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Blockchains and the economic institutions of capitalism

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Abstract. Blockchains are a new digital technology that combines peer-to-peer network computing and cryptography to create an immutable decentralised public ledger. Where the ledger records money, a blockchain is a cryptocurrency, such as Bitcoin; but ledger entries can record any data structure, including property titles, identity and certification, contracts, and so on. We argue that the economics of blockchains extend beyond analysis of a new general purpose technology and its disruptive Schumpeterian consequences to the broader idea that blockchains are an institutional technology. We consider several examples of blockchain-based economic coordination and governance. We claim that blockchains are an instance of institutional evolution.

1. Introduction

Blockchains were invented anonymously and released publicly (under the alias Satoshi Nakamoto: see Nakamoto 2008) as the technology underpinning Bitcoin, a cryptocurrency. Blockchain was the technology that enabled Bitcoin finally to resolve the double-spending problem that hitherto bedevilled all previous attempts to create a digital currency, and thus to emerge as the first native internet-based currency (Evans 2014; Narayan *et al.* 2016).¹ A blockchain is a way to combine peer-to-peer networks, such as the internet, with cryptography (public key messaging and hash functions) to create an immutable time-stamped public ledger (Swan 2015; Pilkington 2016). The technological novelty of a blockchain is that can create consensus about the true state of a ledger (which might, for instance, record exchanges, contracts, ownership, identity or data)

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¹ As a specific technology for digital cryptocurrencies, a blockchain (e.g. the Bitcoin blockchain) is a technical solution to the double-spending problem (the ‘Byzantine General’s problem’) using a decentralised database with network-enforced processes based on a proof-of-work consensus mechanism for updating the database.

32 without needing to trust any centralised or intermediating party – such as an
33 auditor, a corporation, a market exchange or a government – and is in this sense
34 referred to as ‘*distributed ledger technology*’ or a ‘*trustless consensus engine*’
35 (Swanson 2014, original emphasis).

36 Cryptocurrencies have certainly attracted the attention of economists (Böhme
37 *et al.* 2015), particularly those concerned with digital money payments platforms
38 (Mills *et al.* 2016; White 2015). Cryptocurrencies and blockchains together, in
39 the past several years, have notably entered the hype-cycle of media, business
40 and government attention (Tapscott and Tapscott 2016; Walport 2016). We
41 argue that *blockchains* are the true innovation here, and however valuable
42 cryptocurrencies do (or do not) turn out to be, they are simply the first
43 instantiation of the technology. An economic analysis of blockchains should
44 therefore proceed in terms of not only money on the blockchain, but also
45 of all other possible data structures that could be on the blockchain as well.
46 The problem with an economic analysis of blockchains qua cryptocurrencies is
47 that the underlying technology is entirely separate from money and payments,
48 which were just the problem domain in which it first emerged. Blockchains
49 are understood better from an economic perspective as a public database or
50 *ledger technology*, and ledgers are significant because they are a foundational
51 institutional technology of market capitalism. This paper proposes a new way
52 of understanding the economic significance of blockchains from the perspective
53 that they are a new institutional technology.

54 Analysing the economic effect of blockchains as a new technology focuses
55 attention on the question: What type of technology is this? There have been
56 two broad categories of answer. The first is that blockchain is a general purpose
57 technology, meaning that it is expected to have broad transformative application
58 across many sectors of the economy and contribute to multifactor productivity
59 growth (Bresnahan and Trajtenberg 1995; Lipsey *et al.* 2005).² This perspective,
60 whether stated implicitly or explicitly, underpins the case for hype surrounding
61 the prospects of blockchain technology as an ‘engine of growth’. A second per-
62 spective places a different emphasis on the way in which the arrival of blockchain
63 technology might impact the economy by viewing it through a Coasian, rather
64 than a Schumpeterian, lens. Along this line, Catalini and Gans (2016) portray
65 the ‘simple economics of blockchain’ as the analysis of a new technology that
66 lowers *transaction costs* through costless verification and without the need for
67 costly intermediation, which they suggest will improve the efficiency and scope
68 of markets, moving them closer to a direct peer-to-peer ideal. This distinction
69 comes down to whether the blockchain is understood to contribute to *production*
70 *technology* (the general purpose technology view) or to *exchange technology* (the
71 market-enhancing view). Our argument is that the blockchain – or distributed

2 Other recent examples of GPTs are, for instance, 3D printing, smart robots and machine learning, artificial intelligence, virtual reality, nanomaterials and gene editing.

72 ledger technology – is neither a production nor an exchange technology per se,
73 although this is largely how it has been portrayed, but is better understood from
74 the economic perspective as an *institutional technology*.

75 Why does this distinction matter? Surely with the flood of start-up companies
76 doing ‘X, but on the blockchain’, and as X ranges across an ever wider range
77 of applications and sectors, a case can be made that blockchains are indeed a
78 general purpose technology that will improve the productive efficiency of some
79 economic operations. Furthermore, irrespective of the extent of hype (high), or
80 levels of adoption (growing, but still very low), or the actual speed and cost of
81 each transaction (for instance, with the current blocksize constraints and without
82 the use of sidechains, Bitcoin is still orders of magnitude slower and more costly
83 than global payment platforms such as Mastercard/Visa or Paypal), blockchain
84 is plainly a technology that will lower the transaction costs of some exchanges.
85 Those who take a long position on blockchain technology are in effect arguing
86 that it will improve the efficiency of economic systems by disintermediating
87 many current patterns of exchange and production, thus improving economic
88 efficiency. They see this as disruptive, in the Schumpeterian sense, because it
89 disturbs the existing economic rents that can be controlled and captured by large
90 intermediaries providing centralised trust, whether corporate or government.

91 Our claim that the significance of blockchain as an institutional technology
92 amounts to the idea that blockchain is actually a new way of coordinating
93 economic activity. That is, this technology is actually a *new type of economic*
94 *institution*. This is different from the production or exchange efficiency perspec-
95 tives, which are in effect arguing that it offers margins of improvement to existing
96 economic institutions by raising multifactor productivity or lowering transaction
97 costs. Put bluntly, our argument is that until 2009, the economic institutions of
98 capitalism consisted – in the conjoint schemas of Hayek, Williamson, Buchanan,
99 North and Ostrom – of firms, markets, commons, clubs, relational contracts
100 and governments, and that these institutions collectively furnished money, law,
101 property rights, contracts and finance through organisations and networks of
102 production and exchange (Hodgson 2015). But since 2009, there has been an
103 additional mechanism for groups of people to coordinate their economic activity,
104 i.e. through the institutional mechanism of a blockchain.

105 We do not claim to know whether the technological development and
106 adoption of blockchains will increase market efficiency (cf. Catalini and Gans
107 2016) or improve productivity in firms and governments (cf. Böhme *et al.* 2015;
108 Walport 2016). It is unclear at this early stage whether any of the current hype
109 surrounding blockchain is justified. Rather, we argue that blockchain ought to
110 be of special interest to institutional economists because it appears to offer a
111 new way of coordinating economic activity owing to the underlying technology
112 possessing many institutional aspects of market capitalism itself: viz. property
113 rights (ledger entry and private keys), exchange mechanisms (public keys and
114 peer-to-peer networks) (native money (crypto-tokens), law (code) and finance

115 (initial coin offerings). The argument of this paper is that blockchains are actually
116 an institutional technology, and should be analysed from this perspective.

117 [Section 2](#) reviews blockchain technology and how it works. [Section 3](#)
118 distinguishes between technological and institutional innovations and argues that
119 distributed ledger technology is best understood as an institutional innovation
120 (i.e. a governance technology). [Section 4](#) places our argument in the context of
121 the evolving institutions of capitalism.

122 **2. The institutional technology of ledgers and the crypto-technology of** 123 **blockchains**

124 Blockchain is the technology that underpins Bitcoin, the first successful
125 cryptocurrency. The breakthrough was the creation of a distributed ledger, such
126 that each node in the network has a copy of the ledger, and there is a mechanism
127 – a cryptographically secure and crypto-economically incentivised mechanism –
128 to ensure consensus about the true state of the ledger without the need to trust
129 a centralised node or authority.

130 A ledger is an ancient accounting technology to record (i.e. maintain consensus
131 about) who (or what) owns what, of who (or what) has agreed to what, of
132 what counts as a what, and to record when anything of value is transacted.
133 As the fundamental instruments of transactional legitimation, ledgers are an
134 elemental technology of modern market capitalism and statecraft (Allen 2011;
135 Nussbaum 1933; Yamey 1949). So a significant shift in ledger technology –
136 from a centralised method of producing consensus in the ledger (using trust) to a
137 distributed approach to consensus (using the blockchain) – could transform the
138 transactional mechanics of a modern economy.

139 The basic qualities a ledger possesses are clarity (i.e. legibility), consistency
140 and consensus as a factual and agreed-upon recording of the basic datum of
141 an economy: of identity, property, contract and value, and usually recording
142 time and sometimes location. A ledger is basically a recording of the state
143 of an economy, and changes in the ledger register changes in the economy
144 in consequence of economic actions and transactions. But the other quality a
145 ledger must possess is that it is trusted. A well-trusted ledger creates a low
146 transaction cost economy, a precondition for economic efficiency and prosperity
147 (Nooteboom 2002; North 1990). Trust is highest when the ledger is centralised
148 and strong, and so ledgers for property titling, contracts, money and suchlike
149 have long cemented government at the centre of modern capitalism. The need for
150 high-quality trusted ledgers is, in this sense, the same expression of the need for
151 high-quality central government institutions (non-corrupt, efficient) and large
152 centralised aggregating organisations. But large central governments and large
153 aggregator corporations come at a cost, both in overhead processes associated
154 with statecraft (Scott 1998), and in distorted incentives (the subject of public
155 choice economics). Manufacturing trust is necessary, but often expensive.

156 The technology of blockchain combines mathematical cryptography, open-
 157 source software, computer networks and incentive mechanisms. A blockchain
 158 is a cryptographically secured and crypto-economically incentivised class of dis-
 159 tributed ledger – in plain language, a decentralised database. By having a public
 160 distributed ledger the blockchain substitutes public verification and consensus for
 161 auditing by a trusted third party. Many of the technical specifics need not concern
 162 us here, details of which can be found in Buterin (2014b), Nakamoto (2008),
 163 Pilkington (2016), Swan (2015), Swanson (2014) and Wood (2014c). But three
 164 aspects of how they work are instrumental to our perspective of blockchains as
 165 a new institutional technology: first, a blockchain is a database that produces
 166 trustless consensus; second, blockchains operate on the internet, and so the possi-
 167 bilities of economic coordination are limited by the extent of the blockchain; and
 168 third, blockchains are a database, and anything digital can exist on a blockchain.

169 *Blockchains are consensus engines*

170 A ledger is a way of producing consensus about the facts that are necessary for
 171 commerce to function. Moreover, the institutional and organisational outline of
 172 a modern economy is a consequence of those ledgers needing to be centralised (i.e.
 173 in government, in layers of bureaucracy, in large corporations). A blockchain
 174 is a new approach to building and using ledgers, i.e. to producing consensus.
 175 The new part is to have figured out a way to use distributed ledgers (as
 176 opposed to centralised ledgers) securely and effectively and thus to produce
 177 consensus without requiring centralised trust, overturning the old technology
 178 of ledgers that needed to be centralised in order to be trusted. A blockchain
 179 is a ‘trustless’ distributed ledger. Cryptographically secured blockchains are
 180 said to be ‘trustless’ because they do not require third-party verification (i.e.
 181 trust), but instead use high-powered crypto-economic³ incentive protocols to
 182 verify the authenticity of a transaction in the database (i.e. to reach consensus).
 183 This is how blockchains can disintermediate a transaction (a *consequence* of
 184 which is lowered transaction costs), resulting in new forms of organisation
 185 and governance. Examples are the ‘distributed autonomous organisations’
 186 (DAOs) and ‘initial coin offerings’ (ICOs) that disintermediate the allocation
 187 of venture capital;⁴ ‘Steem’ disintermediating user-generated content production
 188 and rewards (Larimer *et al.* 2016); and ‘Backfeed’⁵ disintermediating open

3 ‘Crypto-economic’ refers to any decentralised cryptographic protocol that ‘uses economic incentives to ensure that it keeps going and doesn’t go back in time or incur any other glitch’ (Buterin 2015). The proof-of-work Bitcoin mining protocols are crypto-economic in this sense.

4 The DAO (<http://daohub.org/>) is a crowd-sourced investment fund running on the Ethereum blockchain. It is an example of a DAO (Decentralised Autonomous Organisation). ‘A DAO is effectively a community, with its resources organised according to rules agreed in advance and set out in its code’ (Allen and Overy 2016: 3).

5 ‘Backfeed’ is a protocol for building decentralised organisations, or distributed governance systems, through a proof-of-value consensus mechanism. It runs on the Ethereum blockchain. See <http://backfeed.cc/>.

189 source collaboration. In each case, blockchain provides the ‘technology stack’
 190 to coordinate the economic actions of an emergent community without the need
 191 for a trusted (third-party, centralised, intermediating) coordinator.

192 By contrast, centralised ledger technologies, as deployed by governments
 193 and large corporations, are trust-based technologies because their functioning
 194 is conditional upon trust in their legitimacy and accuracy. The problem is
 195 that trust, and the high-quality institutions required to support it, can be
 196 expensive to manufacture conventionally. Klein (1997) contains several case
 197 studies demonstrating how trust is necessary to facilitate trade – yet establishing
 198 that trust can be very expensive, often involving large, visible and irreversible
 199 investments (De Long 1991; Klein and Leffler 1981). In the case of third-party
 200 enforcement via the nation state, this requires a monopoly on coercive powers
 201 (Olson 1993), and an implicit promise (a social contract) not to abuse that
 202 power. In consequence, enormous rents are locked up behind these centralised
 203 monopolies of trust. Trustless technologies are thus an important step in
 204 unlocking and releasing that value and in overcoming the hazards involved
 205 in manufacturing trust. By removing the need for powerful central third-party
 206 validation, verification and enforcement mechanisms, cryptographically secured
 207 blockchain technologies are in principle safe transaction environments, even in
 208 the presence of powerful or hostile third parties trying to prevent users from
 209 participating, and they achieve this with high transparency as well as furnishing
 210 scope for exit, when irreconcilable disagreements arise, through a ‘fork’ in the
 211 code.⁶

212 *Blockchains are limited by the extent of the internet*

213 Blockchains are ledgers (or databases) and anything that can be coded into a
 214 ledger can be recorded on a blockchain. The most obvious data are numbers
 215 recording units of account. But strings of numbers can be used to represent
 216 identities, or programs, and in this way ledgers can become units of computation.
 217 Blockchain protocols are mechanisms to arrive at consensus about which
 218 numbers or programs are the true and agreed-upon ones, and once time-stamped
 219 these enter as a block into a continuous chain, linked to all previous blocks (hence
 220 block-chain) all the way back to the genesis transaction.

221 Blockchains are a technology that operates on the internet, i.e. on networks
 222 of computers. In the same way the internet was the next generation beyond
 223 (unlinked) computers, blockchains are claimed to be the next generation beyond
 224 the internet. What blockchains bring to the internet are *public ledger protocols*.
 225 What this does, in effect, is to turn the internet into a ‘public computer’, or a
 226 ‘world computer’ (Wood 2014c). This was not initially obvious in the seminal

⁶ ‘Forking’ is a term of art in software engineering when a copy of the source code is made to start (i.e. fork) a new line of development. In open source software, forking does not require developer permission. See <https://bitcoin.org/en/glossary/hard-fork> (accessed 30 April 2017).

227 version of blockchain, built to solve a specific problem – but by adding a general
228 scripting language with programmable functionality blockchains can become a
229 platform for creating ‘smart ledgers’ (Swanson 2014).

230 An example of a smart ledger is *Ethereum* (Buterin 2014b, De Filippi
231 and Mauro 2014). If Bitcoin can be described as a specialised technology,
232 a cryptographically secure transaction-based state machine, then Ethereum
233 attempts to build the generalised technology (a virtual machine) on which
234 all transaction-based state machine concepts may be built. It is a platform
235 for zero-trust computing (Wood 2014c). The generalised Ethereum blockchain
236 technology is the Turing-complete scripting language and protocols for building
237 decentralised applications that run on the Ethereum blockchain using its own
238 native cryptocurrency (Ether). In Ethereum agents can write and execute
239 *smart contracts* (a self-executing digital contract), from which can be created
240 decentralised applications including Distributed Autonomous Organisations
241 (DAOs).⁷ Smart contracts and DAOs enable the internet of things (IoT), which
242 must ultimately require a decentralised register because its scale will vastly exceed
243 any possible centralised ledger.

244 Blockchains enable the basic technology of a public ledger to evolve into a
245 public computer for economic coordination. Vitalik Buterin (2015), co-founder
246 of Ethereum, provides this definition of blockchains:

247 A blockchain can upload programs and leave the programs to self-execute,
248 where the current and all previous states of every program are always publically
249 visible, and which carries a very strong cryptoeconomically secured guarantee
250 that programs running on the chain will continue to execute in exactly the way
251 that the blockchain protocol specifies. . . . Blockchains are not about bringing
252 to the world any one particular ruleset, they’re about creating the freedom to
253 create a new mechanism with a new ruleset extremely quickly and pushing it
254 out. They’re Lego Mindstorms for building economic and social institutions.

255 Blockchains are platforms for building bespoke economic coordination using
256 distributed ledgers augmented with computationally embedded features such
257 as programmable money (cryptocurrencies), programmable contracts (i.e. smart
258 contracts) and organisations made of software (DAOs). These are building blocks
259 of new forms of economic governance. This is the sense in which blockchains
260 are an institutional technology.

261 *Blockchains are digital databases*

262 Third, blockchains are a generalised economic institution in the same way a
263 market is. Just as we can identify a market mechanism without specifying
264 what is actually exchanged in that market, this is also true of a blockchain.
265 Anything configurable or able to be represented in a digital database can be

7 Buterin (2014a), Wood (2014a, 2014b).

266 on a blockchain. Blockchains are of course a very new technology – viz. the
 267 Bitcoin blockchain has been operating continuously since 2009 and the Ethereum
 268 blockchain only since 2015 – and so beyond the initial proof of concept by
 269 putting money on the blockchain (i.e. cryptocurrencies),⁸ much entrepreneurial
 270 attention being paid to the technology is focused on testing experimentally what
 271 else can be put on the blockchain, and the associated costs and benefits of
 272 that action (Allen 2016; De Filippi 2015). The number of blockchain start-
 273 up companies and the amount of venture capital invested has grown rapidly
 274 recently,⁹ ranging across a large domain of applications including: identity,
 275 property and asset titles, financial securities, intellectual property, insurance,
 276 IoT, certification, health records, smart contracts, prediction markets, gambling,
 277 notaries, logistics platforms, provenance, wallets, social networks, and media
 278 and open science, among others.

279 3. What sort of technology is blockchain?

280 It is said that blockchains are a new general purpose technology (Pilkington
 281 2016), of the same class of technological trajectories as, for instance, electricity,
 282 transistors, computers, the internet, mobile phones and so on (Perez 2009).
 283 Popular articles on blockchains often represent the technology as the next
 284 generation of the internet, or as the ‘internet of value’ (e.g. Swan 2015; Tapscott
 285 and Tapscott 2016). Such tropes are intended to foreshadow blockchains as
 286 being similarly large, disruptive and widespread as comparable to computers
 287 or the internet. Yet an economic analysis of blockchain technology needs to
 288 consider carefully just what sort of technology it really is. If blockchains are
 289 a *general purpose technology*, then their significance is in being next in a
 290 line of transformative information technologies, each powering a productivity
 291 revolution: e.g. transistors, computers, the internet and now blockchains. If so,
 292 then what matters is the estimate of the productivity dividend they might bring
 293 (i.e. whether it is large or small and how it is distributed). But if blockchains
 294 are better understood as a new *institutional technology*, then what we have is
 295 the arrival of a new species of economic coordination – *à la* Williamson (1985)
 296 and North (1990) – firms, markets, relational contracting and now blockchains.
 297 If this is the case, then what matters is what economic activities will shift to
 298 this mode of coordination, which is to say that the interesting question is the
 299 reorganisation of the institutional boundaries of economic coordination.

300 We can thus examine the economics of blockchain technology through a
 301 Schumpeterian lens of the productivity consequences of adopting and diffusing

8 See <https://coinmarketcap.com/> for a listing of prices and trade volumes. As of April 2017, the market cap of all cryptocurrencies was about \$USD 23 billion.

9 AngelList (<https://angel.co/blockchains>) lists over 500 blockchain start-ups, with an average valuation at \$USD 4 million, as at March 2017.

302 a new information and communications technology, or through an institutional
303 lens of efficient governance. A general purpose technology (GPT)-focused
304 analysis will emphasise the gains in total factor productivity (TFP) to existing
305 economic operations, as well as its creative-destructive effect on firms, markets,
306 industries and jobs. But an institutionally focused analysis of blockchains as a
307 new coordination technology focuses on a different aspect, viz. how blockchains
308 compete with firms, markets and economies as institutional alternatives for
309 coordinating the economic actions of groups of people.

310 *Two sorts of technology*

311 Blockchain is a new technology, and the invention, adoption and use of this
312 new technology can be examined using economic theory. But there are two
313 distinct (yet commensurable) approaches to the meaning of technological change:
314 the neoclassical approach, and the institutional or evolutionary approach. In
315 the neoclassical production-function model, technological change is a change
316 in factor productivity. In the institutional/evolutionary approach, technologies
317 also include ‘social technologies’, or institutions and organisations, as rules for
318 coordinating people, and so institutional change is also a type of technological
319 change (Nelson and Sampat 2001). In the social technology approach,
320 technological change is a change in institutional efficiency.

321 In the neoclassical model, blockchain technology is factor augmenting.
322 Its adoption drives economic growth by improving efficiencies, or reducing
323 inefficiencies, using a superior technology to achieve a particular task, e.g. as
324 a payments system or asset transfer register (Catalini and Tucker 2016). People
325 adopt the new technology because of these marginal productive efficiency gains.
326 Technological change makes one or more input factors more productive (i.e.
327 it is factor augmenting) and so the aggregate measure of technological change
328 is TFP. TFP is equivalently a measure of economic growth and real income
329 because the rewards of increased factor productivity accrue to the owners of those
330 factors. Technological change in any general purpose technology (say electricity,
331 computers or blockchains) is factor augmenting. The benefit of adopting
332 electricity or computers does not accrue just to the owners of those technologies,
333 but under competition accrues to *all factors* that use those technologies, because
334 their marginal productivity (and therefore marginal revenue product) has been
335 enhanced. Blockchain innovations increase TFP by reducing the production costs
336 associated with any endeavour to produce a particular output. An example is
337 private or permissioned blockchains that reduce the cost of doing a particular
338 thing (such as reconciliation, or international money transfers). Here blockchain
339 technology reduces a production cost by eliminating an intermediate cost or
340 lowering the cost of a process, such as verification (Catalini and Gans 2016).
341 We can model blockchain as a productivity-enhancing technological change by
342 treating it as the latest in a long line of general-purpose technologies. And while
343 the specifics of the size of the aggregate effect and the form of the distributional

344 gains and losses are *ex ante* unknowable, as are the shape of the entrepreneurial
 345 opportunities and also forms of consumer surplus, what can be inferred is that
 346 the new technology will contribute to economic growth and prosperity because,
 347 by making existing factors more productive, it ‘economises’ on scarce resources.

348 But there is another way that economising can occur, which is by economising
 349 not on *production costs*, but on *transaction costs*. This idea was elucidated by
 350 Ronald Coase (1937, 1960) to explain the existence of the firm and the existence
 351 of the law. The basic insight of new institutional economics was asking why some
 352 transactions occur in firms (hierarchies) rather than in markets? The answer was
 353 that because of transaction costs in dealing with uncertainty, asset specificity,
 354 and frequency of dealings, some transactions are conducted more efficiently
 355 in hierarchies rather than in markets (Williamson 1979, 1985). Transaction
 356 costs thus determine the efficiency of different governance institutions. The
 357 basic insight that transaction cost economics can bring to the economics of
 358 blockchain is to ask the same, but now extended, question: why do (or might)
 359 some transactions occur in blockchains, rather than in firms or markets?

360 Transaction costs are the costs of coordinating economic activities, and
 361 reductions in transaction costs do impact TFP measures. The mechanism of
 362 their effect, however, is different. Effective institutional innovations reduce
 363 the transaction costs of coordinating economic activities. Improvements in
 364 institutional orders reduce transaction costs, and drive investment in those
 365 economic orders, which eventually manifest as increases in economic activity per
 366 input unit, and so as TFP growth. In the neoclassical approach, technological
 367 change lowers production costs. In the new institutional approach, technological
 368 change lowers transaction costs.

369 So the question is – which type of technological change is blockchain? Which
 370 type of costs – production costs or transaction costs – does it affect most signifi-
 371 cantly? Now, blockchain is manifestly an information technology – as a software
 372 protocol based on cryptography, a blockchain is a new technology for public
 373 databases of digital information – but blockchain is also manifestly a GPT. So at
 374 first sight it seems to be a productivity-enhancing technology that economises on
 375 production costs. Yet when we dig deeper into the nature of blockchain-based
 376 economising, it is often a consequence of transaction cost efficiencies.

377 *Blockchains are a technology for economic coordination*

378 With a productivity enhancing innovation, the new technology enables more to
 379 be done with less. The new technology should outcompete the old technology
 380 on some important margin. If, however, we focus on blockchains as a
 381 cryptocurrency and payments system, e.g. Bitcoin, on many margins it seems
 382 a vastly inferior technology. With the current state of the technology (with
 383 an average blocksize less than 1MB, and without sidechains) it is slower than
 384 credit card-based payments platforms such as Visa, and has a lower capacity
 385 channel. But new technologies are usually worse on some dimensions, and

386 their value often accrues to properties that were poor or non-existent in the
 387 competing technology. With cryptocurrency payments the relevant feature is the
 388 deep architectural change in how payments work, now entirely peer-to-peer.
 389 This has costs, including transactions being irreversible (although for some that
 390 is a powerful benefit). But the benefits relate to what is no longer required,
 391 namely corporate or government permissioning, monitoring and regulation of
 392 private finance (replaced by a crypto-wallet that can pay anyone, anywhere,
 393 who also has such a wallet). As such, the productivity gains come from the
 394 organisational efficiency gains, from stripping out layers of activity no longer
 395 needed because trusted third parties are not required, or can be achieved more
 396 efficiently using native capabilities in the blockchain technology stack, such as
 397 multisig protocols.¹⁰

398 Distributed ledgers are a technology of decentralisation. Centralisation can
 399 be an efficient source of order and control at small scales, but complex self-
 400 organising systems tend toward decentralisation as they grow because the
 401 coordination costs eventually overwhelm any centralised node, causing fragility.
 402 Loss of centralised control is a cost, but the benefit is that decentralised systems
 403 are more robust. Distributed systems still require system-wide coordination,
 404 however; this is usually achieved through adaptation, for example through the
 405 price system in a market (Hayek 1945).¹¹ Blockchains create distributed systems
 406 by eliminating centralisation, which was needed previously for reconciliation or
 407 consensus on a ledger with an alternative technology for achieving consensus
 408 about economic data. The implication is that by providing an alternative
 409 organisational mechanism to reach agreement about economic facts, which
 410 are used in turn to coordinate economic activity, this technology offers an
 411 alternative way of coordinating economic activity. Distributed ledgers are a
 412 technology for economic coordination that is a potential substitute for the
 413 economic coordination provided by markets, hierarchies, relational contracting
 414 and governments. Blockchains are in this sense an institutional innovation. The
 415 relevant margin of economic analysis is therefore not with TFP and growth, but
 416 rather with substitute mechanisms of economic coordination and governance.
 417 To unpack the relevant margins of governance efficiency that blockchains have
 418 over firms, markets, networks, relational contracting and governments, consider
 419 the underlying problem of the economics of efficient governance.

420 *A transactions cost explanation of the economic efficiency of blockchains*

421 The comparative economic efficiency of blockchains can be understood as
 422 a simple extension of Williamson's (1985) operationalisation of Coase's
 423 transactions cost analysis with respect to the comparative efficiency of firms

10 An explanation of multisig protocols is available here: <https://coincenter.org/entry/what-is-multi-sig-and-what-can-it-do> (accessed 30 March 2017).

11 Tokens within the blockchain can be thought of as being an 'inbuilt' price mechanism.

424 *versus* markets. Williamson argued that a hierarchical organisation and relational
 425 contracting are ways to control *opportunism* in the presence of bounded
 426 rationality and asset specificity, by internalising the (transaction) costs of
 427 opportunism. Control of opportunism is not the only economic reason that
 428 firms exist (Hodgson 2004; Langlois 1995) but it is one force that allocates
 429 economic activity across comparative economic institutions. Blockchains can
 430 also control opportunism, but they do so by harnessing market mechanisms and
 431 internalising them within a closed and guaranteed payments system. Williamson
 432 (1979) argued that under common behavioural, technological and organisational
 433 conditions, firms minimise the transaction costs of controlling opportunism, and
 434 are thus efficient ways to organise economic activity. A similar claim is that
 435 blockchain platforms can minimise opportunism by a combination of radical
 436 public transparency coupled with cryptographic enforcement and execution
 437 through smart contracts and their agents (e.g. DAOs) (Swanson 2014).

438 To the extent that opportunistic behaviour becomes searchable public
 439 information (overcoming bounded rationality), the private costs of opportunism
 440 are now higher. And to the extent that detailed contracts can be written
 441 and executed indefinitely in the future, the counter-party risks associated with
 442 investment in specialised assets are reduced. The implication is that blockchain-
 443 based platforms for coordinating economic activity may compete effectively
 444 with hierarchies (which exploit incomplete contracts to overcome opportunism)
 445 and relational contracting (which requires trust between parties, and exploits
 446 the expectation of repeated exchanges) on some important margins. Where
 447 blockchains can mitigate opportunism through crypto-economic incentives and
 448 mechanisms at a relatively low transaction cost they will be more efficient
 449 (i.e. transaction-cost minimising) institutions for coordinating economic activity
 450 compared to organisational hierarchies and relational contracts (which are in
 451 turn, *à la* Williamson, more efficient than markets).

452 A possible counterargument is that while firms are made of *incomplete*
 453 *contracts* (Hart 1989), blockchain-based smart contracts and DAOs are by
 454 construction a domain of *complete contracts* (Wright and De Filippi 2015).¹²
 455 This sharpens the distinction between blockchains, firms, relational contracts
 456 and markets. In the Coasian view, a firm is a ‘nexus of contracts’, but
 457 specifically a nexus of *incomplete contracts* (Hart and Moore 1990; Jensen and
 458 Meckling 1976; Williamson 1985). In a world with zero transaction costs, all
 459 contracts would be complete and all economic coordination would be through
 460 market transactions. Incomplete contracting models (Tirole 1999) usually invoke

12 Abramowicz (2016: 362) observes that ‘cryptocurrencies cannot solve the problem of incomplete contracts, and as long as contracts are incomplete, humans will need to resolve ambiguities’. Yet building on Wright and De Filippi’s (2015) approach to ‘Lex Cryptographica’, Abramowicz proposes a model of peer-to-peer law in which cryptocurrency protocols incentivise collective human judgment both to make law and to resolve disputes with incomplete contracts.

461 transaction costs arising from: (1) uncertainty, or unforeseen contingencies,
462 as information problems; (2) the costs of writing contracts; (3) the costs of
463 enforcing contracts. The implication is that blockchains may not compete head-
464 to-head with firms, but rather may carve out those parts of firms that can be
465 rendered as complete contracts where they lower transaction costs on any of
466 these three margins. For instance, blockchain-enabled smart contract-facilitated
467 transactions should in principle experience fewer efficiency problems due to
468 information asymmetries – adverse selection (prior to a transaction) and moral
469 hazard (following a transaction). Smart contracts could also be effective ways to
470 load significant numbers of low-probability state contingencies into contracts.
471 These could function like open-source libraries able to be inserted into machine-
472 readable contracts, reducing the complexity cost of writing large state-contingent
473 contracts, and so lowering transaction costs. Both *ex ante* contractual discovery
474 and *ex post* contractual renegotiation costs (i.e. bargaining and haggling costs)
475 are an expected consequence of incomplete contracts. Such contracts have
476 dynamic benefits, enabling adaptation, but in the shadow of these expected
477 but uncertain costs all parties will contract less than is optimal. Blockchains
478 potentially enable the known parts of these relationships to be carved out
479 efficiently from the unknown parts, and executed automatically based upon state
480 conditionals, increasing the range to which economic coordination can extend
481 into the future.

482 In new institutional economic analysis, organisational form is shaped by the
483 need to control opportunism (Williamson 1985: 64–7). The proximate cause
484 of opportunism is the conjoint pay-offs to idiosyncratic investment – i.e. asset
485 specificity, a normal part of all economic production requiring the coordination
486 of joint inputs. But the ultimate cause of opportunism is the intent and ability
487 of agents to exploit trust. Williamson calls this ‘self-interest seeking with guile’,
488 and emphasises the connection with bounded rationality. With full rationality,
489 complete information and costless transactions, all agents can comprehensively
490 contract with no need for trust. But with bounded rationality (i.e. imperfect
491 information and costly transactions) the economic margin of contracting is
492 trust – i.e. contract up to the point where the marginal cost of supplying
493 trust (accumulating agent-specific experience, monitoring reputation) equals the
494 marginal benefit of that trust (the surplus, compared to the next best institutional
495 alternative). In this view, blockchains are an additional mechanism for
496 controlling opportunism, eliminating the need for trust by using crypto-enforced
497 execution of contracts through consensus and transparency. Opportunism is
498 significantly reduced in DAOs compared to in-the-world Williamsonian firms. As
499 Catalini and Gans (2016) emphasise in their claims that blockchain technology
500 lowers verification costs, the lowered costs of opportunism also extend the
501 domain of the market and shrink the domain of organisations. So, if the
502 Williamson model of firms and markets is correct that economic activity and
503 investment is stymied by threats and engagement of opportunism, blockchains

504 are an institutional innovation. If governance exists for reasons other than
 505 opportunism, however, then distributed ledger technologies may well be a source
 506 of productivity growth, but not the institutional revolution argued here.

507 Alchian and Demsetz (1972) suggest another possible avenue whereby a
 508 blockchain governance revolution may unfold at the margin of the economic
 509 efficiency of organisations *versus* markets. They proposed an alternative
 510 transaction costs theory of the firm that emphasised monitoring costs in team
 511 production. When production is more efficient with shared inputs than non-
 512 shared ones, it may be more efficient to establish sets of agreements that
 513 characterise firms as the team use of inputs plus the centralised position of
 514 some party in the contractual arrangements of all other inputs, than to govern
 515 these transactions using markets. The Alchian and Demsetz model argues for
 516 the efficiency of centralised monitoring. What blockchains introduce, however,
 517 is a new prospect of *distributed monitoring*, undermining the main argument for
 518 the comparative efficiency of the firm in the context of the generalised efficiency
 519 of production with shared inputs. In essence the blockchain is not simply a
 520 trustless technology, it is a *self-monitoring technology* too. To illustrate this
 521 point consider Alchian's (1983) definition of a firm:¹³

522 A firm is a (1) coalition of interspecific resources, some of which are owned in
 523 common (2), and some of which are compensated according to some criteria
 524 other than separably additive outputs and other than by directly measured
 525 marginal productivity (3) of saleable products.

526 For Alchian (1983) asset specificity and quasi-rents are the defining features of
 527 the firm. The firm has to own specific assets to prevent *ex post* opportunistic
 528 expropriation. This necessitates a non-market-related monitoring and reward
 529 system within the firm. The blockchain, however, has the potential to resolve, or
 530 at least largely ameliorate, those issues. For example, Bitcoin relies on a proof-of-
 531 work algorithm that is analogous to the Alchian and Demsetz (1972) monitoring
 532 problem: has task A been performed or not? While this is a valuable function, it
 533 is possible to extend the principle.

534 For example, *Backfeed*,¹⁴ a social protocol that builds upon blockchain-
 535 based infrastructure and the smart-contract platform provided by Ethereum,
 536 implements an alternative and more generic consensus algorithm called proof-of-
 537 value that relies on human evaluation to discover the value of every contribution
 538 as perceived according to the distinctive value system of each individual
 539 network. *Steem*,¹⁵ a blockchain-based social media organisation, performs a
 540 similar function though community-voting using its native cryptocurrency.
 541 Individual members of a community or organisation evaluate the contributions

13 This paper is an extension and partial correction to the earlier Alchian and Demsetz (1972) paper.

14 See <http://backfeed.cc/>

15 See <https://steem.io/>.

542 of others, who will be rewarded (according to the value they bring to the
 543 community) with economic tokens (transferable) and a reputation score (non-
 544 transferable) that indicates the influence they hold within the organisation.¹⁶
 545 The Backfeed protocol that substitutes for monitoring deploys a market-like
 546 mechanism (reputation and price) to allow for the collaborative creation and
 547 distribution of value in peer networks. The system relies on a specific protocol to
 548 enable distributed peer networks to contribute to an organisation. Through the
 549 blockchain-based Backfeed protocol they can coordinate themselves indirectly,
 550 mutually exploiting their specialised knowledge (*à la* Hayek 1945). A peer-to-
 551 peer evaluation system determines the perceived value of each contribution in a
 552 decentralised fashion in order to allocate influence and rewards accordingly.

553 Backfeed is an experimental protocol that is itself built on an experimental
 554 platform – Ethereum – and Steem is a proof-of-concept social media platform.
 555 They may or may not succeed. They are interesting, however, because they appear
 556 to be a new type of economic institution. These blockchain protocols enable
 557 a decentralised reputation system to distribute authority among community
 558 members dynamically in order to organise individuals organically into a
 559 meritocracy with a decentralised topology. The values of every individual
 560 that partake in the organisation, weighted according to the influence they
 561 each hold within that organisation, constitute – in aggregate – the overall
 562 value system of the organisation. As the dynamics of the organisation evolve,
 563 with new contributors coming and old contributors leaving, the influence of
 564 every individual will change, and so ultimately will the value system of that
 565 organisation. The blockchain-based Backfeed protocol has firm-like, market-like
 566 and government-like properties, yet is a distinct form of economic governance.

567 The Williamson model of the firm (opportunism) and the Alchian and Demsetz
 568 model of the firm (monitoring) both provide theoretical reasons to expect that
 569 blockchain technology may erode the margin of the comparative efficiency of
 570 firms. Catalini and Gans (2016) make a similar point, indicating that blockchain
 571 shifts the margin of institutional efficiency toward markets. The point we have
 572 made in this paper is that all of these theoretical arguments can be sound, but
 573 that the Williamson, Alchian and Demsetz, or the Gans and Catalini predictions
 574 about the shifted boundaries of firms and markets may not follow because they
 575 failed to consider a further option: namely that the dynamic at work is not a
 576 reallocation of economic activity across a given set of institutions – markets,
 577 hierarchies, relational contracting – but rather the mass adoption of this new
 578 technology may lead to an evolution of the economic institutions of capitalism
 579 itself.

16 The reputation score in the Backfeed protocol can increase in two ways: (1) by making a contribution that is perceived as valuable by the community; and (2) by making a useful evaluation of someone else's contribution. Hence, individuals are judged not only by their actions (or contributions), but also by their judgment (or evaluations) of the actions of others.

580 **4. Blockchains and institutional economic evolution**

581 Blockchain-based distributed ledger technology adds an additional category
 582 to the suite of Williamson's (1985) 'economic institutions of capitalism' –
 583 viz. markets, hierarchies and relational contracting – with a *new type of*
 584 *economic order*: a decentralised collaborative organisation (DCO).¹⁷ A DCO is
 585 a self-governing organisation with the coordination properties of a market, the
 586 governance properties of a commons and the constitutional, legal and monetary
 587 properties of a nation state. It is an organisation, but it is not hierarchical. It
 588 has the coordination properties of a market through the token systems that
 589 coordinate distributed action, but it is not a market because the predominant
 590 activity is production, not exchange. And it has the unanimous constitutional
 591 properties of a rule-of-law governed nation state, by complicit agreement of
 592 all 'citizens' who opt in to such a decentralised collaborative organisation,
 593 and the automatic execution of the rules of that DCO through smart contract
 594 enforcement (Atzori 2015).¹⁸

595 The central argument of this paper has been that much of the extant hype
 596 around blockchain as a new digital technology that will drive productivity
 597 growth – just as previous generations of ICT have done – actually misrepresents
 598 its nature as a technology. We have argued that the interesting thing about
 599 blockchain is that it is an institutional innovation. From this perspective, its
 600 significance is as an evolutionary development in the institutions of market
 601 capitalism (Hodgson 2015). An economy with blockchain technology is
 602 institutionally more varied and complex than an economy without it. From an
 603 analytic perspective, the relevant question is the margin upon which blockchain
 604 institutions compete with alternative modes of economic coordination – markets,
 605 hierarchies and relational contracting (Williamson 1979, 1991), as well as
 606 clubs, commons and government (North 1990; Ostrom 1990, 2005). We have
 607 suggested that transaction costs provide a lens through which to understand
 608 the comparative institutional advantage of blockchains and the co-evolutionary
 609 dynamics with other institutions of market capitalism.

610 One path by which the institutions of market capitalism may adapt to
 611 blockchain technologies is through the substitution of economic governance from
 612 firms, markets, and relational contracts with blockchains. The same economic
 613 activity is institutionally reallocated. Currency transactions or settlement of
 614 financial trades move 'to the blockchain' for instance. But another path is that
 615 blockchains-based coordination may enable new types of economic activity that
 616 were previously not able to be governed by firms, markets or governments
 617 because the transaction costs were too high to justify the expected benefits.

17 See Ostrom (2005) and Stringham (2015) on the evolution of private or community-level rule-governed economic orders.

18 Reijers et al. (2016) argue that blockchain governance is a special type of social contract mechanism, and thereby suffers the same basic problems that are invariably resolved through political action.

618 In this case, a more institutionally varied economy (now containing blockchain
 619 coordination) can support new types of economic activity. In this instance the
 620 economy becomes more institutionally and economically complex. The Ethereum
 621 blockchain-based examples of Backfeed and Steem discussed above illustrate
 622 this, bringing economic coordination and governance institutions to spaces that
 623 currently are either served poorly or served not at all by extant coordination
 624 mechanisms of markets, hierarchies and governments. In other words, the impact
 625 of blockchain technology may be less to improve the efficiency of existing
 626 economic orders (for example dis-intermediating payments and finance) than
 627 to expand the scope and depth of economic governance through the evolution
 628 of new types of coordinating institutions that are native to blockchains.

629 The evolutionary character of modern institutional economic analysis is
 630 Veblenian and Darwinian (Hodgson 1998; Hodgson and Knudsen 2010) or
 631 game theoretic (Schotter 2008). What it is not, generally, is Schumpeterian, for
 632 the simple reason that institutions are understood as coordinating rules, rather
 633 than as disruptive new technologies. But what is interesting about blockchain
 634 technology is that the current mix of hype and scepticism about its status
 635 as a new information technology or general purpose technology (GPT) has
 636 largely overlooked a further possibility: viz. that it is an *institutional technology*.
 637 New technologies of governance are relatively rare but it is important to
 638 identify them because unlike most GPTs, where the main dynamic effect is
 639 diffuse productivity gains, an institutional technology introduces a new mode
 640 of economic coordination and governance. We have argued in this paper that
 641 blockchain technology, while just one of a many Schumpeterian technologies
 642 driving economic evolution, ought nevertheless to be of particular interest to
 643 institutional economists, whether from a transaction costs perspective in seeking
 644 to understand the boundaries of firms and markets, or from the perspective of
 645 the evolution of economic institutions.

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