Hacker-engineers and their economies: The political economy of decentralised networks and 'cryptoeconomics'

Dr Jaya Klara Brekke

Geography Department, Durham University, Durham, UK

j.k.brekke@durham.ac.uk

Phone: +447957207802

Twitter: @jayapapaya

Biographical note: Dr Jaya Klara Brekke is an ESRC Postdoctoral Research Fellow at Durham University, Geography Department where she completed her PhD titled *'Disassembling the Trust Machine: Three Cuts on the Political Matter of Blockchain*. She is expert advisor to the European Commission on blockchain and disruptive technologies, and founding member of Magma Collective think and do tank. She is also the co-author of *The White Paper*, a historical contextualisation of the Bitcoin white paper (Ignota press 2019) and contributes to cultural, policy and industry debates on blockchain, cryptography, data politics and the development of decentralised network technologies.

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Research by political economists typically highlights policymakers, regulators, economists and consultants as the makers of economies. This paper foregrounds a different actor entirely, what I call the 'hacker-engineer' as an important protagonist in the making of decentralised digital network economies that are forged through the emerging field of 'cryptoeconomics' and blockchain and other distributed ledger technologies. Responding to critical literature stating that blockchain and 'cryptoeconomics' merely extend neoliberal processes of economisation, the paper recovers the neglected hacker culture of cypherpunk and histories of peer-to-peer decentralised networks in order to foreground concerns that depart from the continuation of economics and economies as usual. Hacker-engineers are dedicated to decentralisation as a 'disruptive' response to network control and surveillance, and share a pragmatist sensibility that seeks to make decentralised networks 'work' in order to provide informational security and privacy. While further broadening the range of agents that provide the focus for political economy research into the production of economies, the paper also draws attention to the technical decisions of hacker-engineers that attempt to reconfigure the material infrastructures of digital economies.

Keywords: hacker-engineer, digital economies, decentralisation, cryptoeconomics, disruption

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Introduction

This article articulates the motivations and approaches of a new protagonist involved in the making and shaping of contemporary digital network economies. What I call the 'hacker-engineer' features in economies forged through decentralised network engineering, Bitcoin, blockchain and 'cryptoeconomics'. Significant work has been done tracing the ways that monetary and information theory, the Austrian school in particular, feature in the cultures and technical architectures of these technologies (Golumbia 2016; Brunton 2019; Karlstrøm 2014). For some, this means that ostensibly progressive and disruptive hopes animating these are misleading, as they are likely to ultimately replicate existing neoliberal approaches to economisation, not least because of how markets tend to be drawn on as coordination mechanisms (Herian 2018; O'Dwyer 2015). But the employment of neoliberal economic concepts in these technologies is one part of a much larger story of economic experimentation in the development of anti-authoritarian networks and the distributed politics and 'publicness' of cryptography (Monsees 2019).

In response to this critical literature, I argue that the economic approaches in decentralised network engineering do not solely arise from pre-existing economic schools of thought, but should primarily be traced through hacker culture and engineering practices in peer-to-peer networks, whose antagonists are state and corporate actors that centralise the control of information. My hypothesis is that there is a distinct sensibility emerging from these that informs approaches to economics in Bitcoin, blockchain and cryptoeconomics. By 'sensibility', I refer to a shared common sense and vocabulary across the otherwise heterogeneous ideological affinities of programmers, computer engineers, cryptographers, economists, writers and others involved decentralised network development. This hypothesis builds on my doctoral

thesis (Brekke 2019) comprising research into the politics of blockchain, focusing on Bitcoin, Ethereum and Faircoin between 2014-2017. It also connects with research into socio-technical histories of Bitcoin by Swartz (2018) and Brunton (2019), and seeks to contribute to efforts of the likes of Manski to include latent notions of a 'technological commonwealth' and draw out countervailing political tendencies (Manski 2017). By introducing the 'hacker-engineer', I seek to define a protagonist who, informed by such a sensibility, is presently making decentralised network economies. In the words of Swartz: 'Bitcoin may not have gone mainstream, but its structure of feeling has' (2018, 645).

'Bitcoin' describes a specific project built upon a whitepaper by Satoshi Nakamoto (2008), which inspired further experiments with cryptocurrencies. The distributed ledger aspects of the Bitcoin architecture gave rise to the field of 'blockchain' and distributed ledger technologies (DLT) beyond currency applications. 'Cryptoeconomics', meanwhile, is the name used in blockchain and DLT communities to describe efforts to draw together concepts and ideas from computer engineering, economics and game theory in order to achieve particular decentralised network behaviours and security aims. Taken together, cyptocurrencies, blockchain, DLT and cryptoeconomics thus share common histories anchored via Bitcoin, to a broader set of peer-to-peer projects, protocols and cryptographic techniques.

Drawing attention to what is unique about the hacker-engineer reveals a primary concern with engineering decentralised networks of particular kinds. This entails broader experimentation with economic ideas than typically acknowledged by critical literature, and the mobilisation of more specific and pragmatic forms of expert knowledge and metrics of success. More broadly, whereas the influential research of Philip Mirowski identified an earlier turn in economics that was inspired by

developments in computation (Mirowski 2001), here I suggest the inverse is happening in contemporary engineering of decentralised networks, namely an economic turn in computation. What motivates the hacker-engineer, however, is not merely working toward designs conforming to Hayekian economics, but pragmatic concerns with network behaviours, its 'attack vectors' and information security properties (including, privacy properties, and how data is managed and stored). Neither simply rejecting nor adopting economics and economies as usual then, I will show the 'hacker-engineer' sensibility as primarily concerned with addressing problems of network consolidation and control of data and value flows in ways that cuts across established as well as heterodox economic doctrines.

By introducing the 'hacker-engineer' protagonist in the making of decentralised digital network economies, I also seek to offer wider contributions to two research agendas in political economy. The first agenda follows from research by economic sociologists and cultural economists that questions and supplements the long-standing focus of political economists on the agency of policymakers, regulators and their institutions in the production of economies, highlighting how economies and markets are made by economists 'in the wild' (Callon 2007; Çalışkan and Callon 2009; Nik-Khah and Mirowski 2019). Indeed, this article takes its conceptual cue from recent interventions by cultural economists calling for critical attention to processes of 'market design' and the agency of market engineers (Frankel, Ossandón, and Pallesen 2019; Ossandón 2019; Ossandón and Ureta 2019). Whist the engineers who provide our focus here are not those who to date have been brought to the fore by these interventions, there are certainly important similarities between the sensibilities of hacker-engineers and the social engineering practices of market designers, namely a concern with the pragmatics of making these 'work' for particular purposes.

The article also contributes to a second agenda for political economy research, influenced by approaches from science and technology studies, and centred on the infrastructures, materialities and algorithms producing digital economic processes and outcomes (MacKenzie 2018; Bernards and Campbell-Verduyn 2019; Langley and Leyshon 2017). Grandiose and spectacular claims about digital economies are punctured by political economy research into mundane and 'backgrounded' operations of assembled socio-technical infrastructures (Bernards and Campbell-Verduyn 2019, p. 783), but this also raises important research questions about agency in infrastructural design and engineering that this article begins to address. As I will show, hacker-engineers look to explicitly intervene into who or what gets to determine economic processes and flows by reshaping exactly such infrastructures that 'perform' digital network economies, some even seeking to resolve political and economic questions through infrastructural and algorithmic arrangements.

What follows is organised into three parts. Part 1 discusses the critical literature building up around Bitcoin and blockchain, and sets out the insights for the study of cryptoeconomics and decentralised network economies that are available from the two aforementioned wider agendas for political economy research. Part 2 retraces the development of hacker-engineer economies to pre-Bitcoin decentralised networks and hacker cultures, in particular 'cypherpunk'. These histories form part of a shared sensibility amongst hackers, coders, and information security engineers centred on notions of decentralisation and cryptography. Part 3 discusses how this sensibility continues to inform how and why hacker-engineers are making economies, and sets up an interrogation of such economies and 'cryptoeconomics' as fields where economic concepts are employed foremost in order to achieve particular kinds of decentralised networks.

Economic 'disruption' with a difference

A growing body of critical literature has been questioning the 'disruptive' nature of Bitcoin and the blockchain projects that followed, arguing that they are a continuation of neoliberal market logics, Friedman monetary thinking and Austrian school economics (Herian 2016; 2018; O'Dwyer 2015; Kostakis and Giotitsas 2014; Scott 2014; Golumbia 2016). O'Dwyer (2015) has described how encoded in the proposition of Bitcoin are fundamentally neoliberal assumptions about collectives: decentralisation in the Bitcoin architecture presumes there can be no such thing as community or trust, only self-interested individuals, who's behaviours therefore have to be coordinated through economic incentives enforced through cryptography. This form of decentralisation is reminiscent of Hayekian markets 'as an information processor', in the words of economic historian Mirowski (2001). Indeed, Nik-Khah and Mirowksi describe how economists went through an 'informational turn' post-second world war and began to draw on developments in computation to inform their theories (2018). Given such historical and conceptual overlaps it is perhaps unsurprising that Austrian school economics are readily drawn upon now that computer engineers – via Bitcoin – are beginning to look at economics as potential tools to sustain and secure decentralised networks. However, what I would venture to conversely call an *economic turn in computation* entails that the primary aim of hacker-engineers is to develop decentralised computational networks rather than decentralised markets. As a result, although notions of markets as decentralised information processors indeed circulate in Bitcoin, blockchain and cryptoeconomics, there is in fact experimentation with a much broader range of economic ideas.

A number of theorists have done considerable work retracing the histories and ideas that have informed Bitcoin and blockchain, but these tend to centre on North American network cultures and economic ideologies. For example, digital theorist Golumbia, has traced US right wing monetary ideas in notions of Bitcoin as digital gold (2016) and argues that the project is more effective in furthering conspiracy theories against central banking than any technical use. This chimes with ideas and ideologies that Brunton discusses in a history of digital cash leading up to Bitcoin (2019). The crypto-anarchists and 'extropians', a Californian ideology that seeks eternal life, form part of this history, and draw significantly on US right wing economic thinking. Where Golumbia seeks to demonstrate contradictions between extreme exchange rate volatility and the supposed intrinsic value of Bitcoin, Brunton's work reveals a more sinister and entirely coherent set of ideologies between extropian and anarcho-capitalist ideas: volatility is the necessary chaotic dynamic of the market that will propel a techno-utopian future while cryogenics guarantees passage for some to this future in which eternal life has been achieved (Brunton 2019). The mix of Californian techno-optimism, Hayekian economics and US right wing dystopian ideology highlighted in these works form part of a now rather large trove of scandalous and fantastical stories about Bitcoin, cryptocurrencies and blockchain. But ones that therefore easily miss out on what Maddox et al. call the 'community culture' in these technological projects and their attempts at more 'mundane acts of socio-technical disruption' (2016, 65).

Campbell-Verduyn and Hütten (2019) argue that the tendency to scandalise Bitcoin and blockchain projects is part of a broader moral economy that individualises failure and draws attention away from structural concerns, with significant effects. In the case of Bitcoin, this means the project's genesis as a critique of the financial system and handling of the 2008 financial crisis is continuously underplayed. Failures of

bottom-up blockchain and cryptoeconomic experiments are scandalised in a similar manner. As discussed by Faria in her study of post-financial crisis blockchain developments, this allows incumbent economic and financial institutions to position themselves as 'institutions with deep knowledge of financial activities and innovative technologies, which perform experiments wisely' by setting up institutional regulatory 'sandboxes' for such experiments (Faria 2019, 128).

By suggesting the 'hacker-engineer' as an emerging protagonist making economies, I am taking cue from Campbell-Verduyn and Hütten to give space to sincere structural critiques across these 'live', bottom-up blockchain and cryptoeconomic experiments as well as foreground efforts by critical engineers in institutional 'sandboxed' contexts towards infrastructural transformation. Understandings of 'decentralisation' in these do not only reference markets or Hayek, and are far from uniform or coherent (Schneider 2019). Decentralisation forms the crux of the proposition of these network technologies, but arguably the only shared understanding of its meaning is in its particular instantiation as peer-to-peer network topologies. I therefore take such networks and their histories as a starting point for articulating a 'hacker-engineer' sensibility towards making decentralised digital network economies.

To this end, I want to begin by developing insights available from cultural economists and economic sociologists. Expanding the focus of political economy on policymakers, regulators and their institutions, cultural economy has drawn attention to the work of economists in promoting and enacting economic theories 'in the wild'. This has entailed conceptualising the 'performativity' of economics as able to mobilise the necessary regulatory, organisational and infrastructural efforts to establish the conditions under which economic theories can bring into being that which they name (Callon 2007; Çalışkan and Callon 2009; Berndt and Boeckler 2009). Similar

'performative' powers of blockchain, and its operation as 'narrative' technology, has been an object of analysis (Zook and Blankenship 2018; Reijers and Coeckelbergh 2016). Yet beyond these analyses there is still significant work to be done for understanding and articulating what is particular about blockchain and peer-to-peer cryptographic architectures – thereby expanding the list of protagonists that are actively experimenting and making decentralised network economies.

This requires acknowledging and taking seriously a broader political history of decentralised technologies and the particularity of cryptography and security engineering practices shared across these. Recent work by Linda Monsees articulates the ways that encryption creates new kinds of 'publicness' around distributed security practices, rather than an a priori affiliation with either the state or commercial actors as guarantors of security (Monsees 2019). The 'crypto-politics' that is revealed in her analysis of security controversies criss-cross state agencies and institutions as well as non-state actors, showing how these diverge on matters of encryption depending on interests and business models. Instead, the 'publicness' and politics that emerges around encryption are shaped by understandings of what security means, an area that hackers, critical engineers and Internet movements like 'cypherpunk' continue to politicise.

Indeed, cypherpunk is a forerunner to Bitcoin, but it is often neglected in analyses of the political economies of blockchain. Lana Swartz's work is an exception (Swartz 2018) as it traces the influences of intertwining network subcultures of 'crypto-anarchism' and 'cypherpunk' within Bitcoin, to show how the very same Bitcoin architecture has been expressive of two major tendencies: 'digital metallism', closer to the anarcho-capitalist, right wing flavour that Golumbia describes, but also 'infrastructural mutualism' emphasising decentralisation as collectively run infrastructure, strengthened and protected through cryptography. Drawing on the

cypherpunk emphasis on privacy reveals more ways in which engineering cryptographic networks also entail a reengineering of data economies in ways that might indeed prove disruptive of digital capitalism – not least the kinds of surveillance business models discussed by Monsees and others (Monsees 2019; Zuboff 2015).

An 'engineering approach' to economies has been highlighted recently in other domains by the economic sociologist José Ossandón (2019). When market economists are engaged in designing bespoke markets for achieving specific kinds of outcomes – what Ossandón and Ureta (2019) describe as 'putting markets to work' for addressing 'collective concerns' – they are said to be engineering economies to produce certain societal outcomes. Such engineering approaches 'challenges the political expectations found in social studies of markets' (Frankel, Ossandón, and Pallesen 2019, 153). Particular to such engineering approach to economies and markets is that it entails a set of pragmatic measures and metrics used in determining whether the given economic (or cryptoeconomic) design is considered to 'work'. As Ossandón notes (2019) this leaves significant space for critical engagement between (crypto)economists and economic sociologists about what a 'working' system means and for whom.

However, understanding the infrastructures and protocols of digital economies as systems that simply make things happen and therefore can be engineered to produce 'good' or 'bad' outcomes leads easily to a sense of these as neutral, ahistorical mechanisms that can be put to task to solve all manner of societal problems. Such assumptions of neutrality have faced critical scrutiny in political economy, and considered a pitfall of the concept of 'performativity' in cultural economy (Nik-Khah and Mirowski 2019). Foregrounding the political and ideological contexts that give rise to economic thinking Nik-kah and Mirowski describe the productive contradictions between the bespoke markets of market designers and the ideology of the perfect market

implied in Walrasian general equilibrium. For better or worse, the economic turn in computation that I am suggesting might very well provide a new ideological home for market design. The idea that economies, networks and protocols are neutral and 'disinterested' mechanisms for achieving a variety of outcomes is after all a major assumption in blockchain and cryptoeconomics, leading for example to endeavours to mobilise networks and markets as part of large-scale governance systems proclaimed, curiously, to be *alternatives* to capitalism.[1]

This brings me to a second set of literature that I want to draw on and develop here. In a recent special issue of *Review of International Political Economy* dedicated to STS approaches to IPE, Bernards and Campbell-Verduyn look to somewhat puncture the disruptive claims of FinTech innovations, situating these within otherwise 'backgrounded' operations of existing economic and financial infrastructures (2019). This serves, on the one hand, to ground analyses of new network economies as enabled and constricted by already existing politically and financially infrastructuralised arrangements. Infrastructure is not neutral, so to speak. But on the other hand, it also suggests that the engineering of new infrastructures potentially entails the materialisation of new kinds of economies.

Part of a broader infrastructural turn in political economy, MacKenzie has called for a 'material political economy' (2018, 503) attuned to infrastructures and material conditions. For the hacker-engineer, such a 'material political economy' is not the immanent effects of infrastructures, landscapes and weather conditions, but rather a loud and deliberate material political economic proposition, evident in for example the 'practical materialism' of Bitcoin highlighted by Maurer, Nelms and Swartz (2013). This suggests that even the metallist monetary ideas that Golumbia traces to anti-central bank right wing ideology (2016), is to some extent motivated by an ambition to resolve

political economic questions through infrastructure. In the words of Swartz, 'from the cypherpunk perspective, it's possible to advance a theory of money as fundamentally infrastructural' (Swartz 2018, 633). What this means is that economic questions are approached as engineering problems, and therefore less tied to specific economic schools than might seem. The flip side to this infrastructural approach is a relative lack of critical economic engagement that means that often times 'in spite of their noble intentions, these projects do not in fact break with the current financial paradigm' (Lotti 2016, 105).

To summarise, the hacker-engineer sensibility does indeed propose a 'disruption' of financial and economic status quo, but it is a disruption with a difference: rather than a complete rejection of financial capitalism, this sensibility highlights and seeks to disrupt key aspects of the 'material orderings' of current economic and financial processes (MacKenzie 2018, 501). The aim is to decentralise control of economic flows, financial information and data through infrastructure. The meaning of decentralisation here oscillates radically between implying more control for the people and communities who would run such decentralised infrastructures, versus handing over control to decentralised, algorithmic architectures reminiscent of Hayek's markets. There are, in other words, significant political differences, but nevertheless a common anti-authoritarianism for which peer-to-peer networks is understood to be an answer. In the following section I give some pointers to the histories of decentralised network engineering and hacker culture that has informed this shared sensibility.

'Hacker-engineer' sensibilities - recovering the histories of anti-authoritarian decentralised networks

What	Why	How
Decentralisation	To establish networks and flows that cannot be controlled or shut down	Decentralised peer-to-peer networks
Cryptography	To secure privacy and establish shared truths in decentralised networks	Private key cryptography, cryptographic hashing and proofs

Fig 1. Emerging 'hacker-engineer' sensibilities

Underpinning Bitcoin, blockchain, DLT and cryptoeconomics is a shared affinity to decentralised networks and cryptography that I call a 'hacker-engineer' sensibility. Briefly put, the idea is that a decentralised topology ensures that no authority can shut down or control the given network, because it is not dependent on any single (or set of) nodes. The concern is primarily to achieve network autonomy. The governance assumptions implied vary radically, at times emphasising the kind of market-based governance of Hayek, but at other times the kinds of decentralised governance of Swartz's 'infrastructural mutualism' in which communities determine and run their own infrastructure. Cryptography in the meantime ensures security and privacy and establishes shared truths, using private key cryptography, cryptographic hashing and cryptographic proofs. Bitcoin introduced a further element, namely the possibility of economic autonomy for the network, using these very principles of decentralised topologies and cryptographic techniques. These together are considered, in the words of early Bitcoin developer Corallo, a 'technology-based'[2] answer to political, legal and financial authorities. This 'hacker-engineer' sensibility emerged from pre-Bitcoin hacker cultures and experiences requiring further recovery in order to understand the specific anti-authoritarianism and information security approaches informing this sensibility, its 'publicness', performativity and economies.

Two publications give significant clues to this end. The first is a 2001-edited volume titled 'Peer-to-Peer: Harnessing The Power of Disruptive Technologies' (Oram 2001) with contributions from a number of people building peer-to-peer decentralised systems at the time. The book is not so much a set of technical specifications as it is a set of reflections about developing autonomous and self-organised infrastructures and networks. The book can be read as a documentation of peer-to-peer culture, network tinkering and the kind of 'infrastructural mutualist' (Swartz 2018) sensibilities that were forming around decentralised networks. At the heart of it is the idea of returning control to people in order to 'return the Internet to its original vision, in which everyone creates as well as consumes' (Oram 2001, 2).

This was a time when hackers and social movement activists were strategically using network technologies to circumvent authorities, full of giddy excitement but also arrests and heavy sentencing (Coleman 2014). Aspects of this peer-to-peer vision were to clash with authorities, informing ideas of decentralisation as an effective strategy against legal, corporate and government actors. A more detailed history is beyond the scope of this article, but the extensive work on hacker culture by anthropologist Gabriella Coleman is especially informative. Coleman describes a playful obsession and tinkering with legal and technical systems (Coleman 2009); varied and contradictory political affiliations and references of hackers (Coleman 2014); and a particular anti-authoritarianism and anti-institutionalism that sees governments and corporations as repressive bureaucracies that impose unnecessary limitations (see also Ullman 2013).

Hackers and activists were especially critical of the way intellectual property-based industries limit access to knowledge and culture, driven by the open source software ethos and a popular Internet activist saying that 'information wants to be free' (Swartz 2018). Some companies lashed back with lawsuits, and in 2013 a young

Internet activist and innovator, Aaron Swartz, committed suicide after receiving a heavy sentence for setting up an automated download of academic papers from JSTOR to share for free. This, and other legal cases against hackers and activists, informed and justified anti-authoritarian sentiments and strategic reasoning of decentralised networks: if there is no server and no single node then there would be no point from which a government or corporation could shut down a given project, no matter who got arrested or how powerful the authority.

The second publication that is informative for understanding the emergence and sensibilities of the hacker-engineer is a paper from 2017 by a number of computer and information security scientists titled 'Systematising Decentralisation and Privacy: Lessons from 15 Years of Research and Deployments'. The paper reviews decentralised applications since the abovementioned 2001 Oram volume, systematising the pros and cons of different topologies according to a set of privacy properties (Troncoso et al. 2017, 320). For our purposes, this paper serves to highlight, firstly that Bitcoin (and by extension blockchain) sits within a longer history of decentralisation-as-information-security-engineering that includes for example peer-to-peer file sharing system BitTorrent and Tor, a 'relay network' to ensure online anonymity. Secondly, it highlights a shared set of priorities across these projects as techniques and technologies to protect people against what these engineers call 'formidable adversaries' (Troncoso et al. 2017). When traced through such hacker cultures and technical histories, 'decentralisation' emerges as an infrastructural strategy to ensure autonomy, censorship-resistance and systemic resilience in the face of authorities looking to shut these down – articulated as a set of information security engineering problems.

This brings us to the next aspect of the 'hacker-engineer' sensibility, namely cryptography. Already in the 1980s and 1990s, a number of cryptographers and

engineers were concerned with the ways in which the growing importance of the internet would significantly expand oversight and control by powerful actors over ordinary people, in particular in terms of mass surveillance and control of flows of information and value (Chaum 1998). 'Cypherpunk', a name coined by hacker Jude Mihon (Cross 1995), was an internet subculture centred largely on a mailing list[3] that sought to resist this development, based on the capacity of cryptography to protect information networks against powerful actors (Hughes 1993; Assange et al. 2012). As mentioned by Swartz, cypherpunk 'was spurred by developments decades earlier that democratised access to state- of-the-art cryptography' (Swartz 2018, 625). Private key cryptography would encrypt messages between people and cryptographic hashing could be used to prove whether some information had been tampered with. Combined, decentralisation and cryptography were not only becoming important techniques for activists and cryptographers to protect civil liberties, they also increasingly informed and formed the basis of shared sensibilities and vocabularies across otherwise diverse political affiliations. Such 'crypto-politics' began to create forms of 'publicness' that did not sit neatly within public-private binaries. Rather, 'the encryption discourse reaffirms the existing political vocabulary while simultaneously operating outside established political categories' (Monsees 2019, 12).

With Bitcoin, this sensibility became even more prominent and cryptography took on a new meaning. In the Bitcoin architecture cryptographic hashing is also used in order for the network to arrive at a shared understanding of events (transactions) without resorting to an authority. This opened up a number of ideas that continue to inform the economies of hacker-engineers. The following quote from one of the early Bitcoin developers, Corallo, illustrates the motivations for decentralisation as an anti-

authoritarian strategy, but also, importantly, how such a strategy started to inform the idea of a 'technology-based' resolution to political economy:

> …it is very easy to apply pressure on PayPal to make significant business decisions, for example to block Wikileaks, without necessarily applying a law and going straight to PayPal and say 'we are going to sue you', right? Whereas if you have a system like Bitcoin or if you have a system that is much more decentralised and technology-based […] You can't block these things.
> *– Bitcoin developer, Matt Corallo, Apr 2015*[4]

Corallo is referring to an unofficial blockade by the US government, banks and payment platforms against whistleblower site Wikileaks in 2010 after they published documents leaked by US army soldier Chelsea Manning, including drone footage of US army killings of civilians in Iraq and Afghanistan. Bitcoin famously became a means for Wikileaks to continue to receive donations, and the banking blockade therefore became a politically formative moment for the Bitcoin project (Roio 2013). Once again, decentralisation and cryptography were proving effective as a strategy against authorities, this time serving towards economic autonomy: because Bitcoin was decentralised, it would be difficult for governments or financial institutions to block payments or shut it down because the system as a whole did not rely on any single node. But here was also an idea for an alternative to political and economic authorities that would be 'decentralised and technology-based' rather than institutional and driven by politics.

The difference is subtle but important: one emphasises the possibility for networks of activists, projects and communities to make use of decentralised networks to gain economic autonomy, Swartz's 'infrastructural mutualism'. The other suggests technological networks should themselves be autonomous from control by anyone –

what might be called ‘infrastructural solutionism’. This perspective is primarily an extension of decentralised information security perspectives. When the Bitcoin protocol was ‘generalised’ to a broader set of applications with blockchain (Wood 2014), the security model was also increasingly generalised as an idea: from being concerned with attacks by ‘formidable adversaries’ instead, the attacks would be from anyone: no node should be trusted, the network, in other words is ‘trustless’, implying that everything else is a potential ‘attack vector’. Taking its cue from the information security approach to ‘decentralisation’, the ‘trustless’ network thereby became the ‘infrastructural solution’ to political and economic questions altogether.

These tendencies have come at odds with one another when it comes to crucial technical decisions (Swartz 2018; Azouvi, Maller, and Meiklejohn 2018). As discussed above, the ‘metallist’ tendencies, right wing affiliations and other scandalous and scandalising aspects have been widely discussed. But ‘infrastructural mutualist’ and cypherpunk concerns of surveillance and privacy are not sufficiently acknowledged as an important aspect of the political economic remit of Bitcoin, blockchain and cryptoeconomics. This is a serious omission because, as it turns out, these concerns with privacy and network control are also hugely poignant as critiques of today’s digital economies: from data-driven or ‘surveillance-based’ platform business models to credit rating systems and data economies more broadly (Zuboff 2015; Monsees 2019).

The political economies of hacker-engineers

Decentralised cryptographic networks, for hacker-engineers, became an axiomatic ‘disruptive’ response to political, economic and legal authorities. And with Bitcoin, economic notions were added to the toolbox. Decentralised, peer-to-peer networks in the meantime have some unique information security problems, including particular

kinds of attacks (for example 'DDoS' and 'Sybil attacks') as well as forms of information security metrics (such as 'Byzantine Fault Tolerance'). The economic designs of Bitcoin pertain largely to such information security concerns in achieving decentralised networks (it is perhaps telling that there are no references to economic texts in the Bitcoin whitepaper, see Nakamoto 2008). The economics and economies of the hacker-engineer, then, is primarily concerned with achieving decentralised networks, privacy, censorship-resistance and network autonomy. These concerns intersect with, and challenge, mainstream economic ideas in different ways, some examples of which I discuss below.

The term 'cryptoeconomics' is one effort amongst blockchain developers to capture and articulate these particular concerns, techniques and ambitions, and is directly inspired by the mining aspect of Bitcoin. On a simple level, the idea is to incentivise people to operate and secure the network through economic rewards (new bitcoin), while making it computationally expensive to attack it. This 'proof-of-work' technique can be traced further back to computer engineers Cynthia Dwork and Moni Naor who, in the 1990s, first suggested using pricing of email as a way to combat spam (1992). It was then developed into 'hashcash', addressing the information security issue of so-called 'Denial of Service' network attacks (Back 2002). The focus of cryptoeconomics is thereby not towards marketisation per se, rather it is considered as 'a methodology for building systems that try to guarantee certain kinds of information security properties', in the words of Buterin, one of the founders of Ethereum.[5] This leaves some space for productive engagement with how else such information security aims might be achieved. But in practice, the competitive aspects of Bitcoin mining that inspired cryptoeconomics have led to marketisation and indeed centralisation.

Bitcoin mining, its precursors and cryptoeconomic successors are in fact similar to the economic tendencies that Ossandón foregrounds (2019) – designing bespoke markets to address particular concerns. This is especially evident in some of the more recent cryptoeconomic experiments, such as 'bonding curves', where economic incentives are approached as a 'design space' to achieve behavioural outcomes such as addressing the speculative tendencies in cryptocurrency fund-raising schemes (Titcomb 2019). Importantly, cryptoeconomic experiments vary in terms of political approaches to governance, some emphasising market-based automated forms, while others look to articulate 'off-chain' forms of decentralised governance of blockchain protocols and their new market experiments (DuPont 2018; De Filippi 2019).

Cryptoeconomics resembles the behavioural engineering of market design, although with slightly different (information security) vocabularies and metrics. As Swartz has pointed out, there was a very different direction that Bitcoin might have taken, namely, accessible and equitable remuneration for contributing to run the network (Swartz 2018). This latent ambition informed 'forks' of Bitcoin and continues to motivate new DLT projects, emphasising priorities that stem explicitly from hacker and cypherpunk culture, namely how economics might address ambitions of privacy and self-determination. For technical communities looking to develop decentralised (in the sense of censorship resistant) alternatives to centralised cloud infrastructures and platform companies there was the question of how to get people to contribute resources to run such networks. For privacy engineer Danezis, a key novelty of blockchain protocols compared to earlier decentralised systems is therefore the incorporation of economic incentives as a means to encourage participation in running the network and 'to ensure they do not need to be tempted to pry as a business model' (Danezis, 2018). Here, the motivation for making economies is to render existing 'centralised' platform

business models based on surveillance and control, both *technically* and *economically* unfeasible by design, by addressing centralisation in terms of data ownership, access, storage and management.

It is on this question of privacy and network control where the economies of hacker-engineers differentiate themselves from Ossandón's market designer. For Ossandón, digital platforms Uber, Amazon, Google and Tinder feature as examples of market design (2019, 36). For hacker-engineers, blockchain and cryptoeconomics are in fact meant as disruptions to these very platforms. The 'disruption' however is not always aimed at how such platforms marketise online social relations, nor necessarily critical of capitalism or neoliberalism as such but focus instead on questions of surveillance, manipulation and centralisation of ownership over information infrastructures and the resulting control of data and value. Such focus on privacy is a potentially significant intervention into current forms of data-driven 'surveillance capitalist' digital economies. Ocean protocol for example addresses questions of control of data and data value, while a number of other projects are focused mainly on privacy and draw more explicitly from a cypherpunk history, including Monero, Nym and XXCoin. However, when privacy is articulated as an absolute rather than as part of a broader political economic analysis, such infrastructures easily become yet another means for private accumulation and control of wealth. And decentralising data ownership, within a market context, might indeed simply decentralise market approaches from platform companies to individuals.

Other hacker-engineer projects differentiate themselves more explicitly from some of the market approaches and emphasis on automated forms of governance in 'cryptoeconomics', instead adopting cooperative and commons approaches (De Filippi and Hassan 2015; Dickson, Delight, and Diakomichalis 2019; McKelvey 2020). While

critical of especially bitcoin mining, many of these have nevertheless taken inspiration from Bitcoin to incorporate some kind of economics into network projects as a means to achieve economic sustainability towards 'infrastructural mutualism'. This approach is seen for example, projects such as Holochain, FileCoin and OSCoin (Brock et al. 2018; Sellier, Diakomichalis, and Haydon 2019) as well as in the early days of Ripple (Rella 2020). Here the economics that is drawn upon tends to be mutual credit systems rather than neoclassical or Austrian school economics (Scott 2018), with commons and cooperative governance in mind. The economic focus of these is on equitable accounting and tokens as a means for rewarding work done to maintain the networks and community fundraising. These are a few brief examples, but there is significantly more work to be done in tracing and systematising the diverse political economies of hacker-engineers developing in the wake of Bitcoin.

Conclusion

With this article, I have sought to contribute to two broader debates in political economy. Firstly, taking cue from research agendas in cultural economy questioning who makes economies and how (Callon 2007; MacKenzie, Muniesa, and Siu 2007), I suggest that what I call the hacker-engineer should be added to the list of protagonists with particular concerns and approaches that come from hacker culture and histories of decentralised network engineering. Hackers are motivated by tinkering with, and taking apart systems in order to understand their inner workings and direct them towards their own aims. Engineers are concerned with the pragmatics of making things 'work'. I argue that these sensibilities are part of the distributed politics of information security described by Monsees, creating new kinds of publics that do not sit neatly within the categories of public and private, state and market. Rather, they make out a particular

sensibility at work in the making of economies, where the main antagonist is state or corporate forms of centralised control of information infrastructures – the political effects of which I argue should not be categorised and closed off too quickly.

In an inversion of Mirowksi's computational turn in economics, this economic turn in computation implies that economic concepts are drawn on in order to serve network requirements, rather than networks serving to perfect markets. This entails significant political differences in terms of governance implications amongst these, while nevertheless sharing an anti-authoritarian affiliation with decentralised networks. I compare this 'engineering' approach to a similar one described in recent work on market designers by economic sociologist Ossandón (2019). In both cases, an engineering approach to markets focuses on making such systems 'work' for addressing 'collective concerns' (Ossandón and Ureta 2019). This leaves some space for critical and productive engagement in questions of for whom exactly, and the metrics of success that are employed. In the pragmatic practices of hacker-engineers, complex political and economic questions are reconfigured into network information security problems that are then 'solved' through cryptographic means.

I have therefore also drawn on a second set of debates in political economy that calls for an STS approach to developments in FinTech and the digital economy more broadly (Bernards and Campbell-Verduyn 2019). Recent work in this area seeks to ground some of the 'disruptive' claims of FinTech through an infrastructural approach that understands these as a materialisation of particular governance and economic arrangements. This work helps to ground much of the technological determinism at play in hacker-engineer efforts to recode and resolve politics, economics and law by infrastructural and information security means.

Although materiality and infrastructure is rapidly becoming a major focus for political economy, the hacker-engineer as a protagonist raises significant questions about agency in the making of such 'material political economies' (MacKenzie 2018). For the hacker-engineer, engineering decisions are also deliberate and explicit answers to broader questions of political economy. I have sought to lay some initial ground for further research into this area by discussing a number of examples of hacker-engineer approaches to and reasons for which they engage in making economies.

To conclude, then, hacker-engineers are a new protagonist in making and shaping economies and related infrastructures, policies and debates. This protagonist has been forged through distinct network engineering and hacker cultures through which decentralisation and cryptography became an answer to the control of networks by political, legal and financial authorities. I have argued that these histories and the kinds of anti-authoritarianism that they have given rise to have shaped approaches to economies and economics in decentralised networks. Rather than an entrenched affiliation to neoliberal economics, the economies and economics of Bitcoin, blockchain, DLT and cryptoeconomics are better understood as efforts towards engineering particular kinds of network behaviours, and achieving specific information security properties. These were initially shaped by the lens of information security concerns in decentralised network engineering, seeking to counter government and corporate network control and surveillance.

For several critical theorists, including legal theorist Herian, the 'disruptive' moment of 'blockchain' has passed and all that remains is expansion and entrenchment of neoliberalism that urgently needs to be stopped through regulation (2018). I would argue that this only captures part of the picture and that those looking to regulate and counter the spread of neoliberal economisation through these technologies would

benefit from rescuing the motivations, appeal and potential that are not explicitly neoliberal but derive from other concerns. Not least because some of these offer poignant critiques, if not always perfect solutions, to current forms of digital capitalist economies. The hacker-engineer focus on privacy and network control after all points to an important and ambiguous nexus of economic power in the shaping of current digital economies.

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Bibliography

Assange, Julian, Jacob Applebaum, Andy Müller-Maguhn, and Jérémie Zimmermann. 2012. *Cypherpunks, Freedom and the Future of the Internet*. London and New York: OR Books.

Azouvi, Sarah, Mary Maller, and Sarah Meiklejohn. 2018. 'Egalitarian Society or Benevolent Dictatorship: The State of Cryptocurrency Governance'. In . The Fifth Workshop on Bitcoin and Blockchain Research.

Back, Adam. 2002. 'Hashcash - A Denial of Service Counter-Measure'. *Http://Www.Hashcash.Org/Papers/Hashcash.Pdf*, no. August: 1–10.

Bernards, Nick, and Malcolm Campbell-Verduyn. 2019. 'Understanding Technological Change in Global Finance through Infrastructures: Introduction to Review of International Political Economy Special Issue "The Changing Technological Infrastructures of Global Finance"'. *Review of International Political Economy* 26 (5): 773–89. https://doi.org/10.1080/09692290.2019.1625420.

Berndt, Christian, and Marc Boeckler. 2009. 'Geographies of Circulation and Exchange: Constructions of Markets'. *Progress in Human Geography* 33 (4): 535–51. https://doi.org/10.1177/0309132509104805.

Brekke, Jaya Klara. 2019. 'Disassembling the Trust Machine, Three Cuts on the Political Matter of Blockchain'. PhD, Durham, UK: Durham University.

Brock, Arthur, David Atkinson, Emaline Friedman, Eric Harris-braun, Erin Mcguire, Jean M. Russell, Nicholas Perrin, Nicolas Luck, and Will Harris-braun. 2018. 'Holo Green Paper', no. March.

Brunton, Finn. 2019. *Digital Cash: The Unknown History of the Anarchists, Utopians, and Technologists Who Created Cryptocurrency*. Princeton University Press.

Çalışkan, Koray, and Michel Callon. 2009. ‘Economization, Part 1: Shifting Attention from the Economy towards Processes of Economization’. *Economy and Society* 38 (3): 369–98. https://doi.org/10.1080/03085140903020580.
Callon, Michel. 2007. ‘What Does It Mean to Say That Economics Is Performative?’ In *Do Economists Make Markets? On the Performativity of Economics*, edited by MacKenzie, Donald, Muniesa, Fabian, and Siu Lucia, 311–57. Princeton and Oxford: Princeton University Press.
Chaum, David. 1998. ‘Blind Signatures for Untraceable Payments’. Department of Computer Science, University of California.
Coleman, Gabriella. 2009. ‘Code Is Speech: Legal Tinkering, Expertise, and Protest among Free and Open Source Software Developers’. *Cultural Anthropology* 24 (3): 420–54. https://doi.org/10.1111/j.1548-1360.2009.01036.x.
———. 2014. *Hacker-Hoaxer-Whistleblower-Spy, The Many Faces of Anonymous*. Verso.
Cross, Rosie. 1995. ‘Modem Grrrl’. *Wired*, 1 February 1995. https://www.wired.com/1995/02/st-jude/.
De Filippi, Primavera. 2019. ‘Blockchain Technology and Decentralized Governance: The Pitfalls of a Trustless Dream’. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3524352.
De Filippi, Primavera, and Samer Hassan. 2015. ‘Measuring Value in the Commons-Based Ecosystem: Bridging the Gap Between the Commons and the Market’. In *Moneylab Reader: An Intervention in Digital Economy*. INC Reader. Amsterdam: Institute of Network Cultures.
Dickson, Andrew, Ankur Shah Delight, and Eleftherios Diakomichalis. 2019. ‘Seeding Trust Part 3 What the Decentralized Web Can Learn from Wikipedia’. *The Math Shop* (blog). 2019. https://www.mathshop.io/blog/2019/10/14/seeding-trust-part-3.
DuPont, Quinn. 2018. ‘Experiments in Algorithmic Governance: A History and Ethnography of “The DAO,” a Failed Decentralized Autonomous Organization’. In *Bitcoin and beyond: Cryptocurrencies, Blockchains, and Global Governance*. RIPE Series in Global Political Economy. London and New York: Routledge.
Dwork, Cynthia, and Moni Naor. 1992. ‘Pricing via Processing or Combatting Junk Mail’. *Advances in Cryptology — CRYPTO’ 92*. https://doi.org/10.1007/3-540-48071-4_10.
Faria, Inês. 2019. ‘Trust, Reputation and Ambiguous Freedoms: Financial Institutions and Subversive Libertarians Navigating Blockchain, Markets, and Regulation’. *Journal of Cultural Economy* 12 (2): 119–32. https://doi.org/10.1080/17530350.2018.1547986.
Frankel, Christian, José Ossandón, and Trine Pallesen. 2019. ‘The Organization of Markets for Collective Concerns and Their Failures’. *Economy and Society* 48 (2): 153–74. https://doi.org/10.1080/03085147.2019.1627791.
Golumbia, David. 2016. *The Politics of Bitcoin, Software as Righ-Wing Extremism*. University of Minnesota Press.
Herian, Robert. 2016. ‘Anything but Disruptive: Blockchain, Capital and a Case of Fourth Industrial Age Enclosure – Part I’. *Critical Legal Thinking* (blog). 18 October 2016. http://criticallegalthinking.com/2016/10/18/anything-disruptive-blockchain-capital-case-fourth-industrial-age-enclosure-part/.
———. 2018. ‘Taking Blockchain Seriously’. *Law and Critique* 29 (2). https://doi.org/10.1007/s10978-018-9226-y.
Hughes, Eric. 1993. ‘A Cypherpunk’s Manifesto’.

Karlstrøm, Henrik. 2014. 'Do Libertarians Dream of Electric Coins? The Material Embeddedness of Bitcoin'. *Distinktion: Journal of Social Theory* 15 (1): 23–36. https://doi.org/10.1080/1600910X.2013.870083.
Kostakis, Vasilis, and Chris Giotitsas. 2014. 'The (A)Political Economy of Bitcoin'. *Triple C* 12 (2). https://www.triple-c.at/index.php/tripleC/article/view/606/578.
Lotti, Laura. 2016. 'Contemporary Art, Capitalization and the Blockchain: On the Autonomy and Automation of Art's Value'. *Finance and Society* 2 (2): 96. https://doi.org/10.2218/finsoc.v2i2.1724.
MacKenzie, Donald. 2018. '"Making", "Taking" and the Material Political Economy of Algorithmic Trading'. *Economy and Society* 47 (4): 501–23. https://doi.org/10.1080/03085147.2018.1528076.
MacKenzie, Donald, Fabian Muniesa, and Lucia Siu, eds. 2007. *Do Economists Make Markets? On the Performativity of Economics*. Princeton University Press.
Maddox, Alexia, Supriya Singh, Heather A. Horst, and Greg Adamson. 2016. 'An Ethnography of Bitcoin: Towards a Future Research Agenda'. *Journal of Telecommunications and the Digital Economy* 4 (1): 65–78. https://doi.org/10.18080/jtde.v4n1.49.
Manski, Sarah. 2017. 'Building the Blockchain World: Technological Commonwealth or Just More of the Same?' *Strategic Change* 26 (5). https://doi.org/10.1002/jsc.2151.
Maurer, Bill, Taylor C. Nelms, and Lana Swartz. 2013. '"When Perhaps the Real Problem Is Money Itself!": The Practical Materiality of Bitcoin'. *Social Semiotics* 23 (2): 261–77. https://doi.org/10.1080/10350330.2013.777594.
McKelvey, Karissa. 2020. 'Cooperative Ownership of Data without Blockchain'. *Digital Democracy* (blog). 6 March 2020. https://www.digital-democracy.org/blog/blockchain/.
Mirowski, Philip. 2001. *Machine Dreams*. Cambridge, UK: Cambridge University Press.
Mirowski, Philip, and Edward Nik-Khah. 2018. *The Knowledge We Have Lost In Information – The History Of Information in Modern Economics*. Oxford University Press.
Monsees, Linda. 2019. *Crypto-Politics: Encryption and Democratic Practices in the Digital Era*. New Security Studies. Routledge.
Nakamoto, Satoshi. 2008. 'Bitcoin: A Peer-to-Peer Electronic Cash System'. https://bitcoin.org/bitcoin.pdf.
Nik-Khah, Edward, and Philip Mirowski. 2019. 'On Going the Market One Better: Economic Market Design and the Contradictions of Building Markets for Public Purposes'. *Economy and Society* 48 (2): 268–94. https://doi.org/10.1080/03085147.2019.1576431.
O'Dwyer, Rachel. 2015. 'The Revolution Will (Not) Be Decentralised: Blockchains'. *P2P Foundation* (blog). 2015. https://blog.p2pfoundation.net/the-revolution-will-not-be-decentralised/2015/03/23.
Oram, Andy, ed. 2001. *Peer-to-Peer, Harnessing the Benefits of Disruptive Technology*. O'Reilly.
Ossandón, José. 2019. 'Notes on Market Design and Economic Sociology'. *Economic Sociology* 20 (2): 9.
Ossandón, José, and Sebastián Ureta. 2019. 'Problematizing Markets: Market Failures and the Government of Collective Concerns'. *Economy and Society* 48 (2): 175–96. https://doi.org/10.1080/03085147.2019.1576433.

Reijers, Wessel, and Mark Coeckelbergh. 2016. 'The Blockchain as a Narrative Technology: Investigating the Social Ontology and Normative Configurations of Cryptocurrencies'. *Philosophy & Technology* 7. https://doi.org/10.1007/s13347-016-0239-x.

Rella, Ludovico. 2020. 'Steps towards an Ecology of Money Infrastructures: Materiality and Cultures of Ripple'. *Journal of Cultural Economy* 13 (2): 236–49. https://doi.org/10.1080/17530350.2020.1711532.

Roio, Denis Jaromil. 2013. 'Bitcoin, the End of the Taboo on Money'. Planetary Collegium.

Schneider, Nathan. 2019. 'Decentralization: An Incomplete Ambition'. *Journal of Cultural Economy* 12 (4): 265–85. https://doi.org/10.1080/17530350.2019.1589553.

Scott, Brett. 2014. 'Visions of a Techno-Leviathan: The Politics of the Bitcoin Blockchain'. *E-International Relations*.

———. 2018. 'These 5 Rebel Movements Want To Change How Money Works'. *Huffington Post*, 14 September 2018. https://www.huffingtonpost.co.uk/entry/five-monetary-rebellions-change-money-system_n_5b9a819ae4b0b64a336ca248.

Sellier, Alexis, Eleftherios Diakomichalis, and James Haydon. 2019. 'Trust and Sustainability in Open Source Communities', 10.

Swartz, Lana. 2018. 'What Was Bitcoin, What Will It Be? The Techno-Economic Imaginaries of a New Money Technology'. *Cultural Studies* 32 (4): 623–50. https://doi.org/10.1080/09502386.2017.1416420.

Titcomb, Abbey. 2019. 'Deep Dive: Augmented Bonding Curves'. *Giveth* (blog). 10 April 2019. https://medium.com/giveth/deep-dive-augmented-bonding-curves-3f1f7c1fa751.

Troncoso, Carmela, Marios Isaakidis, George Danezis, and Harry Halpin. 2017. 'Systematizing Decentralization and Privacy: Lessons from 15 Years of Research and Deployments'. *Proceedings on Privacy Enhancing Technologies*, no. 4: 307–29. https://doi.org/10.1515/popets-2017-0052.

Ullman, Ellen. 2013. *Close to the Machine: Technophilia and Its Discontents*. Pushkin Press.

Wood, Dr Gavin. 2014. 'ETHEREUM: A SECURE DECENTRALISED GENERALISED TRANSACTION LEDGER EIP-150 REVISION', 32.

Zook, Matthew A., and Joe Blankenship. 2018. 'New Spaces of Disruption? The Failures of Bitcoin and the Rhetorical Power of Algorithmic Governance'. *Geoforum* 96 (November): 248–55. https://doi.org/10.1016/j.geoforum.2018.08.023.

Zuboff, Shoshana. 2015. 'Big Other: Surveillance Capitalism and the Prospects of an Information Civilization'. *Journal of Information Technology* 30 (1).

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[1] See for example https://radicalxchange.org/about/

[2] See IamSatoshi 'Bitcoin Allows Activist To Do Their Work More Easily' 2015 interview with Matt Corallo https://youtu.be/0ve8hqfeM0E [accessed 12.01.2020]

[3] Archives available from: http://mailing-list-archive.cryptoanarchy.wiki/ [accessed12.01.2020]

[4] See IamSatoshi 'Bitcoin Allows Activist To Do Their Work More Easily' 2015 interview with Matt Corallo https://youtu.be/0ve8hqfeM0E [accessed 12.01.2020]

[5] See https://youtu.be/pKqdjaH1dRo 1:46 - 1:56