *Business Insider Australia* <http://www.businessinsider.com.au/australian-startup-coinjar-has-picked-up-and-moved-to-the-uk-to-take-advantage-of-better-tax-policies-2014-12>

Heideggar, M. (1968) *What is a thing?*. Gateway Editions.

Heim, M., (1998) *Virtual Realism*. Oxford University Press.

Heller, N. (2017) Estonia the Digital Republic. *New Yorker* <https://www.newyorker.com/magazine/2017/12/18/estonia-the-digital-republic>

Hellmann, T., and Puri, M. (2002) Venture capital and the professionalization of start-up firms: Empirical evidence. *Journal of Finance* 58 (1): 169-197.

Helmond, A. (2007) Software Studies by Matthew Fuller Book Review. University of Amsterdam.

Hendrickson, J., Hogan, T., and Luther, W. (2015) The political economy of Bitcoin. SSRN.

Hermann, G. (2006) Special money: Ithaca hours and garage sales. *Ethnology* 45 (2): 125-141.

Hermant, E., and Latour, B. (1998) *Paris ville invisible*. Paris: La Découverte-Les Empêcheurs de penser en rond.

Hern, A. (2014, December 22) Bitcoin entrepreneur sentenced to two years in prison. *The Guardian* <https://www.theguardian.com/technology/2014/dec/22/bitcoin-entrepreneur-sentenced-jail>

Hern, A. (2016, May 9) Uber and Lyft pull out of Austin after locals vote against self-regulation. *The Guardian* <https://www.theguardian.com/technology/2016/may/09/uber-lyft-austin-vote-against-self-regulation>

Hern, A. (2018, January 17) Bitcoin's energy usage is huge—we can't afford to ignore it. *The Guardian* <https://www.theguardian.com/technology/2018/jan/17/bitcoin-electricity-usage-huge-climate-cryptocurrency>

Herregraven, F. (2014) Geographies of Avoidance. TED Talks <https://www.youtube.com/watch?v=CQR_Qp04yrg>

Hess, M. (2004) 'Spatial' relationships? Towards a reconceptualization of embeddedness. *Progress in Human Geography* 28 (2) 165-186.

Hertig, A. (2017, January 18) Where's Casper? Inside Ethereum's race to reinvest its blockchain. *CoinDesk* <http://www.coindesk.com/ethereum-casper-proof-stake-rewrite-rules-blockchain/>

Hetzel, R. (2008) *The Monetary Policy of the Federal Reserve: A History*. Cambridge University Press.

Higgins, S. (2014, November 19) Bitcoin Foundation pledges to focus solely on core development. *CoinDesk* <https://www.coindesk.com/bitcoin-foundation-shift-core-development/>

Higgins, S. (2016a, October 28) Swiss railway service to sell Bitcoin. *CoinDesk* <https://www.coindesk.com/swiss-railway-service-sell-bitcoin-ticket-kiosks/>

Higgins, S. (2016b, May 9) Swiss city to accept Bitcoin payments for government services. *CoinDesk* <https://www.coindesk.com/swiss-city-bitcoin-payments-government-services/>

Higgins, S. (2016c, March 19) How Washington State became a battleground for Bitcoin mining. *CoinDesk* <https://www.coindesk.com/bitcoin-miners-public-utility-spar-over-electrical-costs/>

Hileman, G. (2014) From Bitcoin to the Brixton pound: History and prospects for alternative currencies. In Böhme, R., Brenner, M., Moore, T., Smith, M. (eds) *Financial Cryptography and Data Security*. Springer.

Hillis, W. (1998) *The Pattern on the Stone*. Phoenix.

Hillis, K., Petit, M., and Jarrett, K. (2013) *Google and the Culture of Search*. Routledge.

Hine, C. (2000) *Virtual Ethnography*. Sage.

Hinchliffe, S. (1996) Technology, power, and space—The means and ends of geographies of technology. *Environment and Planning D: Society and Space* 14 (6): 659-682.

Hinchliffe, S. (2007) *Geographies of Nature: Societies, Environments, Ecologies*. SAGE.

Hinsley, F., and Stripp, A. (1993) *Codebreakers: The Inside Story of Bletchley Park*. Oxford University Press.

Hirst, P., and Thompson, G. (1992) The problem of 'globalization': international economic relations, national economic management and the formation of trading blocs. *Economy and Society* 21: 357-396.

HMRC (2014) Revenue and customs brief 9: Bitcoin and other cryptocurrencies. Crown Copyright < https://www.gov.uk/government/publications/revenue-and-customs-brief-9-2014-bitcoin-and-other-cryptocurrencies/revenue-and-customs-brief-9-2014-bitcoin-and-other-cryptocurrencies>

HM Treasury (2015) Digital currencies: Response to the call of information. Crown Copyright.

Hochstein, M. (2015, October 5) Fintech (the word, that is) evolves. *American Banker* <https://www.americanbanker.com/opinion/fintech-the-word-that-is-evolves>

Hodges, A. (1983) *Alan Turing: The Enigma*. Simon & Schuster.

Hoefler, D. (1971, January 11) Silicon valley U.S.A. *Electronic News*.

Hölldobler, B., Wilson, E. (2009) *The Superoganism: The Beauty, Elegance, and Strangeness of Insect Societies*. W. W. Norton & Company.

Hoegner, S. (2015) *The Law of Bitcoin*. iUniverse.

Holley, E. (2015, September 23) Digitalisation will double bank IT spending next four years. Banking Technology <http://www.bankingtech.com/374051/digitalisation-will-double-bank-it-spending-says-gartner/>

Horwitz, S. (1992) *Monetary Evolution, Free Banking, and Economic Order*. Westview press.

Howard, P., Duffy, A., Freelon, D., Hussain, M., Mari, W., and Maziad, M. (2011) Opening Closed RegimesL What was the Role of Social Media During the Arab Spring?. Project on Information Technology & Political Islam.

Huber, F. (2011) Do clusters really matter for innovation practices in Information Technology? Questioning the significance of technological knowledge spillovers. *Journal of Economic Geography* 12 (1): 107-126.

Huckle, S., and White, M. (2016) Socialism and the blockchain. *Future Internet* 8 (49) 1-15.

Hudson, R. (2005) *Economic Geographies: Circuits, Flows and Spaces*. Sage.

Hughes, E. (1993) A cypherpunk's manifesto. *The Cyherpunk Mailing List* <https://www.activism.net/cypherpunk/manifesto.html>

Hughes, A. (2004) Retailers, knowledges and changing commodity networks: The case of the cut flower trade. In Amin, A., and Thrift, N. (eds) *Cultural Economy Reader*. Blackwell.

Hughes, K. (2008) Jamelia: whose hair is it anyway?. Minnow Films.

Hughes, A. (2014) Flowers. In Thrift, N., Tickell, A., Woolgar, S., and Rupp, W. (eds) *Globalization in Practice*. Oxford University Press.

Hughes, N., and Lonie, S. (2007) M-PESA: mobile money for the 'unbanked' turning cellphones into 24-hour tellers in Kenya. *Innovations* 2 (1-2): 63-81.

Hutchinson, M. (2013) *A University of the People: A History of the University of Western Sydney*. Allen & Unwin.

Hynes, C. (2017) Meet the cryptocurrency startups targeting the $26 billion remittance industry in the Philippines. *Forbes* <https://www.forbes.com/sites/chynes/2017/09/15/meet-the-cryptocurrency-startups-targeting-the-26-billion-remittance-industry-in-the-philippines/#494b1b2d5510>

iFixit (2017) MacBook Air 13" mid 2012 teardown. iFixit.com <https://www.ifixit.com/Teardown/MacBook+Air+13-Inch+Mid+2012+Teardown/9457>

Indergaard, M. (2004) *Silicon Alley: The Rise and Fall of a New Media District*. Routledge.

Ingham, G. (2004) *The Nature of Money: New Directions in Political Economy*. Polity Press.

Ingold, T. (2000) *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill*. Routledge.

Ingold, T. (2010) Bringing things to life: Creative entanglements in a world of materials. ESRC National Centre for Research Methods <http://eprints.ncrm.ac.uk/1306/1/0510_creative_entanglements.pdf>

Innes, A. (1914) The credit theory of money. *The Banking Law Journal* 31 (Dec/Jan): 151–168.

International Finance Corporation (2011) Mobile money study 201 <http://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate _site/industries/financial+markets/publications/mobile+money+study+2011>

Investopedia (2018a) Soft fork <https://www.investopedia.com/terms/s/soft-fork.asp>

Investopedia (2018b) Hard fork <https://www.investopedia.com/terms/h/hard-fork.asp>

Irrera, A. (2015, April 2) UBS to Open Blockchain Research Lab in London. *Wall Street Journal* <http://blogs.wsj.com/digits/2015/04/02/ubs-to-open-blockchain-research-lab-in-london/>

IRS (2014) IRS virtual currency guidance: Virtual currency is treated as property for U.S. federal tax purposes; General rules for property transactions apply. IRS Virtual Currency Guidance <https://www.irs.gov/newsroom/irs-virtual-currency-guidance>

Jackson, E. (2004) *The PayPal Wars: Battles with eBay, the Media, the Mafia and the Rest of Planet Earth*. World Ahead Publishing Inc.

Jackson, S. (2014) Rethinking Repair. In Gillespie, T., Boczkowski, P., and Foot, K. (eds) *Media Technologies: Essays on Communication, Materiality, and* Society. MIT Press.

Jacob, J., Brinkerhoff, M., and Jovic, E., Wheatley, G. (2004) The social and cultural capital of community currency: an Ithaca HOURS case study survey. *International Journal of Community Currency Research* 8: 42-56.

Jacobs, M., Spillman, L. (2005). Cultural sociology at the crossroads of the discipline. *Poetics* 33 (1): 1–14

Jaffe, A., Trajtenberg, M., and Henderson, R. (1993) Localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics* 108 (3): 577-598.

James, P. (2006) *Globalism, Nationalism Tribalism: Bringing Theory Back In—Towards a Theory of Abstract Community: Volume 2*. SAGE.

Jameson, F. (1998) *The Cultural Turn: Selected Writings on the Postmodern, 1983-1998*. Verso.

Janssens, O. (2017, March 29) The solution to the block size debate. medium.com <https://medium.com/@olivierjanss/the-solution-to-the-block-size-debate-42c3814ff481>

Jansson, J. (2011) Emerging (internet) industry and agglomeration: Internet entrepreneurs coping with uncertainty. *Entrepreneurship & Regional Development* 23 (7-8): 499-521.

Jeftovic, M. (2017, December 20) Bitcoin is deflationary, transparent, and antifragile. *Foundation for Economic Education* <https://fee.org/articles/bitcoin-is-deflationary-transparent-and-antifragile/>

Jentzsch, C. (2016) Decentralized Autonomous Organization to automate governance. <https://download.slock.it/public/DAO/WhitePaper.pdf>

Jeong, S. (2013) The Bitcoin protocol as law, and the politics of a stateless currency. SSRN.

Jevons, W. (1875) *Money and the Mechanism of Exchange*. D. Appleton and Company.

jgarzik (2010, October 3) [PATCH] increase block size limit. Bitcoin Forum <https://bitcointalk.org/index.php?topic=1347.0>

Jin, G. (2006a) Chinese gold farmers in the game world. *Consumers, Commodities & Consumption* 7 (2).

Jin, G. (2006b, March 8) Chinese gold farmers preview. YouTube <https://www.youtube.com/watch?v=ho5Yxe6UVv4>

Jin, G. (2006c, November 16) Chinese gold farmers preview two. YouTube <https://www.youtube.com/watch?v=JRrhpoMd88Y>

Johnson, B., Laszka, A., Grossklags, J., Vasek, M., and Moore, T. (2013) Game-theoretic analysis of DDoS attacks against Bitcoin mining pools. Brenner, M., Rohloff, K., Bonneau, J., Miller, A., Ryan, P., Teague, V., Bracciali, A., Sala, M., Pintore, F., and Jakobsson, M. (eds) *Financial Cryptography and Data Security*. Springer.

Johnson, M. (1970) The cowrie currencies of West Africa part 1. *The Journal of African History* 11 (1):17-49.

Johnson, C., and Squire, K. (2000) Supporting distributed communities of practice with interactive television. *Educational Technology Research and Development* 48 (1): 23-43.

Johnson, C. (2001) A survey of current research on online communities of practice. *Internet and Higher Education* 4: 45-60.

Johnson, O., Abrams, R., Destresse, J., Lybek, T., Roberts, N., and Swinburne, N. (1998) *Payment Systems, Monetary Policy, and the Role of the Central Bank*. International Monetary Fund.

Johnston, M. (1982, October) High tech, high risk and high life in silicon valley. *National Geographic*.

Johnstone, C. (1970) *Chrysal; or The Adventures of a Guinea*. Printed for T. Becket.

Joint Venture (2015) 2015 Silicon Valley index: People, economy, society, place, governance. Silicon Valley Institute for Regional Studies <http://siliconvalleyindicators.org/pdf/index2015.pdf>

Jones, a., Boivan, N. (2010) The malice of inanimate objects: Material agency. In Hicks, D., and Beaudry, M. (eds) *The Oxford Handbook of Material Culture Studies*. Oxford University Press.

Kanngieser, A., Neilson, B., and Rossiter, N. (2014) What is a research platform? Mapping methods, mobilities and subjectivities. *Media, Culture & Society* 36 (3): 302-318.

Kantor, T. (2015) Ulterior States. IamSatoshi Production.

Kar, I. (2016, June 21) The developers behind Ethereum are hacking the hacker that hacked it. *Quartz* <https://qz.com/713078/the-developers-behind-ethereum-are-hacking-the-hacker-that-hacked-it/>

Karame, G., Androulaki, E., Capkun, S. (2012) Two bitcoins at the price of one? Double-spending attacks on fast payments in bitcoin. Conference on Computer and Communication Security.

Karlstrøm, H. (2014) Do libertarians dream of electric coins? The material embeddedness of Bitcoin. *Distinktion: Journal of Social Theory* 15 (1) 23-36.

Karnitschnig, M., Mollenkamp, C., and Fitzpatrick, D. (2008, September 15) Bank of America to Buy Merrill. *The Wall Street Journal* <http://www.wsj.com/articles/SB122142278543033525>

Kashi, E., and Watts, M. (2008) *Curse of the Black Gold: 50 Years of Oil in the Niger Delta*. Powerhouse.

Kauffman, B. (2008) Decentralism. In Hamowy, R. (2008) *The Encyclopaedia of Libertarianism*. SAGE.

Kelleher, D., Hall, S., and Bradley, K. (2012) The cost of the Wall Street-caused financial collapse and ongoing economic crisis is more than $12.8 trillion. Better Markets.

Kelly, J. (2015, September 15) Nine of the world's biggest banks join to form blockchain partnership. *Reuters* <http://www.reuters.com/article/us-banks-blockchain-idUSKCN0RF24M20150915>

Kelty, C. (2008) *Two Bits: The Cultural Significance of Free Software. Duke* University Press.

Kemp-Robertson, P. (2013) Bitcoin. Sweat. Tide. Meet the future of branded currency. TED Talks <https://www.ted.com/talks/paul_kemp_robertson_bitcoin_sweat_tide_meet_the_future_of_branded_currency?language=en>

Keneally, M. (2014) Tim Draper bought the auctioned bitcoins seized from Silk Road. *ABC News* <http://abcnews.go.com/US/tim-draper-bought-auctioned-bitcoins-seized-silk-road/story?id=24399619>

Kenneth, N. (1988) Free Banking Laws and Barriers to Entry in Banking, 1838-1860. *The Journal of Economic History* 48 (4): 877-889.

Kenney, M. (2000) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press.

Kenney, M., and von Burg, U. (2000) Institutions and economies: Creating Silicon Valley. In Kenney, M. (ed) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press.

Kenney, M., and von Burg, U. (2001) Paths and regions: The creation and growth of Silicon Valley. In Garud, R., and Karnøe, P. (eds) *Path Dependence and Creation*. Lawrence Erlbaum.

Kevin L. (2003) Was Y2K Behind the Business Investment Boom and Bust?. Federal Reserve Bank of St. Louis Review January/February.

Keynes, J. (1930) *Economic Possibilities for our Grandchildren.* R. & R. Clark Limited.

Keynes, J. (1936) *The General Theory of Employment, Interest and Money.* Palgrave Macmillan.

Khan, D. (1967) *The Codebreakers: The Story of Secret Writing*. Weidenfeld and Nicolson.

Khanna, D. (1997) *The Rise, Decline, and Renewal of Silicon Valley's High Technology Industry*. Taylor & Francis.

Khondker, H. (2011) Role of the New Media in the Arab Spring. *Globalizations* 8 (5): 675-679.

Khoshaba, C. (2014, January 20) 20Mission, a live/work space for tech workers. *MissionLocal* <http://missionlocal.org/2014/01/20mission-a-livework-space-for-tech-workers/>

Kienzle, J., and Perrig, A. (1996) Digital money: A divine gift or Satan's malicious tool?. STS Project <https://users.ece.cmu.edu/~adrian/projects/memoire1/memoire1.pdf>

Kineally, M. (2014) Tim Draper bought the auctioned bitcoins seized from Silk Road. *ABC News* <http://abcnews.go.com/US/tim-draper-bought-auctioned-bitcoins-seized-silk-road/story?id=24399619>

King, M. (2004) The institutions of monetary policy. *American Economic Review* 94 (2): 1-13.

Kinsley, S. (2013a) The matter of 'virtual' geographies. *Progress in Human Geography* 38 (3) 1-21.

Kinsley, S. (2013b) Beyond the screen: Methods for investigating geographies of life 'online'. *Geography Compass* 7 (8): 540-555.

Kirschenbaum, M. (2008) *Mechanisms: New Media and the Forensic Imagination*. MIT Press.

Kitchin, R. (2011) The programmable city. *Environment and Planning B* 38: 945-951.

Kitchin, R. (2017) Thinking critically about and researching algorithms. *Information, Communication & Society* 20 (1): 14-29.

Kitchin, R., and Dodge, M. (2011) *Code*/Space. MIT Press.

Kitchin, R., and Perng, S. (2016) *Code and the City*. Routledge.

Kittler, F. (1995) There Is No Software. *C-Theory: Theory, Technology, Culture* 32 (Oct.

Kleinknecht, W. (2009) *The Man Who Sold the World: Ronald Reagan and the Betrayal of Main Street America*. Nation Press.

Knapp, G. (1924) *The State Theory of Money*. Macmillan & Company Limited.

Knoespel, K., and Zhu, J. (2008) Continuous materiality through a hierarchy of computational code. *Théorie, Littérature, Epistémologie* 25: 235–247.

Knoke, K. (1996) *Bold New World: The Essential Road Map to the Twenty-First Century*. Kodansha.

Knorr Cetina, K., and Bruegger, U. (2002) Traders' engagement with markets: a postsocial relationship. *Theory, Culture and Society* 19: 161–85.

Knorr Cetina, K., and Preda, A. (2005) *The Sociology of Financial Markets*. Oxford University Press.

Knox, P., and Agnew, J. (2008) *The Geography of the World Economy*. John Wiley and Sons.

Kobie, N. (2017, December 2) How much energy does bitcoin mining really use? It's complicated. *WIRED* <http://www.wired.co.uk/article/how-much-energy-does-bitcoin-mining-really-use >

Koebler, J. (2017, June 22) An update to your Motherboard: Motherboard is under new management. *Motherboard* <https://motherboard.vice.com/en_us/article/xw8ja7/an-update-to-your-motherboard>

Koepp, R. (2002) *Clusters of Creativity: Enduring Lessons on Innovation and Entrepreneurship from Silicon Valley and Europe's Silicon Fen*. John Wiley & Sons.

Koetsier, J. (2017, December 25) Alleged: Bitcoin Cash Insider Trading Discovered Via CoinBase With Potential 8X Return. *Forbes* <https://www.forbes.com/sites/johnkoetsier/2017/12/25/alleged-bitcoin-cash-insider-trading-discovered-via-coinbase-with-potential-8x-return/#57f0c31e6f20>

Kohl, U. (2007) *Jurisdiction and the Internet: Regulatory Competence Over Online Activity*. Cambridge University Press.

Kondor, D., Pósfai, M., Csabai, I., and Vattay, G. (2014) Do the rich get richer? An empirical analysis of the Bitcoin transaction network. *PLoS One* 9 (2): 1-10.

Koning, J. (2013a) Why the Fed is more likely to adopt bitcoin technology than kill it off. Moneyness <http://jpkoning.blogspot.com.au/2013/04/why-fed-is-more-likely-to-adopt-bitcoin.html>

Koning, J. (2013b) Disowned currency: the odd case of Iraqi Swiss Dinars. Moneyness <http://jpkoning.blogspot.com.au/2013/05/disowned-currency-odd-case-of-iraqi.html>

Koning, J. (2014) Fedcoin, Moneyness <http://jpkoning.blogspot.com.au/2014/10/fedcoin.html>

Koning, J. (2016) Fedcoin: A central bank-issued cryptocurrency <https://static1.squarespace.com/static/55f73743e4b051cfcc0b02cf/t/58c7f80c2e69cf24220d335e/1489500174018/R3+Report-+Fedcoin.pdf>

Kopfstein, J. (2013, December 12) The mission to decentralise the Internet. *The New Yorker* <http://www.newyorker.com/tech/elements/the-mission-to-decentralize-the-internet>

Kostakis, V., and Giotitsas, C. (2014) The (a)political economy of Bitcoin. *Triple C* 12 (2): 431-440.

Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukopadhyay, T., and Scherlis, W. (1998) Internet paradox: a social technology that reduces social involvement and psychological well-being?. *American Psychologist* 53: 1017-1031.

Kroll, J., Davey, I., and Felten, E. (2013) The Economics of Bitcoin Mining or, Bitcoin in the Presence of Adversaries. The Twelfth Workshop on the Economics of Information Security.

Kroszner, R. (1995) Free banking: The Scottish experience as a model for emerging economies. World Bank.

Kubrak, A. (2015) Geographies of Imagination. Institute of Network Cultures <http://networkcultures.org/moneylab/2015/10/28/geographies-of-imagination/>

Kuhn, B., and Stallman, R. (2001, August 15) Freedom or Power? O'Rielly Linux Dev Center <http://www.linuxdevcenter.com/pub/a/linux/2001/08/15/free_software.html>

Kutler, J. (2015) Friday flashback: Did Citi coin the term 'fintech'?. *American Banker* <https://www.americanbanker.com/opinion/friday-flashback-did-citi-coin-the-term-fintech>

Laclau, E. (1990) *New Reflections on the Revolution of our Time*. Verso.

Lamport, L., Shostak, R., and Pease, M. (1982) The Byzantine generals problem. *ACM Transactions on Programming Languages and Systems* 4 (3): 382-401.

Lanchester, J. (2016) When Bitcoin grows up. *London Review of Books* 38 (8): 3-12.

Landau, S. (2006) Find me a hash. *Notices of the AMS* 53 (3): 330-332.

Langley, P., and Leyshon, A. (2016) Platform capitalism: The intermediation and capitalisation of digital economic circulation. *Finance & Society* 3 (1) 11-31.

Larkin, B. (2013) The Politics and Poetics of Infrastructure. *Annual Review of Anthropology* 42: 327–343.

Lash, S., and Urry, J. (1994) *Economies of signs and space*. SAGE.

Laszka, A., Johnson, B., and Grossklags, J. (2015) When Bitcoin mining pools run dry: A game-theoretic analysis of the long-term impact of attacks between mining pools. International Conference on Financial Cryptography and Data Security.

Latour, B. (1986) The powers of association. In Law, J. (ed.) *Power, Action, Belief: A new Sociology of Knowledge?*. Routledge.

Latour, B. (1987) *Science in Action*. Harvard University Press.

Latour, B. (1993) *We Have Never Been Modern*. Harvard University Press.

Latour, B. (1996) *Aramis, or, The love of technology*. Harvard University Press.

Latour, B. (1999) *Pandora's Hope: Essays on the Reality of Science Studies*. Harvard University Press.

Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory,* Oxford University Press.

Latour, B., and Woolgar, S. (1979) *Laboratory Life: The Construction of Scientific Facts*. Sage.

Law, J. (1986) On the methods of long distance control: Vessels, navigation and the Portuguese route to India. In Law, J. (ed.) *Power, Action and Belief: a new Sociology of Knowledge?*. Routledge.

Law, J. (1991) Strategies of power. In Law, J. (ed.) *A Sociology of Monsters: Essays on Power, Technology and Domination*. Routledge.

Law, J. (2007) Actor Network Theory and Material Semiotics. <http://www.heterogeneities.net/publications/Law2007ANTandMaterialSemiotics.pdf>

Lea, T. (2016) *Blockchain: Down the Rabbit Hole: Discover the Power of the Blockchain*. 54 Days Pty Ltd.

Lee, A. (2013, November 2) Welcome to the unicorn club: Learning from billion-dollar startups. *TechCrunch* <https://beta.techcrunch.com/2013/11/02/welcome-to-the-unicorn-club/>

Lee, C., Miller, W., Hancock, M., and Rowen, H. (2000). *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship*. Stanford Business Books.

Lee, R. (2006) The ordinary economy: Tangled up in values and geography. *Transactions of the Institute of British Geographers* 31 (4) 413-432.

Leroux, R. (2012) *French Liberalism in the 19th Century*. Routledge.

Leslie, S. (1993) How the West Was Won: The Military and the Making of Silicon Valley. In Aspray, W. (ed) *Technological Competitiveness: Contemporary and Historical Perspectives on the Electrical, Electronics and Computer Industries*. Institute of Electronics and Electrical Engineers.

Leslie, S. (2000) The Biggest "Angel" of Them All: The Military and the Making of Silicon Valley. In Kenney, M. (2000) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press.

Lessig, L. (1999) *Code and Other Laws of Cyberspace*. Basic Books.

Level39 (2015, April 2) UBS, the first global bank to create an innovation lab at Level 39, to focus on blockchain and fintech innovations. Canary Wharf Group PLC <http://www.level39.co/news/ubs-first-global-bank-create-innovation-lab-level39-focus-blockchain-fintech-innovations>

Levi, M. (2014) The Bureau de Change, in Thrift, N., Tickell, A., Woolgar, S., and Rupp, W. (eds) *Globalization in Practice*. Oxford University Press.

Levy, S. (1993, February 1) Crypto rebels. *WIRED* <https://www.wired.com/1993/02/crypto-rebels/>

Levy, S. (1994, December 1) e-money (that's what I want). *WIRED* <https://www.wired.com/1994/12/emoney/>

Levy, S. (2001) *Crypto: How the Code Rebels Beat the Government—Saving Privacy in the Digital Age*. Penguin Books.

Lewenberg, Y., Bachrach, Y., Sompolinsky, Y., Zohar, A., and Rosenschein., J. (2015) Bitcoin mining pools: A cooperative game theoretic analysis. In Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems.

Lewis, M. (2014) *Flash boys: A Wall Street Revolt*. W. W. Norton & Company.

Lewis, T. (2015, April 20) SF Bitcoin Devs seminar: Advanced Stellar development for Bitcoin developers. YouTube <https://www.youtube.com/watch?v=mMEEZBKGcu0&t=2465s>

Leyshon, A. (1993) Crawling from the wreckage: speculating on the future of the European exchange rate mechanism. *Environment and Planning A* 25: 1553-1557.

Leyshon, A. (1995) Geographies of money and finance I. *Progress in Human Geography* 19 (4) 531-543.

Leyshon, A. (1997) Geographies of money and finance II. *Progress in Human Geography* 21 (3) 381-392.

Leyshon, A. (1998) Geographies of money and finance III. *Progress in Human Geography* 22 (3) 433-446.

Leyshon, A., Lee, R., and Williams, C. (2003) *Alternative Economic Spaces*. SAGE.

Leyshon, A., and Thrift, N. (1994) Access to financial services and the process of financial infrastructure withdrawal: problems and policies. *Area* 26: 268-275.

Leyshon, A., and Thrift, N. (1995) Geographies of financial exclusion: financial abandonment in Britain and the United States. *Transactions, Institute of British Geographers, New Series* 20 (3): 312-341.

Leyshon, A., and Thrift, N. (1996) Financial exclusion and the shifting boundaries of the financial system. *Environment and Planning A* 28 (7): 1150-1156.

Leyshon, A., and Thrift, N. (1997) *Money/Space*. Routledge.

Leyshon, A., and Tickell, N., (1994) Money order? The discursive construction of the Bretton Woods and the making and breaking of regulatory space. *Envionment and Planning A* 26: 1861-1890.

Lieberman, M. (2014) Early VC Investment in Bitcoin is like the Internet in 1993. Prezi <https://prezi.com/user/e0xfmx7xu58t/>

Limer, E. (2013) The world's most powerful computer network is being wasted on Bitcoin. *Gizmondo* <https://gizmodo.com/the-worlds-most-powerful-computer-network-is-being-was-504503726>

Lind, N., and Rankin, E. (2015) *Privacy in the Digital Age: 21st-Century Challenges to the Fourth Amendment*. ABC-CLIO.

LiPuma, E. (2017) *The Social Life of Financial Derivatives*. Duke University Press.

Lischke, M., and Fabian, B. (2016) Analyzing the Bitcoin network: The first four years. *Future Internet* 8 (1): 1-40.

Lobo, S. (2014, September 3) Auf dem Weg in die Dumpinghölle. Spiegel Online <http://www.spiegel.de/netzwelt/netzpolitik/sascha-lobo-sharing-economy-wie-bei-uber-ist-plattform-kapitalismus-a-989584.html>

Lodge, G., Zhang, H., and Jegher, J. (2015, February 5) IT spending in banking: A global perspective. Celent <http://celent.com/reports/it-spending-banking-global-perspective-2>

Loeliger, J., and McCullough, M. (2012) *Version Control with Git: Powerful Tools and Techniques for Collaborative Software Development*. O'Reilly Media.

Lofrgren, M. (2015) *The Deep State: The Fall of the Constitution and the Rise of a Shadow Government*. Penguin Books.

Loomis, M. (2005) *Decentralism: Where It Came From—Where Is It Going?*. Black Rose Books.

Lorimer, J. (2007) Nonhuman charisma. *Environment and Planning D* 25: 911-932.

Lovink, G. (2002) *Dark Fiber: Tracking Critical Internet Culture*. MIT Press.

Lovink, G., Tkacz, N., and de Vries, P. (2015) *MoneyLab Reader: An Intervention in Digital Economy*. Institute for Network Cultures.

Lowen, R (1992) Exploiting a wonderful opportunity: The patronage of scientific research at Stanford University, 1937-1965. *Minerva* 30 (3): 391-421.

Ludlow, P. (2001) *Crypto Anarchy, Cyberstates, and Pirate Utopias*. MIT Press.

Ludwig, S. (2013, April 29) Hotshot investor Chris Dixon says 'second wave' of Bitcoin startups is on the way. VentureBeat <https://venturebeat.com/2013/04/29/chris-dixon-second-wave-bitcoin-startups/>

Lunden, I. (2013, May 16) With PayPal-like ambitions for Bitcoin, BitPay raises $2M led by Founders Fund. *TechCrunch* <https://techcrunch.com/2013/05/16/an-offer-you-cant-refuse-bitcoin-startup-bitpay-raises-2m-led-by-founders-fund-the-vc-run-by-the-paypal-mafia/>

Lupton, C. (2006) Authors, it-narratives, and objectification in the eighteenth century. *A Forum on Fiction* 39 (3): 402-420.

Lustig, C., and Nardi, B. (2015) Algorithmic authority: The case of Bitcoin. Hawaii International Conference on System Sciences.

Luther, W. (2013) Cryptocurrencies, network effects, and switching costs. Mercatus Center Working Paper.

MacKenzie, A. (2003) The Problem of Computer Code: Leviathan or Common Power?. Institute for Cultural Research, Lancaster University.

Mackenzie, A. (2005) The Performativity of Code: Software and Cultures of Circulation. *Theory, Culture & Society* 22 (1): 71-92.

Mackenzie, A. (2006) *Cutting Code: Software and Sociality*. Peter Lang.

Mackenzie, A. (2018) 48 million configurations and counting: platform numbers and their capitalization. *Journal of Cultural Economy* 11 (1): 36-53.

Mackenzie, D. (2004) Physics and Finance: S-Terms and Modern Finance as a Topic for Science In Amin, A., and Thrift, N. (eds) *Cultural Economy Reader*. Blackwell.

Mackenzie, D. (2006) *An Engine, Not a Camera: How Financial Models Shape* Markets. MIT Press.

Mackenzie, D. (2014a) LIBOR. In Thrift, N., Tickell, A., Woolgar, S., and Rupp, W. (eds) *Globalization in Practice*. Oxford University Press.

Mackenzie, D. (2014b) Be grateful for drizzle: Donald Mackenzie on high-frequency trading. *London Review of Books* 36 (17): 27-30.

MacLeod, G., and Jones, M. (2001) Renewing the geography of regions. *Environment and Planning D* 19: 669-695.

Madden, D. (2010) Urban ANTs: a review essay. *Qualitative Sociology* 33: 583-599.

Madeira, A. (2016) The DAO, the hack, the soft fork and the hard fork. CryptoCompare <https://www.cryptocompare.com/coins/guides/the-dao-the-hack-the-soft-fork-and-the-hard-fork/>

Mak, K. (2008) Red Dust. Independent Production.

Malecki, . (1981) Science, technology and regional economic development: Review and prospects. *Research Policy* 10 (1): 312-34.

Malecki, E., and Nijkamp, P. (1988) Technology and regional development: Some thoughts on policy. *Environment and Planning C* 6: 383-99.

Malmo, C. (2017, November 1) Bitcoin's surge in price has sent its electricity consumption soaring. *Motherboard* <https://motherboard.vice.com/en_us/article/ywbbpm/bitcoin-mining-electricity-consumption-ethereum-energy-climate-change>

Mamudi, S., (2008, September 15) Lehmen folds with record $613 billion debt. MarketWatch <http://www.marketwatch.com/story/lehman-folds-with-record-613-billion-debt>

Mann, A., and Luo, T. (2010) Crash and reboot: Silicon Valley high-tech employment and wages, 2000-08. *Monthly Labor Review* (Jan) 59-73.

Mann, M. (2013) The end may be nigh, but for whom?. In Wallerstein, I., Collins, R., Mann, M., Drerluguian, G., and Calhoun, C. (eds) *Does Capitalism Have a Future?*. Oxford University Press.

Mannak, M. (2015) Can mobile money conquer new markets?. MIT Technology Review.

Manne, R. (2011) The cypherpunk revolutionary: Julian Assange. *The Monthly* <https://www.themonthly.com.au/issue/2011/february/1324596189/robert-manne/cypherpunk-revolutionary>

Manor, J. (1999) *The Political Economy of Democratic Decentralization*. The World Bank.

Manovich, L. (2001) *The Language of New Media*. MIT Press.

Manovich, L. (2008) *Software Takes Command*. Bloomsbury.

Marino, M. (2006) Critical Code Studies. Electronic Book Review <http://www.electronicbookreview.com/thread/electropoetics/codology >

Marcus, G. (1995) Ethnography in/of the world system: The emergence of multi-sited ethnography. *Annual Review of Anthropology* 24: 95-117.

Mark, D., Zamfir, V., and Sirer, E. (2016) A call for a temporary moratorium on the DAO. Hacking, Distributed <http://hackingdistributed.com/2016/05/27/dao-call-for-moratorium/>

Markham, J. (2002) *A Financial History of the United States: Volume 1*. M.E. Sharpe Inc.

Markusen, A., and Bloch, R. (1985) Defensive cities: Military spending, high technology and human settlements. In Castells, M. (ed) *High Technology, Space and Society*. Sage.

Marr, B. (2018, March 2) Artificial intelligence and blockchain: 3 major benefits of combining these two mega-trends. *Forbes* <https://www.forbes.com/sites/bernardmarr/2018/03/02/

artificial-intelligence-and-blockchain-3-major-benefits-of-combining-these-two-mega-trends/#388983844b44>

Marriott, J., and Minio-Paluello, M. (2012) The Oil Road: Journeys from the Caspian sea to the city of London. Verso Books.

Marshall, J. (2004) Financial institutions in disadvantaged areas: A comparative analysis of policies encouraging financial inclusion in Britain and the United States. *Environment and Planning A* 36: 241–261.

Martin, J. (1978) *The Wired Society*. Prentice Hall.

Martin, A. (2016, November 26) R3 four flew: What's driving banks to flee blockchain consortium. The Register <https://www.theregister.co.uk/2016/11/29/banks_leave_r3_blockchain_consortium/>

Marx, K. (1867) *Capital: A Critique of Political Economy Volume 1: The Process of Production of Capital*. Verlag von Otto Meissner.

Marx, K. (1933) *The Civil War in France*. International Publishers.

Marx, K. (1970) *A Contribution to the Critique of Political Economy*. International Publishers.

Marx, K. (1975) *On the Jewish Question*. In Marx, K., and Engels, F. (eds) *Marx & Engels Collected Works: Volume 3*. Lawrence & Wishart.

Marx, K., and Engles, F. (1965) *The German Ideology*. Lawrence and Wishart.

Mas, I., and Morawczynski, O. (2009) Designing mobile money services: Lessons from M-PESA. *Innovations* 4 (2): 77-91.

Mas, I., and Radcliffe, D. (2011) Mobile Payments Go Viral: M-PESA in Kenya. In Chuhan-Pole, P., and Angwafo, M. (eds) *Yes, Africa Can: Success Stories from a Dynamic Continent*. World Bank Publications.

Massey, D (1991) A global sense of place. *Marxism Today* 38: 24-29.

Massey, D. (1995) Masculinity, dualisms and high technology. *Transactions of the Institute of British Geographers* 20: 487-499.

Massey, D. (2005) *For Space*. Sage.

Massumi, B., (2002) *Parables for the Virtual: Movement, Affect, Sensation*. Duke University Press.

Mateas, M., and Montfort, N. (2005) A box, darkly: Obfuscation, weird languages, and code aesthetics. Digital Arts and Culture, Copenhagen.

Matonis, J. (2012, August 20) WikiLeaks bypasses financial blockade with Bitcoin. *Forbes* <https://www.forbes.com/sites/jonmatonis/2012/08/20/wikileaks-bypasses-financial-blockade-with-bitcoin/>

Maurer, B. (2005) *Mutual Life, Limited: Islamic Banking, Alternative Currencies, Lateral Reason*. Princeton University Press.

Maurer, B. (2006) The anthropology of money. *Annual Review of Anthropology* (35): 15-36.

Maurer, B. (2011) Money nutters. *Economic Sociology: The European Electronic Newsletter* 12 (3): 5-12.

Maurer, B. (2012) An emerging platform: From money transfer system to mobile money ecosystem. *Innovations* 6 (4): 49-64.

Maurer, B. (2015) *How Would You Like to Pay? How Technology is Changing the Future of Money*. Duke University Press.

Maurer, B., Nelms, T., and Swartz, L. (2013) When perhaps the real problem is money itself!": the practical materiality of Bitcoin. *Social Semiotics* 23 (2): 261-277.

Maurer, B., and Swartz, L. (2015) Wild wild west: A view from two Californian schoolmarms. In Lovink, G., Tkacz, N., and de Vries, P. (eds) *MoneyLab Reader: An Intervention in Digital Economy*. Institute for Network Cultures.

Maurer, B., and Swartz, L. (2017) *Paid: Tales of Dongles, Checks, and Other Money Stuff*. MIT Press.

May, T. (1992) The crypto anarchist manifesto. Cypherpunk Mailing List <https://www.activism.net/cypherpunk/crypto-anarchy.html>

May, T. (1994) Crypto anarchy and virtual communities. hackbloc.org <http://groups.csail.mit.edu/mac/classes/6.805/articles/crypto/cypherpunks/may-virtual-comm.html>

Mayer, R. (2015) Localized complementary currencies: The new tool for policymakers?. The Sardex Exchange System, UCL.

Mazzotti, M. (2017) Algorithmic life. *Los Angeles Review of Books* <https://lareviewofbooks.org/article/algorithmic-life/#!>

McCracken, G. (1988) *The Long Interview*. Sage.

McHugh, G. (2013) The Reality of the German Bitcoin Utopia: More Sobering than Bitcoiners would like to admit. BTC Global <https://btcglobal.net/blog/post/reality-of-the-german-bitcoin-utopia>

McKay, A. (2015) The Big Short. Plan B Entertainment and Regency Enterprises.

McKemey, K., Scott, N., Souter, D., Afullo, T., Kibombo, R., and Sakyi-Dawson, O. (2003) Innovative demand models for telecommunications services. Department for International Development.

McKernan, B. (2016, October 24) Facebook 'deliberately targeting' Palestinian accounts after meeting with Israeli government, rights group say. *The Independent* <http://www.independent.co.uk/news/world/middle-east/israel-palestine-facebook-activist-journalist-arrests-censorship-accusations-incitement-a7377776.html>

McLannahan, B. (2016, November 22) Goldman Sachs quits R3 blockchain consortium. *Financial Times* <https://www.ft.com/content/598934e0-b010-11e6-9c37-5787335499a0>

McLeay, M., Radia, A., and Thomas, R. (2014) Money creation in the modern economy, Quarterly Bulletin 1. The Bank of England.

McNeill, D. (2016) Governing a city of unicorns: technology capital and the urban politics of San Francisco. *Urban Geography* 37 (4): 494-513.

McNeill, D. (2017) *Global Cities and Urban Theory*. Sage.

McQueen, S. (2007) Gravesend. Nottingham Contemporary Gallery.

Meerman, M. (2015) The Wall Street Code. VPRO Backlight.

Meiklejohn, S., Pomarole, M., Jordan, G., Levchenko, K., McCoy, D., Voelker, G., Savage, S. (2013) A fistful of Bitcoins: Charecterizing payments among men with no names. ACM SIGCOMM Internet Measurement Conference 127-139.

Meltzer, A (2003) *A History of the Federal Reserve: 1913-1951 (Volume 1)*. University of Chicago Press.

Menezes, A., van Oorschot, P., and Vanstone, S. (1996) *Handbook of Applied Cryptography*. CRC Press.

Merkle, R. (1978) Secure communications over insecure channels. *Communications of the ACM* 21 (4): 294-298.

Merleau-Ponty, M. (1963) *Phenomenology of Perception*. Routledge.

Merriman, P., Revill, G., Cresswell, T., Lorimer, H., Matless, D., Rose, G., and Wylie, J. (2008) Landscape, mobility, practice. *Social and Cultural Geography* 9 (2): 191-212.

Metz, C. (2015) The Bitcoin schism shows the genius of open source. *WIRED* <https://www.wired.com/2015/08/bitcoin-schism-shows-genius-open-source/>

metzdowd.com (2018) The cryptography and cryptography policy mailing list <http://www.metzdowd.com/mailman/listinfo/cryptography>

Meunier, S. (2016, August 4) When do you need blockchain? Decision models. medium.com <https://medium.com/@sbmeunier/when-do-you-need-blockchain-decision-models-a5c40e7c9ba1#.9c3pa9dt7>

Meyer, D. (2017, September 12) This place lets you pay your taxes in Bitcoin. *Fortune* <http://fortune.com/2017/09/12/switzerland-chiasso-bitcoin-tax-zug/>

Michailaki, A. (2014) Mixed reality through the Internet of Things and Bitcoin: How laws affect them. In Sideridis, A., Kardasiadou, Z., Yialouris, C., and Zorkadis, V. (eds) *E-Democracy, Security, Privacy and Trust in a Digital World*. Springer.

Miller, A., Litton, J., Pachulski, A., Gupta, N., Levin, D., Spring, N., and Bhattacharjee, B. (2015) Discovering Bitcoin's public topology and influential nodes. University of Maryland

Miller, C. (2008, September 23) Silicon Valley barely touched by financial crisis—So far. *New York Times* <http://bits.blogs.nytimes.com/2008/09/23/silicon-valley-barely-touched-by-financial-crisis-so-far/?_r=0>

Miller, D. (2010) *Stuff*. Polity Press.

Miller, D., (2011) *Tales from Facebook*. Wiley.

Miller, D., and Slater, D. (2000) *The Internet: An Ethnographic Approach*. Bloomsbury Academic.

Miller, R. and Côté, M. (1985) Growing the next Silicon Valley. *Harvard Business Review* (Jul-Aug): 114- 23.

Miller, P. (1998). The multiplying machine. *Accounting, Organisations and Society* 22 (3-4): 355-364.

Mims, C. (2016, May 2) This tech bubble is bursting. *Wall Street Journal* <http://www.wsj.com/articles/this-tech-bubble-is-bursting-1462161662>

Mintz, S. (1986) *Sweetness and Power: the Place of Sugar in Modern History*. Penguin.

Mitchell, J. (1990) Access to basic banking services: The problems of low-income American consumers. Providence, Rhode Island Consumers Council.

Mitchell., W. (1999) *E-Topia*. MIT Press.

Mittal, S. (2012) Is Bitcoin Money? Bitcoin and Alternative Theories of Money. SSRN <http://ssrn.com/abstract=2434194>

Mol, A. (1999) Ontological politics: A word and some questions. In Law, J., and Hassard, J. (eds) *Actor Network Theory and After*. Blackwell Publishers.

Mol, A. (2002) *The Body Multiple: Ontology in Medical Practice*. Durham, Duke University Press.

Mollin, R. (2000) *An Introduction to Cryptography*. Chapman & Hall/CRC.

Money & Tech (2014) Adam Draper talks about Boost VC. YouTube <https://www.youtube.com/watch?v=ZyuJL0uovWE>

Montamedi, S. (2014, July 21) Will bitcoins ever become money? A path to decentralized central banking. Tannu Tuva Initiative <http://tannutuva.org/blog/2014/7/21/will-bitcoins-ever-become-money-a-path-to-decentralized-central-banking>

Montfort, N. (2004, December 28) Continuous paper: The early materiality and workings of electronic literature. Talk given at the Modern Language Association Convention.

Montgomery, K. (2014, April 7) A Confused Valencia Street Now Segregating 'Techies' and 'Real San Franciscans'. uptownalmanac.com <http://uptownalmanac.com/2014/04/confused-valencia-street-now-segregating-techies-and-real-san-franciscans>

Moore, D. (2016, January 6) How life in San Francisco will change after the tech bubble bursts. The Bold Italic <https://thebolditalic.com/how-life-in-san-francisco-will-change-after-the-tech-bubble-bursts-the-bold-italic-san-francisco-75972018b5d1#.7h959h5ml>

Moore, T., and Christin, N. (2013) Beware the middleman: empirical analysis of Bitcoin-exchange risk. In Sadeghi, A. (ed) *Financial Cryptography and Data Security*. LCNS 7859: 25-33.

Moreno, F. (2013, July 25) Erik Voorhees: 'Bitcoin is the New Frontier'. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/erik-voorhees-new-frontier-1374794545/>

Morozov, E. (2015, June 7) Where Uber and Amazon rule: Welcome to the world of the platform. *The Observer* <http://www.theguardian.com/technology/2015/jun/07/facebook-uber-amazon-platform-economy/>

Motamedi, S. (2014, July 21) Will bitcoins ever become money? A path to decentralized central banking. Tannu Tuva Initiative <http://tannutuva.org/blog/2014/7/21/will-bitcoins-ever-become-money-a-path-to-decentralized-central-banking>

Motherboard (2015) Life inside a secret Chinese Bitcoin mine. Vice Media LLC <https://www.youtube.com/watch?v=K8kua5B5K3I>

Mougayar, W. (2016) *The Business Blockchain: Promise, Practice and Application of the Next Internet Technology*. John Wiley & Sons.

Mross, D. (2014) The Rise and Rise of Bitcoin. 44th Floor Productions. DARONIMAX Media. Fair Acres Media.

Mu, E. (2015, June 8) My Life Inside a Remote Chinese Bitcoin Mine. *CoinDesk* <https://www.coindesk.com/my-life-inside-a-remote-chinese-bitcoin-mine/>

Munt, S. (2001) *Technospaces: Inside The New Media.* Continuum International Publishing Group Ltd.

Murillo, E. (2008) Searching Usenet for virtual communities of practice: Using mixed methods to identify the constructs of Wenger's theory. *Information Research* 13 (4): 1-36 <https://files.eric.ed.gov/fulltext/EJ837276.pdf>

Naisbitt, R. (1995) *The Global Paradox*. Avon Books.

Nakamoto, S. (2008) Bitcoin: A peer-to-peer electronic cash system. <https://bitcoin.org/bitcoin.pdf>

Nakamoto, S. (2009, February 11) Bitcoin open source implementation of P2P currency. P2P Foundation <http://p2pfoundation.ning.com/forum/topics/bitcoin-open-source>

Nakamoto, S. (2010a, December 5) Re: Wikileaks contact info?. Bitcoin Forum <https://bitcointalk.org/index.php?topic=1735.msg26999#msg26999>

Nakamoto, S. (2010b, December 11) Re: PC World article on Bitcoin. Bitcoin Forum <https://bitcointalk.org/index.php?topic=2216.msg29280#msg29280>

Narula, N. (2016) The Future of Money. TED Talks <https://www.ted.com/talks/neha_narula_the_future_of_money#t-380133>

Nashif, N. (2017, October 23) Surveillance of Palestinians and the Fight for Digital Rights Al-Shabaka <https://al-shabaka.org/briefs/surveillance-palestinians-fight-digital-rights/>

Narayanan, A. (2013) What happened to the crypto dream? Part 1. *EEE Security and Privacy Magazine* (Mar/Apr) <http://randomwalker.info/publications/crypto-dream-part1.pdf>

Nayak, K., Kumar, S., Miller, and Shi, E. (2016) Stubborn mining: Generalizing selfish mining and combining with an eclipse attack. IACR Cryptology ePrint Archive.

Needleman, S., and Ante, S. (2013, May 4) Bitcoin startups begin to attract real cash, *Wall Street Journal* <http://www.wsj.com/articles/SB10001424127887323687604578469012375269952>

Negroponte, N. (1995) *Being Digital*. Vintage.

Neilson, B. (2016a, March 10) From warehouse to data centre: Poetics and infrastructure of political form. Institute for Culture and Society Seminar (Western Sydney University) Seminar Series

Neilson, B. (2016b) Platform research. *Western Sydney University* <https://www.westernsydney.edu.au/__data/assets/pdf_file/0005/1149881/Platform_Research.pdf>

Mezzadra, S., and Neilson, B. (2013) *Border as Method, or, the Multiplication of Labour*. Duke University Press.

Nel, E., and Binns, T. (2003) Decentralising development in South Africa. *Geography* 88 (2): 108-116

Nelson, A. (1999) *Marx's Concept of Money: The god of commodities*. Routledge.

Nelson, T. (2013) I think I know who Satoshi is. YouTube <https://www.youtube.com/watch?v=emDJTGTrEm0&feature=youtu.be>

Nieves, E. (2000, November 5) Mission district fights case of dot-com fever. *New York Times* <http://www.nytimes.com/2000/11/05/us/mission-district-fights-case-of-dot-com-fever.html>

NISENet (2014) Zoom into a microchip. YouTube <https://www.youtube.com/watch?v=Knd-U-avG0c&index=3&list=PLyQF0oE_rs5vFn9DeLbDQShS6zPKE9z-D>

North, P., Longhurst, N. (2013) Grassroots localisation? The scalar potential of and limits of the 'Transition' Approach to Climate Change and Resource Constraint. *Urban Studies* 50 (7): 1423-1438.

Norris, P. (2001) *Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide*. Cambridge University Press.

Noyen, K., Volland, D., Worner, D., and Fleisch, E. (2014) When money learns to fly: Towards sensing as a service applications using bitcoin, ETH. Zurich and University of St. Gallen.

nustiudinastea (2016) Critical update RE: DAO Vulnerability. Reddit <https://www.reddit.com/r/ethereum/comments/4oiqj7/critical_update_re_dao_vulnerability/>

NYDFS (2015) Virtual currencies, New York codes, rules and regulations. NYDFS <http://www.dfs.ny.gov/legal/regulations/adoptions/dfsp200t.pdf>

O'Brien, J. (2007, November 14) The PayPal Mafia. *Fortune* <http://fortune.com/2007/11/13/paypal-mafia/>

O'Brien, M. (2015, January 14) Bitcoin revealed: a Ponzi scheme for redistributing wealth from one libertarian to another. *The Washington Post* <https://www.washingtonpost.com/news/wonk/wp/2015/01/14/bitcoin-is-revealed-a-ponzi-scheme-for-redistributing-wealth-from-one-libertarian-to-another/?utm_term=.9a0c6d31ffa0>

O'Brien, R. (1992) *Global Financial Integration: The End of Geography*. Royal Institute of International Affairs.

O'Connell, J. (2016a, May 11) Andreas Antonopoulos' folly on private blockchains. *Bitcoinist* <http://bitcoinist.com/antonopoulos-private-blockchains/>

O'Connell, J. (2016b, June 20) What are the use cases for private blockchains? The experts weigh in. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/what-are-the-use-cases-for-private-blockchains-the-experts-weigh-in-1466440884/>

O'Dwyer, R. (2015) Money talks: The enclosure of mobile payments. In Lovink, G., Tkacz, N., and de Vries, P. (2015) *MoneyLab Reader: An Intervention in Digital Economy*. Institute for Network Cultures.

O'Hagan, A. (2016) The Satoshi Affair. *London Review of Books* 38 (13): 7-28.

O'Mahony, S. (2006) Developing community software in a commodity world. In Downey, G., and Fisher, M. (eds) *Frontiers of Capital: Ethnographic Reflections on the New Economy*. Duke University Press.

O'Rian, S. (2004) Net-working for a living: Irish software developers in the global workplace. In Amin, A., and Thrift, N. (eds) *Cultural Economy Reader*. Blackwell.

O'Riordan, K. (2001) Playing with Lara in virtual space. In Munt, S. (2001) *Technospaces: Inside the New Media*. Continuum.

Oates, J. (2013, May 20) Has Ted Nelson named the real Satoshi Nakamoto? *CoinDesk* <http://www.coindesk.com/ted-nelson-names-the-real-satoshi-nakamoto/>

Ohmae, K. (1990) *The Borderless World: Power and Strategy in the Interlinked Economy*. HarperCollins.

Olma, S. (2014, October 16) Nevermind the sharing economy: Here's platform capitalism. *Institute of Network Cultures Blog* <http://networkcultures.org/mycreativity/2014/10/16/never-mind-the-sharing-economy-heres-platform-capitalism/>

Omwansa, T., and Sullivan, N. (2012) *Money, Real Quick: The story of M-PESA*. Guardian Creative.

Ormsby, E. (2012) Silk Road: The eBay of illegal drugs. *Kill Your Darlings* 11.

Ortega, M. (2013) The Bitcoin Transaction Graph Anonymity. *Universitat Autònoma de Barcelona*. Masters Thesis.

Ouellet, M. (2010) Cybernetic capitalism and the global information society: From the global panopticon to a 'brand' new world. In Best, J., and Paterson, M. (ed.) *Cultural Political Economy*. Routledge.

Packer, G. (2011, November 28) No death, no taxes: The libertarian futurism of a Silicon Valley billionaire. *New Yorker* <http://www.newyorker.com/magazine/2011/11/28/no-death-no-taxes>

Packer, J., and Wiley, S. (2011) *Communication Matters: Materialist Approaches to Media, Mobility and Networks*. Routledge.

Pal, R. (2013) Valuing Bitcoin using a macro framework. *Global Macro Investor* <https://www.zerohedge.com/sites/default/files/images/user5/imageroot/2013/11/Bitcoin.pdf>

Paled, M. (2005) China Blue. Teddy Bear Films.

Paragon Real Estate Group (2016) Recessions, recoveries & bubbles: 30+ years of housing market cycles in the San Francisco Bay Area <http://www.paragon-re.com/3_Recessions_2_Bubbles_and_a_Baby>

Parden, R. (1981) The manager's role and the high mobility of technical specialists in the Santa Clara Valley. *IEEE Transactions on Engineering Management* 28 (1): 2-8.

Parker, L. (2015, April 7) Bitcoin Foundation: Insolvent and broken. *BraceNewCoin* <https://bravenewcoin.com/news/bitcoin-foundation-insolvent-and-broken/>

Parker, L. (2016, September 4) Bitcoin remittances '20 percent' of South Korea-Philippines corridor. *Brave New Coin* <https://bravenewcoin.com/news/bitcoin-remittances-20-percent-of-south-korea-philippines-corridor/>

Parkin, M. (1978) In search of a monetary constitution for the European communities. In Frattiani, M., and Peters, T. (eds) *One Money for Europe*. Praeger.

Parkin, M. (1987) Domestic monetary institutions and deficits. In Buchanan, M., Rowley, C., and Tollison, D. (eds) *Deficits*. Basil Blackwell.

Parikka, J. (2015) *A Geology of Media*. University of Minnesota Press.

Parr, H. (2003) Researching bodies in virtual space. In Blunt, A., Gruffudd, P., May, J., Ogborn, M., and Pinder, D. (eds) *Cultural Geography in Practice*. Arnold.

PBS (2015, April 18) The hack attack that takes your computer hostage until you pay. PBS News Hour <https://www.pbs.org/newshour/show/ransomware-hack-attacks-holding-data-hostage-avoid>

Peel, J. (2000) *Religious Encounter and the Making of the Yoruba*. Bloomington: Indiana University Press.

Peetz, D., and Mall, G. (2018) Why Bitcoin is not a currency but a speculative real asset. SSRN.

Peikoff, L. (1993) *Objectivism: The Philosophy of Ayn Rand*. Meridian.

Pel, A. (2015) Money for nothing and bits for free: The geographies of bitcoin. *University of Toronto*. Masters Thesis.

Pels, P. (1998) The spirit of matter: On fetish, rarity, fact, and fancy. In Spyer, P. (ed) *Border Fetishisms: Material Objects in Unstable Space*. Routledge.

Pels, P. (2010) Magical things: On fetishes, commodities, and computers. In Hicks, D., and Beaudry , M. (eds) *The Oxford Handbook of Material Culture Studies*. Oxford University Press.

Penenberg, A. (2011, October 11) The Bitcoin crypto-currency mystery reopened. The Fast Company <http://www.fastcompany.com/1785445/bitcoin-crypto-currency-mystery-reopened>

peoplma (2015, October 18) Bitcoin's block size debate: The mining perspective for blockchain security. medium.com <https://medium.com/@peoplma/bitcoin-s-block-size-debate-the-mining-perspective-for-blockchain-security-596ad1cc86a5>

Perens, B. (1999) The open source definition. In DiBona, C., Ockman, S., and Stone, M. (eds) *Open Sources: Voices from the Open Source Revolution*. O'Reilly.

Perez, Y. (2015, August 13) The real cost of applying for a New York BitLicense. *CoinDesk* <http://www.coindesk.com/real-cost-applying-new-york-bitlicense/>

Perez, C. (2016, May 27) Arcade City is the 'black market' Uber that runs on Facebook. *Motherboard* <https://motherboard.vice.com/en_us/article/arcade-city-is-the-black-market-uber-that-runs-on-facebook-christopher-david>

Perrig, A., and Song, D. (1999) Hash Visualization: A New Technique to Improve Real-World Security. International Workshop on Cryptographic Techniques and E-Commerce (CrypTEC '99) 439–458.

Peters, G., Panayi, E., and Chapelle, A. (2015) Trends in crypto-currencies and blockchain technologies: A monetary theory and regulation perspective. SVB.

Peyton, A. (2017, February 24) R3 turns its back on blockchain?. *FinTech Futures* <http://www.bankingtech.com/746692/r3-turns-its-back-on-blockchain/>

Pham, L. (2017, October 27) This company added the word 'Blockchain' to its name and saw its shares surge 394%. *Bloomberg Technology* <https://www.bloomberg.com/news/articles/2017-10-27/what-s-in-a-name-u-k-stock-surges-394-on-blockchain-rebrand>

Philo, C. (1995) Where is poverty? The hidden geography of poverty in the United Kingdom. In Philo, C. (ed.) *Off the Map: The Social Geography of Poverty in the UK*. Child Poverty Action Group.

Piepenbring, D. (2016, May 16) Tag archives: The adventure of a guinea. Paris Review <https://www.theparisreview.org/blog/tag/the-adventures-of-a-guinea/>

Pietz, W. (1985) The problem of the fetish, I. *Anthropology and Aesthetics* (9): 5-17.

Pike, A., Lagendijk, A., and Vale, M. (2000) Critical reflections on 'embeddedness' in economic geography: The case of labour market governance and training in the automotive industry in the north-east region of England. In Giunta, A., Lagendijk, A., and Pike, A., (eds) *Restructuring Industry and Territory: The Experience of Europe's Regions*. The Stationery Office.

Pike, A., Rodriquez-Pose, and A., Tomaney, J. (2006) *Local and Regional Development*. Routledge.

Pilkington, M. (2017) Bitcoin through the lenses of complexity theory: Some non-orthodox implications for economic theorizing. In Martin, R., and Pollard, J. (eds) *Handbook on the Geographies of Money and Finance*. Edward Elgar.

Plant, S. (1997) *Zeroes + Ones: Digital Women + The New Technoculture*. Doubleday.

Polanyi, K. (1944) *The Great Transformation*. Holt, Rinehart.

Polanyi, K., Arensberg, C., and Pearson, H. (1957) *Trade and Market in the Early Empires*. Free Press.

Pollard, S., and Holmes, C. (1973) *Documents of European History. Vol. 3: The End of the Old Europe, 1914-1939*. St. Martins Press.

Pollert, A. (1988) Dismantling Flexibility. *Capital and Class* 34: 42-75.

Popper, N. (2015a) *Digital Gold: Bitcoin and the Inside Story of the Misfits and Millionaires Trying to Reinvent Money*. Harper.

Popper, N. (2015b, May 18) How Silicon Valley joined the Bitcoin gold rush. The Fast Company <https://www.fastcompany.com/3046417/when-bitcoin-went-to-silicon-valley>

Popper, N. (2015c, May 18) What is 21.com really building? An excerpt from Digital Gold. *TechCrunch* <https://techcrunch.com/2015/05/18/what-is-21-co-really-doing-an-excerpt-from-digital-gold/>

Popper, N. (2017, July 18) Some Bitcoin backers are defecting to create a rival currency. *New York Times* <https://www.nytimes.com/2017/07/25/business/dealbook/bitcoin-cash-split.html>

Power Ledger (2018a) Power Ledger: The democratization of power. <https://powerledger.io>

Power Ledger (2018b) Power Ledger whietpaper. *Power Ledger Pty Ltd* <https://powerledger.io/media/Power-Ledger-Whitepaper-v8.pdf>

Pratt, A. (1997a) The cultural industries production system: a case study of employment change in Britain, 1984-91, *Environment and Planning A* 29: 1953-74.

Pratt, A. (1997b) The cultural industries sector: its definition and character from secondary sources on employment and trade, Britain 1984-91. *Research Papers in Environmental and Spatial Analysis, London School of Economics* 41: 3-31.

Preukschat, A., Busquet, J., and Ares, J. (2014) *Bitcoin: The Hunt for Satoshi Nakamoto*. Europe Comics.

Price, R. (2016, June 13) We got a look inside a vast Icelandic bitcoin mine. *Business Insider UK* <http://uk.businessinsider.com/photos-iceland-bitcoin-ethereum-mine-genesis-mining-cloud-2016-6?r=US&IR=T>

Prisco, G. (2015a, April 3) UBS to open blockchain innovation lab in London. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/ubs-open-blockchain-innovation-lab-london-1428094554/>

Prisco, G. (2015b, December 11) SWIFT to launch global payments innovation initiative, develop blockchain roadmap. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/swift-to-launch-global-payments-innovation-initiative-develop-blockchain-roadmap-1449860661/>

Quartz India (2016) 'Organised loot, legalised plunder': The man who opened up India's economy trashes Modi's demonetisation move. *Quartz India* <https://qz.com/845609/organised-loot-legalised-plunder-manmohan-singh-the-man-who-opened-up-indias-economy-trashes-narendra-modis-demonetisation-move-in-the-rajya-sabha/>

R3 (2017) About R3. r3cev.com <http://www.r3cev.com/about/>

Rajeevan, R., and Ganapatye, M. (2016, November 11) Demonetisation: Rush for cash kills 2 in Kerala, 1 in Maharashtra; Congress blames Modi government. *India Today* <https://

www.indiatoday.in/india/story/demonetosation-deaths-congress-modi-government-351593-2016-11-11>

Rajput, V. (2013) Research on Know Your Customer (KYC). *International Journal of Scientific and Research Publications* 3 (7): 1-6.

Rancière, J. (1995) *La mésentente—politique et philosophie*. Editions Galilée.

Rancière, J. (1998) *Disagreement*. University of Minnesota Press.

Rancière, J. (2005) *Chroniques des Temps Consensuels*. Seuil.

Rand, A. (1959) The Mike Wallace Interview of Ayn Rand. No Free Lunch Distributors.

Rand, A., (1984) *Philosophy: Who Needs It?*. Signet.

Rand, A., Branden, N., Greenspan, A., and Hessen, R. (1967) *Capitalism: The unknown ideal*. Signet.

Raskin, M. (2013, April 12) Meet the Bitcoin millionaires: early adopters of the virtual currency are suddenly rich. *Bloomberg* <https://www.bloomberg.com/news/articles/2013-04-10/meet-the-bitcoin-millionaires>

Ratcliff, J. (2014, January 11) Bring out your dead… Bitcoin that is. Code Suppository <https://codesuppository.blogspot.co.uk/2014/01/bring-out-your-dead-bitcoins-that-is.html>

Raval, S. (2016) *Decentralized Applications: Harnessing Bitcoin's Blockchain Technology*. O'Rielly Media.

Raymond, E., (1998) A brief history of hackerdom. In DiBona, C., Ockman, S., and Stone, M. (eds) *Open Sources: Voices from the Open Source Revolution*. O'Reilly.

Raymond, E. (2001) *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*. O'Reilly.

Raza, A. (2018, January 28) Coinbase warns VCs to back off after booking $1 billion in revenue. CryptoSlate <https://cryptoslate.com/coinbase-warn-vcs-back-off-booking-1-billion-revenue/>

Reddy, N. (2017, November 24) Demonetisation, corruption and black money. Frontline <http://www.frontline.in/cover-story/demonetisation-corruption-and-black-money/article9946457.ece>

Redmon, D. (2005) Mardis Gras: Made in China. Carivalesque Films.

Reid, F., and Harrigan, M. (2012) An analysis of anonymity in the Bitcoin system. In Altshuler Y., Elovici Y., Cremers A., Aharony N., Pentland A. (eds) *Security and Privacy in Social Networks*. Springer.

remotemass (2013) 12,222 lines of code? Bitcoin Forum <https://bitcointalk.org/index.php?topic=289807.0> (see https://pastebin.com/MfABqyJd for code)

Rheingold, H. (1993) *The Virtual Community: Homesteading on the Electronic Frontier*. Addison-Wesley Publishing Company.

Rheingold, H. (1994) *The Millennium Whole Earth Catalogue*. Harper San Francisco.

Richards, B. (2014) Bitcoin is a Ponzi scheme. The Forum <http://tabbforum.com/videos/bitcoin-is-a-ponzi-scheme-marathons-richards>

Rizzo, P. (2014, February 5) CoinSummit San Francisco announces itinerary and speakers. *CoinDesk* <https://www.coindesk.com/coinsummit-san-francisco-announces-itinerary-speaker-list/>

Rizzo, P. (2015a, October 5) US Government to sell 44,000 BTC in final Silk Road auction. *CoinDesk* < http://www.coindesk.com/us-government-to-sell-44000-btc-in-final-silk-road-auction/>

Rizzo, P. (2015b, May 22) Internet security pioneer unveil project at Blockchain University. *CoinDesk* <https://www.coindesk.com/founding-ssl-developer-unveils-project-at-blockchain-university/>

Roberts, D. (2015, June 12) Bitcoin company ditches New York, blaming new regulations. *Fortune* <http://fortune.com/2015/06/11/bitcoin-shapeshift-new-york-bitlicense/>

Roberts, S. (1994) Fictitious capital, fictitious spaces: the geography of Offshore Financial Flows. In Corbridge, S., Martin, R., Thrift, N. (eds) *Money, Power and Space*. Blackwell.

Robles, G., Guervós, J., and Gonzalez-Barahona, J., (2005) Self-organized development in Libre software: A model based on the stigmergy concept. 6th International Workshop on Software Process Simulation and Modelling <https://www.researchgate.net/publication/287329946_Self-Organized_Development_in_Libre_Software_a_Model_based_on_the_Stigmergy_Concept>

Rockoff, H. (1989) Lessons from the American experience with free banking. NBER Historical Working Paper 9.

Rodden, J., Eskeland, G., and Litvack, J. (2003) *Fiscal Decentralisation and the Challenge of Hard Budget Constraints*. MIT Press.

Rogers, E., and Larsen, J. (1984) *Silicon Valley Fever*. Basic Books.

Rolnick, A., and Weber, W. (1983) New evidence on the free banking era. *American Economic Review* (Dec) 1090-1091.

Rolnick, A., and Weber, W. (1984) The causes of Free bank failures. *Journal of Monetary Economics* 14: 267-291.

Rolnick, A., and Weber, W. (1988) Explaining the demand for free notes. *Journal of Monetary Economics* 21: 47-71.

Ron, D., and Shamir, A. (2013) Quantitative analysis of the full Bitcoin transaction graph. In Sadeghi, A. (ed) *Financial Cryptography and Data Security* LNCS 7859: 6-24. Springer.

Rose, G. (2016) Rethinking the geographies of cultural 'objects' through digital technologies: interface, network and friction. *Progress in human geography* 40(3): 334–351.

Ross, A. (2003) *No-collar: The Hidden Cost of the Humane Workplace*. Basic Books.

Rossiter, N. (2006) *Organized Networks: Media Theory, Creative Labour, New Institutions*. NAI.

Rossiter, N. (2016) *Software, Infrastructure, Labor: A Media Theory of Logistical Nightmares*. Routledge.

Rossiter, N. (2017) Automation, platform capitalism, and the state. Institute for Culture and Society—Digital Life Research Program (Western Sydney University). Technology's Limits: Automation, Invention, Labour, and the Exhausted Environment <https://www.westernsydney.edu.au/ics/events/technologys_limits>

Ruparelia, N. (2010) The history of version control. *ACM SIGSOFT Software Engineering* 35 (1) 5-9.

Russell, J., and Tepper, F. (2017, December 19) Coinbase is investigating claims of insider trading from its Bitcoin Cash launch. *TechCrunch* https://techcrunch.com/2017/12/19/coinbase-inside-information-bitcoin-cash-launch/>

Rutter, J., and Smith, G. (2005) Ethnographic presence in a nebulous setting. In Hine, C. (ed) *Virtual Methods: Issues in Social Research on the Internet*. Berg.

Rutter, D. (2017, February 14) When is a blockchain not a blockchain. The R3 Report <http://www.r3cev.com/blog/2017/2/24/when-is-a-blockchain-not-a-blockchain>

Ryle, G. (1949) *The Concept of Mind*. University of Chicago Press.

Samani, R. (2013) Digital Laundry: An analysis of online currencies, and their use in cybercrime. McAfee.

Sample, M. (2011, January 14) Criminal code: The procedural logic of crime in videogames. Sample Reality <http://www.samplereality.com/2011/01/14/criminal-code-the-procedural-logic-of-crime-in-videogames/>

Sams, R. (2015, February 5) Which Fedcoin?. Cryptonomics <https://cryptonomics.org/2015/02/05/which-fedcoin/>

Sassen, S. (1991) *The Global City*. Princeton University Press.

Sassen, S. (2004) The locational and institutional embeddedness of electronic markets: the case of the global capital markets. In Bevir, M., and Trentmann, F. (eds) *Markets in Historical Context: Ideas and Politics in the Modern World*. Cambridge University Press.

Sassen, S. (2005) The embeddedness of electronic markets: The case of global capital markets. In Knorr Centina, K., and Preda, A. (eds) *The Sociology of Financial Markets*. Oxford University Press.

Saul, M. (2004) Money in colonial transition: Cowries and francs in West Africa. *American Anthropologist* 106 (1): 71-84.

Saxenian, A. (1981) Silicon chips and spatial structures: The industrial basis of urbanization in Santa Clara County, California. Institute of Urban and Regional Development, University of California.

Saxenian, A. (1983) The urban contradictions of Silicon Valley: regional growth and the restructuring of the semiconductor industry. *International Journal of Urban and Regional Research* 7 (2): 237-262.

Saxenian, A. (1989a) In search of power: the organization of business interests in Silicon Valley and Route 128. *Economy & Society* 18 (1): 25-70.

Saxenian, A. (1989b) The Cheshire cat's grin: Innovation and regional development in England. *Economy & Society* 18 (4): 448-477.

Saxenian, A. (1990) Regional networks and the resurgence of Silicon Valley. *California Management Review* 33 (1): 89-112.

Saxenian, A., (1996) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Harvard University Press.

SBB (2016) Bitcoin on SBB ticket machines. SBB/CFF/FFS <https://company.sbb.ch/en/media/media-relations/press-releases/detail.html/2016/10/2810-3>

Schaefer, S. (2013, March 14) A look back at Bear Stearns, five years after its shotgun wedding to JPMorgan. *Forbes* <http://www.forbes.com/sites/steveschaefer/2013/03/14/a-look-back-at-bear-stearns-five-years-after-its-shotgun-marriage-to-jpmorgan/#2a97bd917ddc>

Schafran, A., and Walker, R. (2015) The strange case of the Bay Area. *Environment and Planning A* 47: 10-29.

Scheper-Hughes, N. (2000) The global traffic in human organs. *Current Anthropology* 41 (2): 191-224.

Scheper-Hughes, N. (2001) Commodity fetishism in organs trafficking. *Body & Society* 7 (2-3): 31-62.

Scheper-Hughes, N. (2002) Bodies for Sale—Whole or in Parts. In Scheper-Hughes, N., and Wacquant, L. (eds) *Commodifying Bodies*. Sage.

Scheper-Hughes, N. (2003) Keeping an eye on the global traffic in human organs. *The Lancet* 361 (9369): 1645-1648.

Scheper-Hughes, N. (2004) Parts unknown: undercover ethnography of the organs-trafficking underworld. *Ethnography* 5 (1) 29-73.

Scheper-Hughes, N. (2007) The last commodity: Post-human ethics and the global traffic in 'Fresh' organs. In Ong, A., and Collier, J. (eds) *Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems*. Blackwell.

Schmidt, V. (1990) *Democratizing France*. Cambridge University Press.

Schneider, N. (2014, April 7) Code your own utopia: Meet Ethereum, bitcoin's most ambitious successor. *Aljazeera America* <http://america.aljazeera.com/articles/2014/4/7/code-your-own-utopiameetethereumbitcoinasmostambitioussuccessor.html>

Scholz, T. (2017) *Uberworked and Underpaid: How Workers Are Disrupting the Digital Economy*. John Wiley and Sons.

Schonfield, E. (2011, May 25) The Top 10 VC Firms, According to InvestorRank. *TechCrunch* <https://techcrunch.com/2011/05/25/top-10-vc-firms-investorrank/>

Schuhmacher, S. (2014, December 18) Blockchain University: Creating more blockchain developers. *Brave New Coin* <https://bravenewcoin.com/news/blockchain-university-creating-more-blockchain-developers/>

Schumpeter, J. (1976) *Capitalism, Socialism and Democracy*. Harper Perennial.

Scott, A. (2001) Capitalism, cities, and the production of symbolic forms. *Transactions of the Institute of British Geographers* (26) 1: 11-23.

Scott, B. (2014a, December 30) Peer-to-peer review: The state of academic Bitcoin research 2014. Suitpossom: Anarchic Adventures in Arts, Activism, Anthropology and Alternative Economics.

Scott, B. (2014b, June 1) Visions of a Techno-Leviathan: The Politics of the Bitcoin Blockchain. E-International Relations <http://www.e-ir.info/2014/06/01/visions-of-a-techno-leviathan-the-politics-of-the-bitcoin-blockchain/>

Scott, B. (2016) How can cryptocurrency and blockchain technology play a role in building social and solidarity finance? UNRISD.

Scott, Mel. (1985) *The San Francisco Bay Area: A metropolis in perspective*. University of California Press.

Scott, S., and Zachariadis, M. (2013) *The Society for Worldwide Interbank Telecommunication (SWIFT): Cooperative Governance for Network Innovation, Standards and Community*. Routledge.

Selgin, G. (2015) Synthetic commodity money. *Journal of Financial Stability* 17: 92-99.

Selwyn, N. (2004) Reconsidering political and popular understandings of the digital divide. *New Media & Society* 6 (3): 341-362.

Senate of Canada (2014, October 8) Proceedings of the Standing Senate Committee on banking, trade and commerce. Parliament of Canada 15 <https://sencanada.ca/en/Content/Sen/committee/412/banc/15ev-51627-e>

Sexenian, A. (1988) The Cheshire Cat's grin: Innovation and regional development in England. *Technology Review* 71 (Feb/Mar): 67-75.

Shah, A. (2008) *Macro Federalism and Local Finance, Public Sector Governance and Accountability Series*. The World Bank.

Shaiken, H., Herzenberg, S., and Kuhn, S. (1986) The Work Process under More Flexible Production. *Industrial Relations* 25 (2): 167-83.

Shields, R. (2013) *Spatial Questions: Cultural Topologies and Social Spatialisation*. SAGE.

Shrestha, A., Zhu, Y., and Miller, B. (2013) Visualizing time and geography of open source software with storygraph. IEEE Working Conference on Software Visualization (VISSOFT).

Sidel, R., Berman, D., and Kelly, K. (2008, March 17) J.P. Morgan buys Bear in fire sale, as Fed widens credit to avert crisis, *Wall Street Journal* <http://www.wsj.com/articles/SB120569598608739825>

Shieber, J. (2014, March 12) Goldman Sachs: Bitcoin is not a currency. *TechCrunch* <https://techcrunch.com/2014/03/12/goldman-sachs-bitcoin-is-not-a-currency/>

Siegel, D. (2016, June 25) Understanding the DAO attack. *CoinDesk* <http://www.coindesk.com/understanding-dao-hack-journalists/>

Simmel, G. (1900) *The Philosophy of Money*. Verlag von Duncker & Humblot.

Simmonds, F. (2008) Primark – on the rack. BBC.

Simone, A. (2006) Intersecting Geographies? ICTS and Other Virtualities in Urban Africa. In Downey, G., and Fisher, M. (eds) *Frontiers of Capital: Ethnographic Reflections on the New Economy*. Duke University Press.

Simpson, R. (2016) *Crypto Wars: 2000 Years of Cipher Evolution*. CreateSpace Independent Publishing Platform.

Sindreu, J. (2016, July 19) The Central Bankers' bold new idea: Print Bitcoins. *Wall Street Journal* <https://www.wsj.com/articles/the-central-bankers-bold-new-idea-print-bitcoins-1468936751>

Singh, S. (1999) *The Code Book: The Secret History of Codes and Code-Breaking*. Fourth Estate.

Sisney, J., and Garosi, J. (2014) California is the world's eighth largest economy. Legislative Analyst's Office, California Economy and Taxes <http://www.lao.ca.gov/LAOEconTax/Article/Detail/1>

Sisney, J., Garosi, J. (2015) 2014 GDP: California ranks 7th or 8th in the world. Legislative Analyst's Office, California Economy and Taxes <http://www.lao.ca.gov/LAOEconTax/Article/Detail/90>

Skuchain (2015, May 1) Thingchain, Bitcoin & the blockchain. Thingchain Blog <http://blog.thingchain.com/2015/05/01/thingchain-bitcoin-blockchain/>

Slashdot (2016, May 29) Researchers criticize new DAO Ethereum VC fund <https://news.slashdot.org/story/16/05/30/003202/researchers-criticize-new-dao-ethereum-vc-fund>

Slavin, K. (2011) How algorithms shape our world. TED Talks <https://www.ted.com/talks/kevin_slavin_how_algorithms_shape_our_world#t-282571>

Smart, E. (2015, May 27) Top 10 countries in which Bitcoin is banned. *CryptocoinNews* <https://www.cryptocoinsnews.com/top-10-countries-bitcoin-banned/>

Smith, A. (1759) *The Theory of Moral Sentiments*. A. Millar.

Smith, A. (1776) *An Inquiry into the Nature and Causes of the Wealth of Nations*. William Strahan & Thomas Cadell.

Smith, B. (1985) *Decentralization: The Territorial Dimension of the State*. George Allen & Unwin Ltd.

Smith, J. (2017, August 11) The Bitcoin Cash hard fork will show us which coin is best. *Fortune* <http://fortune.com/2017/08/11/bitcoin-cash-hard-fork-price-date-why/>

Smith, P. (2015) Blockchain. *WIRED MONEY* <https://www.youtube.com/watch?v=3ehQY6M4X5M>

Smith, T. (2004) Electricity theft—comparative analysis. *Energy Policy* 32 (18): 2067–2076.

Smith, V. (1936) *The Rationale of Central Banking*. P. S. King & Son Ltd.

Snyder, R. (2008) *Fugitive Denim: A Moving Story of People and Pants in the Borderless World of Global Trade*. Norton & Co.

Soble, J. (2015, April 1) Mark Karpeles, Chief of bankrupt Bitcoin exchange, is arrested in Tokyo. *New York Times* <https://www.nytimes.com/2015/08/02/business/dealbook/mark-karpeles-mt-gox-bitcoin-arrested.html>

Sokol, M. (2011) *Economic Geographies of Globalisation: A Short Introduction*. Edward Elgar.

Solnit, R. (2014a, February 20) Diary. *London Review of Books* 36 (4): 34-35 <http://www.lrb.co.uk/v36/n04/rebecca-solnit/diary>

Solnit, R. (2014b, January 7) Rebecca Solnit: Resisting monoculture. *Guernica* <https://www.guernicamag.com/rebecca-solnit-resisting-monoculture/>

Solnit, R. (2016a, May 3) Gentrification's toll: 'It's you or the bottom line and sorry, it's not you'. *The Guardian* <https://www.theguardian.com/cities/2016/may/03/gentrification-climate-change-sierra-club-san-francisco>

Solnit, R. (2016b, March 22) Death by Gentrification: the killing that shamed San Francisco. *The Guardian* <https://www.theguardian.com/us-news/2016/mar/21/death-by-gentrification-the-killing-that-shamed-san-francisco>

Sorkin, A. (2008, September 14) Bank of America in talks to acquire Merrill Lynch. *New York Times* <http://dealbook.nytimes.com/2008/09/14/bank-of-america-in-talks-to-buy-merrill-lynch/>

Sorkins, A. (2009) *Too Big to Fail*. Viking Press.

Sotarauta, M., and Spinivas, S. (2005) The co-evolution of policy and economic development: A discussion on innovative regions. Massachusetts Institute of Technology, Industrial Performance Center, Special Working Paper Series on Local Innovation Systems.

Southurst, J. (2014a, January 3) Alpha Technology takes pre-orders for Litecoin ASIC miners. *CoinDesk* <http://www.coindesk.com/alpha-technology-pre-orders-litecoin-asic-miners/>

Southurst, J. (2014b, December 1) Bitcoin startup CoinJar cites tax as influence on UK relocation. *CoinDesk* <https://www.coindesk.com/bitcoin-startup-coinjar-cites-tax-influence-uk-relocation/>

Sparkes, M. (2015, March 5) US auctions 50,000 Bitcoins seized from Silk Road. *The Telegraph* <http://www.telegraph.co.uk/technology/news/11451379/US-auctions-50000-Bitcoins-seized-from-Silk-Road.html>

Spaven, E. (2015, March 30) Bitcoin's 'first felon' Charlie Shrem begins 2-Year sentence. *CoinDesk* <http://www.coindesk.com/bitcoins-first-felon-charlie-shrem-begins-2-year-sentence/>

Spencer, L. (2014, December 1) Australia's CoinJar moves HQ to UK for 'progressive' bitcoin scene. ZDNet <http://www.zdnet.com/article/australias-coinjar-moves-hq-to-uk-for-progressive-bitcoin-scene/>

Srnicek, N. (2017) *Platform Capitalism*. Polity Press.

Stalder, F. (2007) *Open Cultures and The Nature of Networks*. Ram Distribution.

Stallman, R. (1999) The GNU operating system and the Free Software movement. In DiBona, C., Ockman, S., and Stone, M. (eds) *Open Sources: Voices from the Open Source Revolution*. O'Reilly.

Star, S. (1999) The ethnography of infrastructure. *American Behavioural Scientist* 43 (3): 377–91.

Star, S. (2002) Infrastructure and ethnographic practice: Working on the fringes. *Scandinavian Journal of Information Systems* 14 (2).

Starosielski, N. (2015) *The Undersea Network*. Duke University Press.

Steiner, C. (2012) Algorithms are taking over the world. TED Talks <https://www.youtube.com/watch?v=H_aLU-NOdHM>

Steinmetz, G. (1999) *State/Culture: State-Formation after the Cultural Turn*. Cornell University Press.

Bontems, V., Petit, P., and Stiegler, B. (2008) *Economie de l'hypermatériel et psychopouvoir*. Mille et Une Nuits

Stiegler, B. (2016) *Automatic Society: The Future of Work*. John Wiley & Sons.

Stinson, D. (2006) Some observations on the theory of cryptographic hash functions. *Designs, Codes and Cryptography* 38 (2): 259–277.

Storj (2018) Homepage. Storj Labs Inc. <https://storj.io>

Strange, S. (1988) S*tates and markets*. Pinter.

Stuckler, D., Meissner, C., King, L. (2008) Can a bank crisis break your heart?. *Globalization and Health—BioMed Central* 4 (1).

Sturgeon, T. (2000) How Silicon Valley came to be. In Kenney, M. (2000) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press.

Sturgeon, T. (2003) What really goes on in Silicon Valley? Spatial clustering and dispersal in modular networks. MIT Working Paper.

Šurda, P. (2012) Economics of Bitcoin: Is Bitcoin an alternative to fiat currencies and gold?. *WU Vienna University of Economics and Business*. Masters Thesis.

Swan, D. (2014, December 2) Aussie Bitcon start-up CoinJar moves to the UK, *The Australian* <https://www.theaustralian.com.au/business/business-spectator/aussie-bitcoin-startup-coinjar-moves-to-the-uk/news-story/551f384bbeddf09ba7c001435624febe?nk=02413eae5c168d1d5a23f892fe64a232-1519912830>

Swan, M. (2015) *Blockchain: Blueprint for a New Economy*. O'Rielly.

Swanson, T. (2014a) *The Anatomy of a Money-like Informational Commodity: A Study of Bitcoin*. Creative Commons.

Swanson, T. (2014b, November 22) Approximately 70% of all bitcoins have not moved in 6 or more months. *Great Wall of Numbers* <http://www.ofnumbers.com/2014/11/22/approximately-70-of-all-bitcoins-have-not-moved-in-6-or-more-months/>

Swanson, T. (2014c) Great chain of numbers: A guide to smart contracts, smart property, and trustless asset management. Creative Commons.

Swanson, T. (2017a, February 27) A brief history of R3—the Distributed Ledger Group. *Great Wall of Numbers* <http://www.ofnumbers.com/2017/02/27/a-brief-history-of-r3-the-distributed-ledger-group/>

Swanson, T. (2017b, March 14) R3 report on Fedcoin. The R3 Report <http://www.r3cev.com/blog/2017/3/14/b772lwbuk4rkk429h1obxjqbxt3rdc>

Swanson, T. (2017c, February 13) Chainwashing. Great Wall of Numbers <http://www.ofnumbers.com/2017/02/13/chainwashing/>

Swartz, A. (2011) Squaring the triangle: Secure, decentralized, human-readable names. <http://www.aaronsw.com/weblog/squarezooko>

SWIFT (2016) SWIFT on distributed ledger technologies. *Accenture* <http://www.ameda.org.eg/files/SWIFT_DLTs_position_paper_FINAL1804.pdf>

SWIFT (2017, January 12) SWIFT explores blockchain as part of its global payments innovation initiative. SWIFT <https://www.swift.com/news-events/press-releases/swift-explores-blockchain-as-part-of-its-global-payments-innovation-initiative>

Swyngedouw, E. (2007) Impossible 'sustainability' and the postpolitical condition. In Krueger, R., Gibbs, D. (eds) *The Sustainable Development Paradox: Urban Political Economy in the United States and Europe*. The Guilford Press.

Swyngedouw, E. (2009) The antinomies of the postpolitical city: In search of a democratic politics of environmental production. *International Journal of Urban and Regional Research* 33.3: 601-620.

Swyngedouw, E. (2011) Interrogating post-democratization: Reclaiming egalitarian political spaces. *Political Geography* 30: 370-380.

Szabo, N. (2008, December 27) Bit gold. Unenumerated <https://unenumerated.blogspot.co.uk/2005/12/bit-gold.html>

Taffel, S. (2012) Escaping attention: Digital media hardware, materiality and ecological cost. *Culture Machine* 13 1-28.

Taffel, S. (2015a) We have never been open: Activism and cryptography in surveillance societies. *MediaNZ: Media Studies Journal of Aotearoa New Zealand* 14 (2): 52-72.

Taffel, S. (2015b) Archeologies of electronic waste. *Journal of Contemporary Archeology* 2 (1): 78-85.

Taffel, S. (2015c) Perspectives on the postdigital: Beyond rhetorics of progress and novelty. *Convergence: The International Journal of Research into New Media Technologies* 22 (3): 324–338.

Taffel, S. (2016) Invisible bodies and forgotten spaces: Materiality, toxicity, and labour in digital ecologies. In Randell-Moon, H., and Tippet, R. (eds) *Security, Race, Biopower: Essays on Technology and Corporeality*. Palgrave Macmillan.

Taibbi, M. (2010) The great American bubble machine. *Rolling Stone* <https://www.rollingstone.com/politics/news/the-great-american-bubble-machine-20100405>

Takhteyev, Y. (2012) *Coding Places: Software Practice in a South American City*. MIT Press.

Takhteyev, Y., and Hills, A. (2010) Investigation the geography of open source software through GitHub. University of Toronto <http://takhteyev.org/papers/Takhteyev-Hilts-2010.pdf>

Tam, P,, Worthen, B., and Guth, R. (2008, October 10) Silicon Valley finds it isn't immune from credit crisis. *Wall Street Journal* <http://www.wsj.com/articles/SB122359422742921079>

Tapscott, D. (2015, March 12) What's the next-generation Internet? Surprise: It's all about the blockchain!. *The Huffington Post* <http://www.huffingtonpost.com/don-tapscott/whats-the-nextgeneration-_b_6859156.html>

Tapscott, D. (2016) How the blockchain is changing money and business. TED Talks <https://www.ted.com/talks/don_tapscott_how_the_blockchain_is_changing_money_and_business>

Tapscott, D., and Tapscott, A. (2016) *Blockchain Revolution: How the Technology Behind Bitcoin and Cryptocurrency Is Changing the Money, Business and the World*. Portfolio Penguin.

Taylor, T. (1983) High-technology industry and the development of science parks. *Built Environment* 9 (1): 72-78.

Taylor, T. (2002) Living digitally: Embodiment in virtual worlds. In Schroeder, R (ed.) *The Social Life of Avatars: Presence and Interaction in Shared Virtual Environments*. Springer-Verlag.

Taylor, E. (2014) Mobile money and the 'social good' of global financialization. MoneyLab Conference, Amsterdam <http://vimeo.com/90208804>

Taylor, E. (2015) Mobile money: Financial globalization, alternative, or both. In Lovink, G., Tkacz, N., and De Vries, P. (2015) *MoneyLab Reader: An Intervention in Digital Economy*. Institute for Network Cultures.

Taylor, M. (2013) Bitcoin and the age of bespoke silicon. International Conference on Compilers, Architecture and Synthesis for Embedded Systems.

Taylor, M. (2014) 'Being useful' after the Ivory Tower: combining research and activism with the Brixton Pound. *Area* 46 (3): 305-312.

Taylor, T. (1983) High-technology industry and the development of science parks. *Built Environment* 9 (1): 72-78.

Tendler, S., and May, D. (2007) *The Brotherhood of Eternal Love: From Flower Power to Hippie Mafia—The Story of the LSD Counterculture*. Cyan Books.

Tepper, F. (2016a, August 8) Hacked Bitcoin exchange Bitfinex will reduce balances by 36% to distribute losses amongst all users. *TechCrunch* <https://techcrunch.com/2016/08/08/hacked-bitcoin-exchange-bitfinex-will-reduce-balances-by-36-to-distribute-losses-amongst-all-users/>

Tepper, F. (2016b, June 7) How a 30K-member Facebook group filled the void left by Uber and Lyft in Austin. *TechCrunch* <https://techcrunch.com/2016/06/07/how-a-30k-member-facebook-group-filled-the-void-left-by-uber-and-lyft-in-austin/>

Terlouw, K. (2001) Regions in geography and the regional geography of semiperipheral development. *Journal of Economic and Social Geography* 92 (1): 76-87.

Terranova, T. (2004) *Network Culture: Politics for the Information Age*. Pluto Press.

Terranova, T. (2006) Of sense and sensibility: Immaterial labour in open systems. In Krysa, J. (ed) *Curating Immateriality: The Work of the Curator in the Age of Network Systems*. Autonomedia.

Terranova, T. (2014) Red stack attack! Algorithms, capital and the automation of the common. *Quarderni di San Precario* <http://effimera.org/red-stack-attack-algorithms-capital-and-the-automation-of-the-common-di-tiziana-terranova/>

Tett, G. (2018, February 9) When algorithms reinforce inequality. *Financial Times* <https://www.ft.com/content/fb583548-0b93-11e8-839d-41ca06376bf2>

The Department of the Treasury (2012) The financial crisis response in charts. The Department of the Treasury.

The Economist (2001, March 21) The dotcom wreckage <http://www.economist.com/node/540488>

The Economist (2013) Goldman versus Google: A career on Wall Street or in Silicon Valley?. YouTube <https://www.youtube.com/watch?v=O6ecPxD_tV0>

The Economist (2015, October 31) The trust machine <http://www.economist.com/news/leaders/21677198-technology-behind-bitcoin-could-transform-how-economy-works-trust-machine>

The Economist (2016, May 2) Craig Steven Wright claims to be Satoshi Nakamoto. Is he? <http://www.economist.com/news/briefings/21698061-craig-steven-wright-claims-be-satoshi-nakamoto-bitcoin>

The Wall Street Journal (2013) The Silicon Valley vs. Wall Street talent war. YouTube <https://www.youtube.com/watch?v=hVFKxHFmy5s>

thehighfiveghost (2016) Critical update RE: DAO Vulnerability. Reddit <https://www.reddit.com/r/ethereum/comments/4oiqj7/critical_update_re_dao_vulnerability/>

Thacker, E. (2004) Foreward: Protocol as protocol does. In Galloway, A. (2004) Protocol: How Control Exists After Decentralization. MIT Press.

Thiel, P. (2009, April 13) The education of a libertarian. *Cato Unbound: A Journal of Debate* <https://www.cato-unbound.org/2009/04/13/peter-thiel/education-libertarian>

Thomas, K. (2010) Could the Wikileaks scandal lead to new virtual currency?. *PC World* <https://www.pcworld.com/article/213230/could_wikileaks_scandal_lead_to_new_virtual_currency.html>

Thornton, H. (1802) *An Enquiry into the Nature and Effects of the Paper Credit of Great Britain*. Hatchard.

Thrift, N. (1994) On the social and cultural determinants of international financial centres: the case of the City of London. In Corbridge, S., Thrift, N., and Martin, R., (eds) *Money, Power and Space*. Blackwell.

Thrift, N. (1996) *Spatial Formations*. Sage.

Thrift, N. (2000) Performing cultures in the new economy. *Annals, Association of American Geographers* 90: 674-692.

Thrift, N. (2004) Movement-space: The changing domain of thinking resulting from the development of new kinds of spatial awareness. *Economy & Society* 33 (4): 582-604.

Thrift, N. (2008) *Non-Representational Theory: Space, Politics, Affect*. Routledge.

Thrift, N., and French, S. (2002) The automatic production of space. *Transactions of the British Institute of Geographers* 27 (3): 309-335.

Thung, F., Bissyande, T., Lo. D., and Jiang, L. (2013) Network structure of social coding in GitHub. European Conference on Software Maintenance and Reengineering 323-326.

Timberlake, R. (1978) *The Origins of Central Banking in the United States*. Harvard University Press.

Timberlake, R. (1984) The Central Banking Role of Clearinghouse Associations. *Journal of Money, Credit, and Banking* 16 (1): 1-15.

Tkacz, N. (2015) *Wikipedia and the Politics of Openness*. The University of Chicago Press.

Toffler, A. (1970) *Future Shock*. Random House.

Toffler, A. (1981) *The Third Wave*. Morrow.

Torpey, K. (2016, March 4) Four key disagreements between Bitcoin Classic and Bitcoin Core. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/four-key-disagreements-between-bitcoin-classic-and-bitcoin-core-four-key-disagreements-between-bitcoin-classic-and-bitcoin-core-four-key-disagreements-between-bitcoin-classic-and-bitcoin-core-1457106744/>

Tschorsch, F., and Scheuermann, B. (2016) Bitcoin and beyond: A technical survey on decentralized digital currencies. *IEEE Communications & Tutorials* 18 (3) 2084-2123.

Tsing, A. (2004) Inside the economy of appearances. In Amin, A., and Thrift, N. (eds) *Cultural Economy Reader*. Blackwell.

Tsing, A. (2005) *Friction: An Ethnography of Global Connection*. Princeton University Press.

Tucker, P. (2014) Regulatory reform, stability and Central Banking. Hutchings Center on Fiscal & Monetary Policy, Brookings Institution.

Turner, F. (2006) *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism*. University of Chicago Press.

Tuwiner, J. (2017, June 13) Bitcoin mining in China. Buy Bitcoin Worldwide <https://www.buybitcoinworldwide.com/mining/china/>

Ullman, E. (2012) *Close to the Machine: Technophilia and its Discontents*. Pushkin Press.

Underhill, G. (1991) Markets beyond politics? The state and the internationalization of financial markets. *European Journal of Political Research* 19: 197-225.

Urry, J. (2007) *Mobilities*. Polity Press.

van der Laan, W. (2015, May 7) Re: [Bitcoin-development] block size increase. bitcoin-dev-request@lists.linuxfoundation.org <https://www.mail-archive.com/bitcoin-development@lists.sourceforge.net/msg07472.html>

van Hout, M., and Bingham, T. (2014) Responsible vendors, intelligent consumers: Silk Road, the online revolution in drug trading. *International Journal of Drug Policy* 25 (2) 183-189.

van Houtum, H., Kramsch, O., and Zierhofer, W. (2005) *B/ordering Space*. Ashgate.

van Houtum, H., Van Naerssen, T. (2001) Bordering, ordering and othering. *Journal of Economic and Social Geography* 93 (2): 125-136.

van Valkenburgh, P. (2017) What is 'open source' and why is it important for cryptocurrency and open blockchain projects? Coin Center <https://coincenter.org/entry/what-is-open-source-and-why-is-it-important-for-cryptocurrency-and-open-blockchain-projects>

van Wirdrum, A. (2014, March 18) Why Bitcoin really does represent the democratization of money. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/bitcoin-really-represent-democratization-money-1395137137/>

van Wirdum, A. (2015, June 5) Chinese exchanges reject Gavin Andresen's 20 MB block size increase. *The Cointelegraph* <https://cointelegraph.com/news/chinese-exchanges-reject-gavin-andresens-20-mb-block-size-increase>

van Wirdum, A. (2016, April 6) Who funds Bitcoin Core development? How the industry supports Bitcoin's 'reference client'. *Bitcoin Magazine* https://bitcoinmagazine.com/articles/who-funds-bitcoin-core-development-how-the-industry-supports-bitcoin-s-reference-client-1459967859/>

van Wirdrum, A. (2017, July 27) The future of 'Bitcoin Cash:' An interview with Bitcoin ABC lead developer Amaury Sechét. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/future-bitcoin-cash-interview-bitcoin-abc-lead-developer-amaury-séchet/>

Vanity Fair (2011, September 1) The 2011 new establishment list: And the top spot goes to… *Vanity Fair* <https://www.vanityfair.com/news/2011/09/the-2011-new-establishment-list--and-the-top-spot-goes-to--->

Vannini, P. (2012) *Non-representational Theory and Ethnographic Research*. Routledge.

Varian, H. (2004, January 15) Why is that dollar bill in your pocket worth anything?. *New York Times* <http://people.ischool.berkeley.edu/~hal/people/hal/NYTimes/2004-01-15.html>

Vasilescu, B., Filkov, and V., Serebrenik, A. (2013) StackOverflow and GitHub: Associations Between Software Development and Crowdsourced Knowledge. Conference on Social Computing 188-195.

Velasco, P. (2016) Sketching Bitcoin: Empirical research of digital affordances. In Kubitschko, S., and Kaun, A. (eds) *Innovative Methods in Media and Communication Research*. Springer.

Vermeulen, J. (2017, April 22) Bitcoin and Ethereum vs Visa and Paypal—Transactions per second. Mybroadband <https://mybroadband.co.za/news/banking/206742-bitcoin-and-ethereum-vs-visa-and-paypal-transactions-per-second.html>

Vian, K., and Michalski, J. (2011) Banking Deconstructed. Institute for the Future.

Vigna, P. (2015, September 15) BitBeat: Wall Street, City banks join blockchain-focused consortium. *Wall Street Journal* <http://blogs.wsj.com/moneybeat/2015/09/15/bitbeat-wall-street-city-banks-join-blockchain-focused-consortium/>

Vigna, P., and Casey, M. (2015) *The Age of Cryptocurrency: How Bitcoin and Digital Money Are Challenging the Global Economic Order*. St. Martins Press.

Vincent, D. (2016, May 4) We looked inside a secret Chinese bitcoin mine. *BBC* <http://www.bbc.com/future/story/20160504-we-looked-inside-a-secret-chinese-bitcoin-mine>

VLAB (2015) Fintech: Silicon Valley takes on Wall Street. YouTube <https://www.youtube.com/watch?v=1XWdaHzKAgk>

Volpicelli, G. (2017, October 6) This ICO for an AI blockchain is the most tech-hype idea of the year. *Wired* <http://www.wired.co.uk/article/singularitynet-is-an-ico-for-artificial-intelligence>

von Schnitzler, A. (2008) Citizenship prepaid: Water, calculability, and techno-politics in South Africa. *Journal of Southern African Studies* 34 (4) 899-917.

Voorhees, E. (2015, January 22) Is Bitcoin truly decentralized? Yes – and here is why it's important. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/bitcoin-truly-decentralized-yes-important-1421967133/>

Waldman, S. (2015, April 2) Soylent blockchains. Interfluidity <http://www.interfluidity.com/uploads/2015/04/soylent-blockchains-ethsv.pdf>

Waldrip-Fruin, N. (2009) *Expressive Processing: Digital Fictions, Computer Games, and Software Studies*. MIT Press.

Walker, H., and Wile, R. (2014, April 1) What did this Swiss software developer have to do with the launch of Bitcoin? *Business Insider* <http://www.businessinsider.com/swiss-software-developer-bitcoin-2014-4?IR=T>

Walker, J. (2012) *Ayn Rand Cult*. Open Court.

Walker, R. (1993) *Inside/Outside. International Relations as Political Theory*. Cambridge University Press.

Wallerstein, I. (2013) Structural crisis, or why capitalists may no longer find capitalism rewarding. In Wallerstein, I., Collins, R., Mann, M., Drerluguian, G., and Calhoun, C. (2013) *Does Capitalism Have a Future?*. Oxford University Press.

Wallerstein, I., Collins, R., Mann, M., Derluguian, G., and Calhoun, C. (2013) *Does Capitalism Have a Future?*. Oxford University Press.

Walters, W. (2006) Rethinking Borders Beyond the State. *Comparative European Politics* 4 (2): 141-159.

Warburg, P. (1930) *The Federal Reserve System: Origins and Growth (Volume 1)*. The MacMillan Company.

Wardrip-Fruin, N. (2009) *Expressive Processing: Digital Fictions, Computer Games, and Software Studies*. MIT Press.

Warschauer, M. (2004) *Technology and Social Inclusion: Rethinking the Digital Divide*. The MIT Press.

Waters, R. (2016, May 17) Automated company raises equivalent of $120M in digital currency. *The Financial Times* <https://www.ft.com/content/600e137a-1ba6-11e6-b286-cddde55ca122>

Watson, S. (1995) *The Birth of the Beat Generation: Visionaries, Rebels and Hipsters 1944-1960*. Pantheon Books.

Weatherford, J. (1997) *The History of Money*. Crown Publications.

Weber, B. (2014) Bitcoin and the legitimacy crisis of money. *Cambridge Journal of Economics* 40 (1) 17-41.

Weber, W. (2016) A Bitcoin standard: Lessons from the gold standard. Bank of Canada <http://www.bankofcanada.ca/wp-content/uploads/2016/03/swp2016-14.pdf>

Weiss, G. (2012) *Ayn Rand Nation: The Hidden Struggle for America's Soul*. St. Martin's Press.

Wenger, E. (1998) *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press.

Wenger, E., McDermott, R., and Snyder, W. (2002) *Cultivating Communities of Practice: A Guide to Managing Knowledge*. Harvard Business School Press.

Wenger, E., White, N., and Smith, J. (2009) *Digital habitats: Stewarding technology for communities*. CPsquare

Werthmann, K. (2003) Cowries, gold and 'bitter money' gold-mining and notions of ill-gotten wealth in Burkina Faso. *Paideuma: Mitteilungen zur Kulturkunde* 49: 105-124.

Whatmore, S. (2000) Heterogeneous geographies: reimagining the spaces of N/nature. In Cook, I., Crouch, D., Naylor, S., and Ryan, J. (eds) *Cultural Turns/Geographical Turns: Perspectives on Cultural Geography*. Routledge.

Whatmore, S. (2002) *Hybrid Geographies: Natures Cultures Spaces*. Sage.

Whatmore, S. (2006) Materialist returns: Practising cultural geography in and for a more-than-human world. *Cultural Geographies* 13 (4): 600-609.

White, I. (2017) Blockchain and the material foundations for socialism. From here to there <https://ianwrightsite.wordpress.com/2017/01/02/blockchain-and-the-material-foundations-for-socialist-institutions/>

White, L. (1984) *Free Banking in Britain: Theory, Experience and Debate, 1800*-1845. Cambridge: University Press.

White, L. (1992) Free banking in Scotland before 1844. In Dowd, K. (ed.) *The Experience of Free Banking*. Routledge.

White, L. (1995) Free Banking in Britain: Theory, Experience and Debate 1800-1845. Institute of Economic Affairs.

Whitehead, A. (1920) *The Concept of Nature*. Cambridge University Press.

Whitley, R. (1999) *Divergent Capitalism: The Social Structuring and Change of Business Systems*. Oxford University Press.

Whittle, A., and Spicer, A. (2008) Is actor network theory critique? *Organization Studies* 29 (4): 611-629.

Wikipedia (2018) Bitcoin. <https://en.wikipedia.org/wiki/Bitcoin>

Wilcox-O'Hearn, Z. (2001) Names: decentralized, secure, human-meaningful: choose two <https://web.archive.org/web/20011020191610/http://zooko.com/distnames.html>

Wilhelm, A. (2014, July 16) Popular Bitcoin mining pool promises to restrict its compute power to prevent feared '51%' fiasco. *TechCrunch* <https://techcrunch.com/2014/07/16/popular-bitcoin-mining-pool-promises-to-restrict-its-compute-power-to-prevent-feared-51-fiasco/>

Wilkinson, S., Boshevski, T., Prestwich, J., Hall, G., Gerbes, P., Hutchins, P., Pollard, C., and Buterin, V. (2016) Storj: A peer-to-peer cloud storage network <https://bravenewcoin.com/assets/Whitepapers/storj.pdf>

Williams, C. (2013, September 21) The money never stopped flowing in Silicon Valley. *The Telegraph* <http://www.telegraph.co.uk/finance/newsbysector/mediatechnologyandtelecoms/digital-media/10324092/The-money-never-stopped-flowing-in-Silicon-Valley.html>

Williams, R. (2014, July 7) What's the PayPal Mafia up to next?. *Wall Street Daily* <https://www.wallstreetdaily.com/2014/07/07/paypal-founders/>

Williams-Grut, O. (2015, September 16) The CBA has joined eight other massive banks to take the technology behind bitcoin mainstream. *Business Insider: Australia* <https://www.businessinsider.com.au/jpmorgan-barclays-and-others-join-r3-on-blockchain-project-2015-9?r=UK&IR=T>

Wilson, D. (2014, August 21) Why electronic banking transactions can take so much time. *Sydney Morning Herald* <http://www.smh.com.au/money/planning/why-electronic-banking-transactions-can-take-so-much-time-20140821-106v32.html>

Wilson, S. (2016, May 6) Blockchain: Almost everything you hear is wrong. CIO <http://www.cio.co.nz/article/599399/blockchain-almost-everything-read-wrong/>

Winner, L. (1993) Upon opening the black box and finding it empty: social constructivism and the philosophy of technology. *Science, Technology and Human Values* 18: 362-378.

Winner, L. (1997) Cyberlibertarian myths and the prospects for community. *ACM SIGCAS Computers and Society* 27 (3): 14-19.

Wistrom, B. (2017, August 17) Scrutinized by governments, Austin's Arcade City expands Uber alternative ride-hailing model. *Austin Inno* <https://www.americaninno.com/austin/scrutinized-by-governments-austins-arcade-city-expands-uber-alternative-ride-hailing-model/>

Wolff, J. (2013) *Western Union and the Creation of the American Corporate Order, 1945-1893.* Cambridge University Press.

Wolfsfeld, G., Segev, E., and Shaefer, T. (2013) Social media and the Arab Spring. *The International Journal of Press/Politics* 18 (2): 115-137.

Wong, J. (2014) Bitcoin VC investment this year already 30% higher than 2013's total. *CoinDesk* <https://www.coindesk.com/years-vc-funding-bitcoin-startups-already-beaten-last-years/>

Wong, J. (2015, April 8) Brock Pierce: Bitcoin Foundation 'Close To Running Out of Money'. *CoinDesk* <https://www.coindesk.com/bitcoin-foundation-running-out-of-funds/>

Wong, J. (2017a, December 17) Bitcoin's mysterious inventor is now one of the world's 50 richest people. *Quartz* <https://qz.com/1159188/bitcoin-price-approaches-20000-making-satoshi-nakamoto-worth-19-4-billion/>

Wong, J. (2017b, July 28) There's a strange new twist in bitcoin's 'civil war'—and a way to be on the outcome. *Quartz* https://qz.com/1037971/bitcoin-cash-is-a-new-twist-in-the-hard-fork-debate-and-a-way-to-bet-on-the-outcome-of-the-cryptocurrencys-civil-war/>

Wood, P. (1997) *Maps of World Financial Law*. Allen and Overy.

Woodward, D., Figueiredo, O., and Guimarães, P. (2006) Beyond the Silicon Valley: University R&D and high-technology location. *Journal of Urban Economics* 60: 15-32

Woolf, N. (2016, June 9) With no Uber or Lyft, a Texas city is crowdsourcing rides on Facebook. *The Guardian* <https://www.theguardian.com/technology/2016/jun/09/uber-lyft-austin-texas-facebook-rideshare-program>

World Bank (2004) *Decentralization in Madagascar*. World Bank Publications

World Bank (2009) *Decentralization, Democracy, and Development: Recent Experience from Sierra Leone.* World Bank Publications

World Bank (2012, April 19) Who are the Unbanked? <http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTFINANCIALSECTOR/0,,contentMDK:23174014~pagePK:210058~piPK:210062~theSitePK :282885,00.html >

World Bank (2013) What is Decentralization?. *Earth Institute: Columbia University* <http://www.ciesin.org/decentralization/English/General/Different_forms.html>

Worner, D., von Bomhard, T., Schreier, Y., and Bilgeri, D. (2016) The Bitcoin ecosystem: Disruption beyond financial services?. *Twenty-Fourth European Conference on Information Systems (ECIS), Istanbul, Turkey*

Wriston, W. (1992) *The Twilight of Sovereignty: How the Information Revolution is Transforming Our* World. Charles Scribner's Sons

Wylie, J. (2007) *Landscape*. Routledge

Wylie, J. (2010) Non-representational subjects?. In Anderson, B., and Harrison, P. (2010) *Taking Place: Non-Representational Theories and Geography*. Routledge

Xingzhe, L. (2017, June 21) Inside the World of Chinese Bitcoin 'Mining'. *ChinaFile* <http://www.chinafile.com/multimedia/photo-gallery/inside-world-of-chinese-bitcoin-mining>

Yates, T. (2017, June 7) The consequences of allowing a cryptocurrency takeover, or trying to head one off. *Financial Times* <https://ftalphaville.ft.com/2017/06/07/2189849/guest-post-the-consequences-of-allowing-a-cryptocurrency-takeover-or-trying-to-head-one-off/>

Yee, H. (2014) Internet architecture and the layers principle: a conceptual framework for regulating Bitcoin. *Internet Policy Review: Journal on Internet Regulation* 3 (3)

Yeoman, K. (2014) M-Pesa helps world's poorest go to the bank using mobile phones. *The Christian Science Monitor* <http://www.csmonitor.com/World/Making-a-difference/Change-Agent/2014/0106/M-Pesa-helps-world-s-poorest-go-to-the-bank-using-mobile-phones>

Yermack, D. (2013) Is Bitcoin a real currency?. *National Bureau of Economic Research*

Yoon, A. (2015, October 1) Total global losses from financial crisis: $15 Trillion. *Wall Street Journal* <http://blogs.wsj.com/economics/2012/10/01/total-global-losses-from-financial-crisis-15-trillion/>

Young, J. (2015a, August 30) BitPay: 'Silicon Valley is Becoming a Bitcoin Hub'. *The CoinTelegraph* <https://cointelegraph.com/news/bitpay-silicon-valley-is-becoming-a-bitcoin-hub>

Young, J. (2015b, August 10) Kraken joins exchanges refusing to apply for a BitLicense, suspends service in New York. *Bitcoin Magazine* <https://bitcoinmagazine.com/articles/kraken-joins-exchanges-refusing-apply-bitlicense-suspends-service-new-york-1439245937/>

Young, J. (2015c, August 9) BitFinex exits New York due to BitLicense. *The CoinTelegraph* <https://cointelegraph.com/news/bitfinex-exits-new-york-due-to-bitlicense>

Zaloom, C. (2006) *Out of the Pits: Traders and Technology from Chicago to London*. University of Chicago Press.

Zelizer, V. (1989) The Social Meaning of Money: 'Special Monies'. *American Journal of Sociology* 95 (2): 342-377.

Zerlan, J. (2014) Bitcoin as the ultimate democratic tool. *WIRED* <https://www.wired.com/insights/2014/04/bitcoin-ultimate-democratic-tool/>

Zhang, J. (2003) *High-Tech Start-Ups and and Industry Dynamics in Silicon Valley*. Public Policy Institute of California.

Zhang, L. (2006) Behind the 'Great Firewall': Decoding China's Internet media policies from the inside. *Convergence: The International Journal of Research into New Media Technologies* 12 (3): 271-291

Zimmermann, P. (1995) *The Official PGP User's Guide*. MIT Press.

Žižek, S. (1999) *The Ticklish Subject: The Absent Centre of Political Ontology*. Verso.

Zook, M. (2002). Grounded capital: Venture financing and the geography of the Internet industry, 1994-2000. *Journal of Economic Geography* 2: 151-177.

Zook, M. (2005) *The Geography of the Internet Industry: Venture Capital, Dot-Coms, and Local Knowledge*. Blackwell.

Zook, M. (2012) Code/Space: Software and Everyday Life. *Regional Studies* 46 (8): 1105-1106.