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New spaces of disruption? The failures of Bitcoin and the rhetorical power of algorithmic governance

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ABSTRACT

In less than a decade Bitcoin and the technology of blockchain – a cryptographically-secured, algorithmically-regulated, distributed-ledger – emerged as the *enfant terrible* of the global economy. Ironically, as crypto-currencies reached collective valuations of hundreds of billions of dollars the Bitcoin project failed in its original purpose as an alternative currency governed by code rather than trust. Not only has Bitcoin not become a popular means of global peer-to-peer transactions but the much vaulted purity of algorithmic governance is heavily entangled in social relations. This article reviews blockchain's computer architectures, its connections to materiality and space and the complexity of its established practices. This analysis shows that rather than occupying an algorithmic place apart, blockchain contains multiple and conflicting agencies and is messily embedded in the code/space of materiality. Nevertheless the faith in the superiority of algorithmic governance has injected a powerful discourse in economies that has proven more important and disruptive than the actual practices of Bitcoin or blockchain.

1. The *enfant terrible* of the global economy

In 2010, a Florida-based programmer named Laszlo Hanyecz paid for two pizzas with 10,000 Bitcoins (Bort, 2014), which would be valued at close to $118 million dollars by late 2017. At the time, few expected this blockchain-based alternative currency to gain significant traction. In less than a decade, however, the technology of blockchain – a system of cryptographically-secured, algorithmically-regulated, store-of-value on a distributed-ledger – emerged as the *enfant terrible* of the global economy. As cryptocurrencies reached collective valuations of hundreds of billions of dollars, industries, central banks and governments scrambled to implement their own versions of the technology while entrepreneurs and developers received enormous capital investments to develop the *killer app* for blockchain.

Ironically, all of this frenzied activity runs counter to the original intent of Bitcoin. Envisioned as a "purely peer-to-peer version of electronic cash", Bitcoin was designed to "allow online payments" between individuals in a way that explicitly avoided the need to go "through a financial institution." (Nakamoto, 2008a, 2008b). Bitcoin was a utopian project and like earlier alternative currencies was designed to bypass distrusted, centralized institutions for the benefit of its network of participants. The rhetoric of Bitcoin, however, differed in two fundamental ways from earlier systems. First, rather than relying on social norms of trust found within communities, Bitcoin promoted "an electronic payment system based on cryptographic proof" (Nakamoto, 2008a, 2008b), essentially an algorithmic intermediation for a hitherto socially embedded function. Second, in contrast to earlier systems of alternative currencies that function at the local scale or within solidarity networks (North, 2005), Bitcoin was designed as a global means of exchange from its inception.

Notwithstanding the surrounding hype and meteoric valuations, in many ways Bitcoin can be judged a failure. The much-vaulted purity of algorithmic governance in creating cryptographic trust is heavily entangled in social relations (De Filippi and Loveluck, 2016; Dodd, 2018). Moreover, cryptocurrencies have not emerged as a popular means of global peer-to-peer transactions, ironically relying on state-backed currencies for value, rather than functioning as a unit of exchange. Despite these demonstrable shortcomings, Nakamoto's vision for pure algorithmic governance has remarkable endurance, turning what is essentially a database for shared, distributed record keeping into the potential disruptor of the technology and finance industries.

To better understand how the rhetoric of blockchain-based algorithmic governance has been designed and actualized, this article reviews the basic parameters of its computer architectures, its connections to materiality and space and the complexity of its established practices. In so doing we demonstrate that rather than occupying an

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algorithmical place apart, blockchain is best understood as an assemblage with multiple agencies that are messily embedded in the code/space of materiality. In short, the discourse surrounding Bitcoin and the blockchain systems it has engendered has proven more important and disruptive than the actual practices of these technologies (Cockayne, 2016).

2. Visions of alternative economies

A key part of economic geography scholarship is attending to topics such as local specificity that are often discounted by more neoclassical approaches. A particularly productive example of this approach emerges from Gibson-Graham's (2006, 90) feminist and post-structural call to study alternative economic practices "not subsumed to capital flows" including alternative currencies. While blockchain's current notoriety as a libertarian, tech-bro playground seems antithetical to this call (Bowles, 2018), Bitcoin's original vision shares much with other efforts to build alternative currencies and create "fairer" systems of exchange.[1]

2.1. Challenges of trust and scale

North (2007) outlines a number of alternative currency systems beginning with 19th century utopian socialists such as Robert Owen who founded the National Equitable Labour Exchange in the U.K. with the goal of making time the standard medium of exchange. Other cases emerged from the great depression in the U.S. such as the End Poverty in California (EPIC) movement which sought to support locally based scripts or the Red Global de Trueque that gained mass popularity in Argentina during the financial meltdown at the end of the 20th century (North, 2007). Central to these practices is the creation of a community, often driven by a utopian vision or political agenda, which supports exchange by like-minded individuals outside the purview of national states or banks. This social embedding of alternative currencies is absolutely central to their ability to function and in many ways the encounter and relationship building is more important than the exchange it facilitates. Participants must trust in each other to honor the currency as a valid medium of exchange and believe in the goals of the larger project. This trust and belief profoundly shapes the development and success of an alternative currency. As Dodd (2018, 18) argues "Human, social, and political factors inevitably emerge as those who interact with and use these artifacts both shape and are shaped by their practical use."

Common to most (if not all) alternative currencies is their emergence at moments of failure in capitalist systems, when trust in standard currencies is lost. In these efforts to manage economic downturns, the alternative visions offered by these systems shift performative practices and ontological expectations for exchange (Gibson-Graham, 2008); in short these currencies create a kind of resistance to capitalism (North, 2007). Of special importance is the operational scale of alternative currencies, and the challenge to not "create money out of proportion to or outside of real economic activity" (North, 2007, 178). This is particularly problematic for merchants supplied by vendors outside the alternative currency network, as they are unable to replenish stocks and risk holding a surplus of unused currency. For this reason North (2014) maintains that strategies for alternative currencies must go beyond simply supporting local business to also focus on local production. Moreover, "scaling up" an alternative currency, in terms of moving beyond either an initial locality or community of activists, has proven problematic. For example, the Argentine currency, Red Global de Trueque, encountered issues in its expansion as the trust – built either between neighbors or via a commitment to the goals of solidarity – broke down. As a result, North (2005, 229) argues, "the non-local nature of the Argentine currency networks was also fundamental to its eventual downfall". The vision propelling Bitcoin represents a decidedly different conceptualization of trust and scale.

2.2. Codifying algorithmic governance in Bitcoin

Echoing the history of earlier alternative currencies, Bitcoin emerged during the 2008 global financial crisis with the release of a white paper by the still unidentified Satoshi Nakamoto (Bearman, 2017). Since then over 1500 blockchain-based currencies have achieved a combined market capitalization of close to $US 456 billion (see Fig. 1) making speculative store-of-value a highly visible function. Bitcoin's success in its original purpose as a medium of exchange is much more questionable (Wang, 2014). Moreover, the speculative success of cryptocurrencies – especially well established exchange rates to Dollars or Euros – is also a clear failure to bypass the global financial system. Indeed, the exchanges for cryptocurrencies are highly opaque and centralized institutions themselves with histories of security failures and price manipulation, e.g., the Mt. Gox and Bitfinex hacks (Popper, 2017).

For its first participants, a key appeal of Bitcoin was a belief in the project's goal; namely the creation of a decentralized governance structure where security and validation is architecturally distributed rather than centralized or dependent on institutions or social practices. This is readily found in the rhetoric of developers (first Nakamoto and later others) that prioritize replacing;./. state- and corporate-regulated infrastructures of control with more libertarian ones (Bohr and Bashir, 2014). This began in Nakamoto's (2008a, 2008b, 1) original vision calling for governance structures of "a peer-to-peer distributed timestamp server" which produces "computational proof of the chronological order of transactions", to facilitate exchange without the concerns of intermediaries and government regulations. This algorithmic solution stands in sharp contrast to the relational networks deeply embedded in society common to other alternative currencies (North, 2007).

Nakamoto (2010) was particularly focused on replacing the existing social practices of trust and centralized organization with code. "Proof-of-work has the nice property that it can be relayed through untrusted middlemen. We don't have to worry about a chain of custody of communication. It doesn't matter who tells you a longest chain, the proof-of-work speaks for itself." In this vision, human-based intermediaries such as central bankers were inherently problematic. Not only do bankers impose transaction fees on exchange but they are also explicitly tied to malfeasance at the macro and micro scales. "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." (Nakamoto, 2009). While this wariness of centralized banks echoes the motivations for earlier alternative currencies, the practices of trust proposed by Bitcoin differed sharply.

Unlike most alternative currencies that re-centered trust in a local or like-minded community, Nakamoto's solution was to replicate its function through encryption algorithms and a globally decentralized database. Nakamoto (2009) saw algorithmic governance as key to making Bitcoin work. "A lot of people automatically dismiss e-currency as a lost cause because of all the companies that failed since the 1990's. I hope it's obvious it was only the centrally controlled nature of those systems that doomed them. I think this is the first time we're trying a decentralized, non-trust-based system." Moreover Nakamoto (2008b) explicitly saw Bitcoin as a struggle against state power to "win a major battle in the arms race and gain a new territory of freedom for several

[1] It is important to acknowledge that the blockchain community is an extremely male space, even compared to the bro-culture of high technology more generally (Bowles, 2018). This clearly shapes understandings of "fair" and "liberatory" used in these system (Blankenship, 2017).

Rank	Name	Symbol	Market Cap (Billions of $USD)	Price ($USD)	Circulation Supply (Millions of Coins)
1	Bitcoin	BTC	$153.07	$9,087.68	16.8
2	Ethereum	ETH	$92.02	$944.78	97.4
3	Ripple	XRP	$35.87	$0.92	39,009.2
4	Bitcoin Cash	BCH	$21.28	$1,255.74	16.9
5	Cardano	ADA	$11.62	$0.45	25,927.1
6	Litecoin	LTC	$9.00	$163.37	55.1
7	Stellar	XLM	$8.09	$0.44	18,431.2
8	NEO	NEO	$7.80	$119.95	65.0
9	EOS	EOS	$6.34	$9.81	646.8
10	NEM	XEM	$5.65	$0.63	9,000.0
11	IOTA	MIOTA	$5.52	$1.99	2,779.5
12	Dash	DASH	$4.95	$629.54	7.9
13	Monero	XMR	$3.90	$248.97	15.7
14	TRON	TRX	$2.89	$0.04	65,748.2
15	Lisk	LSK	$2.64	$22.44	117.7
16	VeChain	VEN	$2.49	$5.33	467.1
17	Ethereum Classic	ETC	$2.38	$23.87	99.6
18	Tether	USDT	$2.21	$1.00	2,217.1
19	Qtum	QTUM	$2.18	$29.51	73.9
20	Populous	PPT	$2.12	$57.21	37.0

Fig. 1. List of top 20 Cryptocurrencies, February 2018. (See above-mentioned reference for further information.)
Source: https://coinmarketcap.com/historical/20180204/

years. Governments are good at cutting off the heads of a centrally controlled networks like Napster, but pure P2P networks like Gnutella and Tor seem to be holding their own." Thus, Nakamoto and other early Bitcoin participants codified their vision of encryption and decentralization into the technical specifications of blockchain, which was conceived as a space disconnected from the society from whence it came. It is unsurprising that this naive expectation was soon challenged as blockchain engaged with the actual everyday economic practices of an alternative currency.

3. Assembling the algorithmic governance of blockchain

Within economic geography (and human geography more generally) the past two decades mark increased attention to theories of performativity that analyze economies as dynamic and contingently created processes rather than predetermined. For example, Berndt and Boeckler (2011, 566) argue that approaching economies as "assemblages of heterogeneous elements enables us to unmask the process of marketization as a deeply ambivalent endeavor … never complete and always prone to failure." This formulation emphasizes the complex networks of technologies, algorithms and humans that comprise society and influence its spatial organization (see also Latour, 2005; MacKenzie, 2006; Caliskan and Callon, 2010). Particularly relevant to practices of blockchain is the agency of its algorithms that codify the beliefs of its developers and dynamically affect the function of the system. Accurately representing this kind of software based agency, however, is challenging. Rose (2017) proposes the theoretical concept of posthuman agency as a way of blending the influence of social difference of all types such as human actions, digital mediation and the contingencies that arise from habituated practice. Rose (2017, 789) argues that posthuman agency "is necessarily co-produced with digital technic" and that "Geographers must therefore reconfigure their understanding of digitally mediated cities and acknowledge both the reinventiveness and the diversity of urban posthuman agency."

While lacking space to fully engage with these ideas, it is evident that new types of digital organization are changing agency within economies. Langley and Leyshon (2017) analyze a new practice of economic circulation – dubbed platform capitalism by Lobo (2014) – in which digitally based interactions such as knowledge exchange, use rights and labor all take place within a single, centrally controlled and owned system. A key effect of these platforms – such as Amazon, Apple, or Facebook – is the ability to achieve monopoly rents allowing for new capital practices such as changes in venture investing to better target windfalls. Langley and Leyshon (2017) also note the parallel degradation and precarity of working conditions (Strauss, 2017) supported by discursive tropes, most notably the "sharing economy", to mask the problematic nature of these new relations. As Cockayne (2016, 74) argues, discourse about an economic practice is "not incidental to economic practice, but instead is co-produced alongside it, and essential to capitalism itself … not only an exploitative system but also one that is also affective, in which attachment, intimacy, and identification are endemic to the mode of production." (see also Richardson, 2015). Echoing platform capitalism, we note the fundamental importance of discourse in establishing the new economic practices associated with blockchain.

This discursive point supporting blockchain is centered in the agency assigned to the practice of algorithmic governance (Yeung, 2017; Danaher et al., 2017); namely the ways software regulates the daily lives, experiences and opportunities afforded to individuals within society. Promoted as a way to increase efficiency and reduce bias, algorithmic governance has been strongly critiqued for its reductive tendencies, inaccuracy and opaqueness (see Pasquale, 2015; Leszczynski, 2016; Zarsky, 2016; Crampton and Miller, 2017). Often framed in terms of security, algorithmic governance depends on what Amoore (2011, 28) dubs a "data derivative" that problematically is "not centered on who we are, nor even on what our data says about us, but on what can be imagined and inferred about who we might be – on our very proclivities and potentialities." In critiquing this practice, Amoore is careful not to over-assign power to software actants. Paralleling Rose's (2017) co-produced posthuman agency, Amoore and Raley (2016, 6) argue that assigning "sovereign decision-making and ethical responsibility" only to digital computers or human beings "is to forget

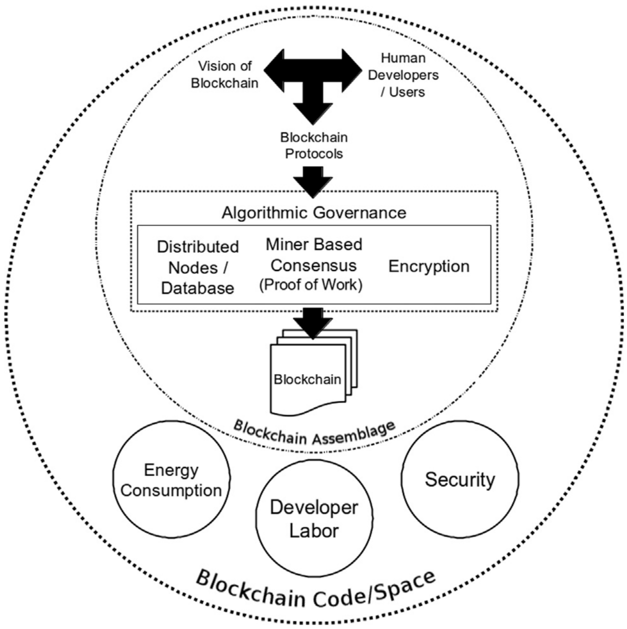

Fig. 2. Schematic of blockchain.

the extent to which algorithms are necessarily instantiated within both." Restated in the context of blockchain and algorithmic governance, we argue that the software systems put in place and the rhetoric deployed to justify and support them represent a similar instantiation, dynamically and continually produced through the blending of machine and human agency (see Fig. 2).

To flesh out this schematic we build upon a qualitative methodology[2] to review the three key technical elements of algorithmic governance: distributed databases for recording interactions, networks of computer nodes and encryption protocols. In addition to outlining the mechanics of operations, we highlight how these technical structures directly reflect the belief in algorithmic governance contained in the original Bitcoin white paper and how these simplistic expectations are confounded by the reality of practice.

3.1. Distributed databases recording "unalterable" entries

The distributed database of blockchain technology is simply a permanent record of all interactions occurring within a network running a particular instantiation of the software, e.g., Bitcoin, Ethereum, etc. This database is the actual blockchain and contains all interactions sequentially stored in sections called blocks. In the initial forms of the technology the interactions were simply records of transactions (e.g., Alice sends Tad one Bitcoin) appended to the end of the blockchain as they occur. The design of blockchain software has evolved as developers sought new functionality such as smart contracts, e.g., Alice created a smart contract that will automatically deliver a product when Sue gives it a coin, or decentralized applications known as Dapps (Ethereum, 2018). Smart contracts and Dapps are also added to the blockchain, and generally can be used by anyone using with accessing the system willing to pay a fee to validate the interaction (much as one does in traditional financial transactions) and securely store it on the blockchain.

This distributed network of nodes and their decentralized regime of algorithmic governance is what distinguishes blockchains from centralized databases. While databases do have automated processes for entry and transformation, individuals with power and the proper permissions can remove or alter data. In contrast, the blockchain regulates data storage and validation through its distributed network of computer miners, sharing control so that no single central power can alter the data alone. This shift to more decentralized algorithmic governance is a key discursive point for blockchain proponents, "blockchain has unalterable data and is owned by no one", as well as a key mechanism through which blockchain can impact firm structures and labor practices, e.g., potential loss of back office jobs in accounting, data management, and human resources (Chronobank, 2018). However, as shown in the 2010 coding error in the Bitcoin protocol or the 2016 DAO attack on Ethereum outlined later, the co-produced agency of blockchain means that the so-called unalterable nature of blockchain data has failed multiple times in practice.

3.2. Networks of computer miners building consensus

The second component of the system – a network of computers called miners – provides security and validation for blockchain's algorithmic governance. Miners within the same network maintain distributed versions of the blockchain and most importantly come to consensus on which blocks are legitimate. This consensus process is at the heart of how blockchain governs and secures its record of interactions within a distributed yet canonical database. Blockchain networks can use many different forms of consensus; the most common to date is called proof-of-work[3] (it is the one used by Bitcoin) and is organized around miners competing to add new blocks to the blockchain in exchange for rewards such as new coins. Proof-of-work consensus is important because it only allows the addition of blocks if there is agreement within the miner network, thus preventing someone from adding a block with a false interaction (e.g., Jeremy says that Alice sends him all her coins).

While the consensus of miners takes place within software, its continual instantiation is deeply embedded in human decision-making. People running mining nodes choose which networks to join, and these choices affect the security of blockchains, i.e., the more nodes in miner networks the more secure a blockchain is against some attempts to control proof-of-work consensus. This intersection between the spaces of code and human practices is a particular visible example of how blockchain assemblages blend algorithms, human choices and materiality (Kitchin & Dodge, 2014). Decisions to run a particular form of code (Michael chooses to join the Bitcoin mining network) and the subsequent shifts in the behavior of these systems (Michael's participation increases the requirements for proof-of-work consensus), result in real and specific outcomes in the world, e.g., more expenditures of energy and CPU cycles dedicated to solving proof-of-work encryptions.

[2] Despite the novel nature of blockchain technologies the analysis presented in this paper is based on well-established methodologies within economic geographies. This includes multiple years of direct participation in the blockchain community, structured qualitative fieldwork and close readings of Bitcoin and blockchain discussions, documentation and commentary. More specifically the article is based on (a) 21 open conversations and/or semi-structured interviews with blockchain developers, investors and users; (b) analyzing the public postings of Satoshi Nakamoto, the author of the founding white paper for the original Bitcoin system; (c) collecting and evaluating key newsgroup postings (such as at Reddit.com) and other blockchain related sources (Wired.com, Hackernoon.com, etc.); (d) extensive review of popular and academic press on blockchain including the white papers and websites of initial coin offerings (ICOs); and (e) direct participation in running blockchain miners, implementing an Ethereum client and structuring a mock ICO to better understand the technical architecture of blockchain and smart contracts. The limitations of this approach is that this a rapidly evolving space and what we present here may not be representative of future blockchain technology practices. The rapidly evolving nature of this space is a key factor in the limitations of our methodological approach, indicating that our current findings may not be representative of future blockchain technology practices.

[3] Proof-of-work is popular with developers because of familiarity but it is not a technical requirement for blockchain. Other forms of consensus, proof-of-stake, delegated-proof-of-state, proof-of-authority, are available.

3.3. Encryption for proof-of-work and identity

Establishing consensus around proof-of-work fundamentally depends on encryption because miners can only add blocks after solving a computationally-intense encryption problem (a hash); this is also known as "mining a block". The first miner to find the solution adds the block to the blockchain and receives a reward, a coin payment plus transaction fees from the system. The solution is verified by other miners (although hard to solve, it is trivial to verify) and then propagated through the network to create a consensus on which blocks are part of the one true blockchain. Under proof-of-work consensus, changes to the database are only possible if a majority of miner nodes agree. Moreover, because each block is tied to those before it via hash-based encryption, the further in the past an interaction is, the more difficult it is to amend (Bitcoin, 2017).

In addition to providing the mechanism for proof-of-work consensus, encryption is central to securing identity and ownership on blockchains. All interactions are based on public addresses (or wallets) that are simply strings of letters and numbers, e.g., 0xd3f25d7707A2667477fEF9da880171935960e1C5, used to track which coins (or smart contracts or Dapps) are associated with each public identity. To authorize an interaction for a blockchain address one uses the associated private key (another string of letters and numbers) to unlock it. Using encryption to establish identity provides some anonymity to users (a useful discursive argument for proponents) although this is far from foolproof (Bohr and Bashir, 2014; Bohannon, 2016). Moreover, if one's private key is stolen, the thief can authorize the transfer of coins (Patricia uses Alice's private key to send all of Alice's coins to her own wallet) without any recourse for the victim.

Although each of these technologies – databases, networks and encryption – existed previously, Nakamoto's bundling them into the blockchain system created the particular architecture of algorithmic governance used by Bitcoin and copied by later systems (see Fig. 2). Moreover this messy assemblage, including human choices such as which networks to join, was presented as a purely technical "solution" for trust and thus preferable to existing centralized organizations. This performance of Bitcoin was studiously naïve in its understanding of how technology, society and space are co-constituted. The discourse of a system of record keeping owned by no one is compelling enough to allow blockchain proponents to ignore the unexpected and often problematic results when code is introduced to our everyday spaces and economies (Leszczynski, 2016; Crampton and Miller, 2017; Zook, 2017). The messy reality of blockchain mining and the assemblages of people, codes, mistakes, cables, malfeasance, machines, electricity and capital that briefly and continuously come together around the practice of proof-of-work to create another Bitcoin is essential for our understanding of this phenomenon.

4. Code/spaces of algorithmic governance

Paralleling the dynamism emphasized within performativity, Kitchin's and Dodge (2014) theory of code/space outlines the ways software is a central, albeit not necessarily overriding element, in the production of space. Code/space is ontogenetic – continually in a process of becoming – through a context and materially specific process blending human and algorithmic agency. Kitchin and Dodge (2014, 18) take care to emphasize that code/space is "contingent, relational, and context dependent. Code/space unfolds in multifarious and imperfect ways, embodied through the performance and often unpredictable interactions of the people within the space". This complex intertwining of code and materiality is also evident in the agency of blockchain based algorithmic governance as it interacts with non-digital elements to create its own manifestations of code/space.

One of blockchain systems' most significant interactions with materiality is the consumption of energy and computational hardware (de Vries, 2018). The proof-of-work form of algorithmic governance relies heavily on computational power to solve the hash encryptions. As Bitcoin gained monetary value, it fueled a hardware-driven, energy intensive arms race – including community-based mining pools and large-scale, corporate mining farms – as people sought to gain an advantage within the network. The human users controlling miners prefer specific hardware platforms, commonly referred to as application-specific integrated circuit chips (ASICs) that offer greater computational speed but consume more electricity. While this made mining nodes with ASIC more expensive to run they have remained prevalent as these higher costs are offset by the increasingly valuable Bitcoins awarded as incentives. According to one analysis, Bitcoin's estimated energy consumption is as much as the country of Singapore and is equivalent to the power used by more than 4.3 million houses in the US (Digiconomist, 2018). Some estimate that Bitcoin mining may represent as much 0.5 percent of the world's total consumption by the end of 2018 (de Vries, 2018); a staggering amount especially in comparison to the electrical demands of the traditional financial sector. The key role of electricity as an input has produced a particular geography around cheap energy such as the massive mining operations in China organized around state-subsidized power (Fairley, 2017) and even malware applications designed to use stolen computer cycles and electricity (Lau, 2017).

Labor to create and maintain blockchain systems represents another key material connection. While blockchain developers have largely been clustered in the USA and Europe (Friedlmaier et al., 2017) much of the engagement is done remotely via digital communication networks spanning the globe (Garcia et al., 2014; Blankenship, 2017). Indeed, the geographies of blockchain development are remarkably dispersed, contrasting to previous patterns of innovation tied to localized agglomerations of specialized labor, culture practices, knowledge sharing or investment capital (Saxenian, 1996; Storper, 1997). Despite this diffusion, the success of blockchain systems depend on assembling skilled technical labor making developers a critical factor in the continued security, potential viability and ultimate value of these systems. The low supply of labor persists for the largest systems, e.g., Bitcoin and Ethereum, even though their code is open-source.

A final example of blockchain's intersection with materiality and code/space is how users implement security through a combination of code and practice. User-level security concerns largely revolve around cryptocurrency wallets that store public and private cryptographic key pairs for approval of any transaction in the blockchain system. In the early days of Bitcoin, wallets were very rudimentary and extremely hard to use, often requiring the use of command line interfaces. Today, however, wallets are assembled in desktop, mobile, hardware, online, and paper varieties greatly increasing the ease-of-access and ease-of-use for blockchain systems. This proliferation of accessible wallets and wallet services has been accompanied by a number of security concerns. For online wallets the threat of being hacked has acted as a deterrent to those thinking of becoming involved with cryptocurrencies (BitcoinExchangeGuide, 2017). As a result many users, particularly those with strong security concerns (Sedgwick, 2018) turn to hardware wallets (generally USB devices that must be physically attached to a computer to authorize transactions) or paper wallets (material documents with the necessary private code for authorizing transactions). In some cases, these paper wallets are even hand-written to avoid creating a digital copy of crucial elements such as a private key.

5. Algorithmic dreams confront practice

In addition to interacting with materiality and code/space, blockchain has manifested in economic spaces most notably through the meteoric rise in value of Bitcoin and the accompanying rhetoric about the inevitable disruption of industry, capital and finance (Nowiński & Kozma, 2017; Collomb & Sok, 2016). There are, however, fundamental questions as to the actual value of blockchain technology beyond speculation (see Fig. 1). Despite large amounts of money, energy, and labor there has yet to be a blockchain application that fundamentally shifts the structure of financial practice or the global economy. In practice, the proof-of-work method of adding blocks to the blockchain is simply not conducive to facilitating exchange. Even the most recent iterations of blockchain – smart contracts, decentralized applications, and decentralized autonomous organizations (Dapps and DAOs) are often much more prosaic in practice than the hype suggests.

It is this disconnect between the rhetoric of the disruptive power of algorithmic governance and the reality of practice that is one of our most striking findings. In short, the power of blockchain technologies seems primarily to be in the discursive trope emphasizing the advantages of algorithms as a technical agency separate from the messiness of society and the economy. The problem, of course is that such a separation is false, a fact repeatedly established within the histories of Bitcoin and blockchain.

5.1. The failures of Bitcoin as an alternative currency

One of the biggest roadblocks to Bitcoin as an alternative currency is the challenge of scale and latency that come with proof-of-work mining-based consensus, ultimately limiting its usability for exchange (Decker & Wattenhofer, 2015). Existing systems for transactions such as Visa or Mastercard routinely handle tens of thousands of transactions each second, several orders of magnitude more than Bitcoin, and do so with a fraction of the electricity used by Bitcoin given the computational power needed for proof-of-work. While no hard figures exist on how Bitcoins are used (Foley et al., 2018), Ron and Shamir (2013) estimate that less than a quarter of Bitcoins show any signs of active circulation and even these were not necessarily tied to economic exchange.

In response to latency problems, cryptocurrency exchanges and miners often charge extra fees to facilitate faster transactions (Houy, 2014; Huberman et al., 2017) and sometimes include other fees to cover risks including slow exchange (Angel & McCabe, 2014). The inability to act as an exchange mechanism operating at speed and scale means that Bitcoin (and many other popular cryptocurrencies) has largely been relegated to store of value and speculative trading. Further complicating its use as an alternative currency are security issues from potential loopholes made more findable given the open-source nature of these projects. For example, there are known issues with PGP encryption used in many blockchain systems (Portnoy et al., 2018; Green, 2014) as well as hacks of popular wallet applications (Condon, 2017; Wieczner, 2018).

However, perhaps the most dramatic sign of how the reality of practice differs from the original vision of blockchain is the cooptation by mainstream financial practices. For example, the challenges of setting up proof-of-work blockchain mining systems are significant and it has often been easier to buy Bitcoin using existing currencies. While this initially was relatively peer-to-peer, trading cryptocurrency wallets for cash, over time cryptocurrency exchanges emerged as centralized financial mediators and gatekeepers. This currently includes mainstream banks like USAA, which allow clients to integrate cryptocurrency wallets into their systems and Goldman Sachs' plan to provide customers access to cryptocurrency trading. This is a far cry from avoiding government regulation and financial mediators (Nakamoto's, 2008a, 2008b) and Bitcoin and other blockchain currencies are now firmly entrenched in valuations based not on their ability to facilitate trade but in their worth in terms of Dollars or Euros. This has placed cryptocurrencies square in the sights of state regulators (De Filippi, 2014), which are quickly establishing legal precedents for crypto-assets such as Initial Coin Offerings (ICOs). While this remains fluid, the efforts of mainstream financial institutions to bring blockchain within corporate boundaries could contribute a similar lock-in effect of customers seen within platform capitalism (Langley and Leyshon, 2017). In less than a decade, an alternative currency system established in the face of global crisis is now seamlessly melding into these very same systems.

5.2. Embedding algorithmic governance in society

In addition to integrating with the financial industry, the rhetoric of Bitcoin and blockchain technologies as a purely technocratic form of algorithmic governance confronts the reality of the maintenance of its own software protocols. Code updates to fix security problems, increase performance, etc., are an inherent part of technical systems and when these changes are widely supported and go smoothly they are often little noticed or noted. Software failures, however, are always possible and when this occurs solutions come from society rather than lines of code. For example, in 2010 a coding error in the Bitcoin protocol allowed a hacker to create 92 billion Bitcoins from nothing; a situation that was only solved when core developers (an ironically centralized power structure for a decentralized system) rapidly changed the software and users running miners on the distributed network agreed to reset the blockchain (Shubber, 2014).

Larger changes in software or new architectures are even more complicated as human participants can disagree both over necessity and technique aptly highlighting the intertwining of agencies (Rose, 2017; Amoore and Raley, 2016). De Filippi and Loveluck, (2016, 18) trace a failed 2015 proposed technical enhancement to the Bitcoin protocol –increasing the block size to help with scaling – to the ways such a change is preformed via the social organization of Bitcoin. They note, how the "technologically-driven approach currently endorsed by the Bitcoin project, aiming to create a governance structure that is solely and exclusively dictated by technological means (governance by infrastructure) has also been shown to be bound to failure, since a purely technological system cannot fully account for the whole spectrum (and complexity) of social interactions." While De Filippi and Loveluck (2016, 18) note that other online governance problems have found solutions in centralized institutions, such as ICANN emerging as a regulator for domain name activity, the fact that Bitcoin's founding *raison d'etre* was to remove central authority confounds the processes of its own technical evolution.

The social and political nature of blockchain governance is even more evident in the case of hard forks, resulting when disagreements among users about preferred software protocols splits mining networks and creates two separate blockchains from one. Hard forks often result over disputes on how to address new user practices, particularly unexpected ones. For example, a hack to the Ethereum blockchain-based protocol known as the DAO attack took place in 2016 when a poorly designed smart contract written by Slock.it was exploited to channel approximately $70 Million dollars worth of Ether to the hacker (Madeira, 2018). This hack was not a rewriting of code or an attack on the system hardware; rather it exploited a loophole in the code by behaving in unanticipated ways (Zook and Graham, 2018). However, since the hack transferred Ether contrary to the intent of its creators – who wanted to incentivize new projects – they viewed it as an unfair exploitation of the smart contract. As a result, Ethereum core developers used their centralized power to introduce a hard fork with a blockchain rollback that did not contain the transfer of Ether caused by the hack. In doing this, they also established a new standard within the Ethereum community that humans have the final say in governing the blockchain rather than simply abiding by governance-via-code.

This ran afoul of a sub-community of Ethereum developers and users who believed that the immutability of the blockchain transactions needed to be maintained above any unfortunate losses or mistakes. They saw the actions of the Ethereum developers as nothing more than a reproduction of centralized governance structures that blockchain technologies were designed to oppose. This group chose not to implement the new protocol from the hard fork and instead maintained the original blockchain in which the hack still occurred; this created a new blockchain and cryptocurrency now known as Ethereum Classic. While both currencies remain operational, the Ethereum blockchain is significantly more popular than Ethereum Classic with a market capitalization close to forty times larger (see Fig. 1).

5.3. Smart contracts and possible futures for blockchain

Having documented the failures of blockchain as an alternative currency for exchange and that the much touted algorithmic governance of blockchain is undergirded by human agency, one might wonder what is left? To be sure it remains difficult to sort hype from reality when it comes to blockchain but the emergence of smart contracts, decentralized applications (Dapps) and decentralized autonomous organizations (DAOs) open up new functionality and combinations of human and algorithmic agency (Ethereum, 2017). Smart contracts are blockchain-based agreements, designed to react to input from humans or other smart contracts without oversight and initiate pre-specified interactions recorded to the blockchain. This can range from distributing coins to activating infrastructure elements such as heat or light; theoretically they can be written to replicate any kind of social or economic interaction. Dapps are user interfaces to smart contracts, designed to make human engagement easier and run across the distributed network of the system (rather than on a central server) offering ways around corporate control or state efforts at censorship. Of course, as the Ethereum DAO attack demonstrates, smart contracts also open up the possibility for exploitation and unintended outcomes.

A particularly significant example of a Dapp are initial coin offerings (ICOs) in which coins and tokens in a new venture are given in return for a specified amount of other cryptocurrencies, generally Bitcoin or Ether; a kind of blockchain-based crowd-sourcing. In this way ICOs are similar to the angel investing in entrepreneurial networks or initial public offering (IPO) of stocks in a traditional financial market, although ownership of coins or tokens does not equate with control over the enterprise (Rhue, 2018). Moreover, ICOs are highly risky as there are few regulatory avenues of recourse in the case of scams, hacking, or systemic failures and the design of ICOs means that reversing transfers is nigh well impossible. While paralleling other capital raising efforts – both offline and online – ICOs are distinct in that the capital invested comes almost exclusively in the form of cryptocurrency and that Dapps guide the processes.

DAOs or decentralized autonomous organizations are arrangements of smart contracts, each with their own simple sets of tasks, designed to work together securely within their intended area of application (e.g., a series of smart contracts designed to manage a supply chain or to manage a budget and task listings for ad-hoc labor). Theoretically DAOs could emulate entire corporations worth of labor tasks, for example, tracking material movements across commodity chains, discrete logistics, and other provenance systems, but the failures of initial attempts to implement secure DAOs has deterred many from deploying new, large-scale projects.

While standard databases also provide unique identifiers, the decentralized and encrypted systems of blockchain are particularly useful for inter-firm supply chains where multiple participants need to update and share records selectively. As a result a number of projects such as Provenance (2018) and IBM Blockchain (2018) promote distributed monitoring and accountability in logistics and supply chains while others such as Ripple (2018) provide efficient, scalable settlement systems for cross-border exchanges. These variants of blockchain, so called permissioned blockchains, are only accessible to those given permission, a far cry from Nakamoto's original vision of transparent, peer to peer interaction, and are generally operated by industry groups augmenting existing infrastructure without making the data about the exchanges public (see also R3 and Hyperledger).

Smart contracts, Dapps and DAOs are ultimately labor-savings technologies; i.e., rather than having back office workers one can trust in smart contracts, and are likely to contribute to further labor precarity (Strauss, 2017). The experiences of blockchain thus far, however, ranging from hard forks within cryptocurrencies to the shift to permissioned blockchains where permission to participate is centrally controlled, show that despite the endurance of rhetoric and belief in algorithmic governance, blockchains are ultimately embedded in society. In short, effects on labor and the economy more generally, are grounded in the decisions that developers codify in into blockchain protocols.

6. Conclusion

The initial vision of blockchain to create a global alternative currency and do away with financial intermediaries has largely failed. Far from the reworking of exchange envisioned by Nakamoto's (2008a, 2008b), blockchain currencies have become merely another means of speculative accumulation based on massive inputs of electricity (de Vries, 2018). Even the most promising developments such as the Ethereum alliance to standardize blockchain frameworks (Higgins, 2018) does not have a clear use case but is largely driven by competitive fears of closed permissioned blockchains of industry groups. In short, blockchain has become the proverbial hammer and every societal and financial problem a nail, even though there has yet to be a widely used application beyond currency trading.

The remarkable enthusiasm for blockchain is largely based on its supportive discourse (Cockayne, 2016); a compelling dream of a decentralized public database, a type of digital commons, in which pure algorithmically-controlled, tamper-proof transactions can be recorded. This project, however, failed in practice because algorithmic governance is simply not separate from society and a larger assemblage deeply entangled with the materiality of code/space. As the review of blockchain practices shows, algorithmic agency is deeply imbricated with human action both in daily operations and even more visibly in the rollout of larger and systemic design decisions (see Kitchin and Dodge, 2014, 149).

Even more fundamentally, the goal of replacing "untrusted middlemen" with code mis-understands the economic value of socially based trust and the difficulty (including the expense) of replacing it. This is why other alternative currencies make community trust a centerpiece of their practices and struggle when networks of trust weaken (North, 2005). In the case of proposed uses for blockchain such as verification, identification and tracking, there are already existing systems – certification, regulation, trusted brokers, etc. – that function well, or at least better than their current blockchain counterparts. Startups seeking to disrupt these industries and systems through blockchain based algorithmic governance have yet to provide convincing use cases that the addition of blockchain's shared public ledger provides a more valuable service than existing practices.

Innovative, disruptive technologies are not new for the economy or economic geography. Utopian visions that foreground purely technical approaches at the expense of socially constructed understandings have earlier antecedents (Zook, 2017) although the opacity of algorithmic "black boxes" (Pasquale, 2015) such as blockchain is remarkable. Indeed, as machine learning and artificial intelligence become standard tools for managing the economy, it is likely to become increasingly difficult to comprehend larger system behavior, leading to decisions rooted in affect rather than understanding (Cockayne, 2016). In the case of blockchain, the affective attachment to supposed superiority of algorithmic governance led to a rush to implement technical solutions while discounting the importance of understanding the nature and constituency of social phenomenon that can make many (if not most) problems intractable to technical approaches alone. While the vision of a public repository of unalterable records is compelling – not only for managing alternative currencies but also for safeguarding records from powerful, centralized authorities – the naive belief that this can be separated from society is central to the failures of Bitcoin. How much more useful might blockchain be if community based trust was tied to it rather than a coded simulacrum?

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