Blockchain and supply chains: 
V-form organisations, value redistributions, de-commoditisation and quality proxies

Darcy W. E. Allen, Alastair Berg and Brendan Markey-Towler

This version 12 December 2018

Abstract: In this paper we apply institutional cryptoeconomics to the information problems in global trade networks, model the incentives under which blockchain-based supply chain infrastructure will be built, and make predictions about the future of supply chain governance. We propose that blockchain will not simply make supply chains more efficient, but might fundamentally change the patterns and dynamics of how, where and what we trade by: (1) facilitating new forms of economic organisation governing supply chain coordination (e.g. the V-form organisation); (2) shifting economic power towards the ends of supply chains (e.g. primary producers) by decreasing information asymmetries; (3) de-commoditising goods and disaggregating price signals by changing the dimensions along which goods may be reliably differentiated; and (4) lowering reliance on proxies (e.g. production within national borders) for the quality of goods. We also discuss the policy implications of blockchain-based supply chain infrastructure.

Keywords: Blockchain, Institutional Cryptoeconomics, Supply Chain, Blockchain Trade, V-form Organisation

1 Dr Darcy W. E. Allen and Mr Alastair Berg are with the RMIT Blockchain Innovation Hub, RMIT University, Melbourne. Correspondence: darcy.allen@rmit.edu.au. Dr Brendan Markey-Towler is an affiliated researcher with RMIT Blockchain Innovation Hub, RMIT University, Melbourne.

Electronic copy available at: https://ssrn.com/abstract=3299725
1. Introduction

Blockchain technology is poised to act as new economic infrastructure underpinning global trade networks (Allen et al. 2018b). As a technology for creating distributed ledgers of information, blockchain may act as the infrastructure on which information about goods are validated, stored and accessed. By decreasing costs and increasing transparency, blockchain might not simply make our existing supply chain structures more efficient. Rather, blockchain might transform how, where and what we trade. We can see this by observing trade technologies through history. For instance, when the standardised shipping container was invented in the 1950s it didn’t just make goods cheaper; it also altered trading patterns, opened up new trade networks, and made traditional port infrastructure redundant (Levinson 2016).

In this paper we draw on the existing literature of blockchain-based supply chains (Allen et al. 2018b) together with the emerging field of institutional cryptoeconomics (Berg 2017; Davidson et al. 2018; MacDonald et al. 2016) to examine how blockchain-based supply chain infrastructure changes the way we move goods. After modelling the incentives for supply chain actors to implement and build blockchain-based infrastructure we generate four predictions:

1. The creation of new forms of economic organisation to coordinate the information problems along global supply chains, such as the V-form organisation (Berg et al. 2018b, 2018d).

2. Shifting economic power towards the ends of the supply chain (e.g. primary producers and consumers) through reduced information asymmetries (e.g. information about markets, prices and the structure of the supply chain itself).

3. The de-commoditisation of goods—that is, greater differentiation of goods and disaggregation of price signals—due to deeper information enabling consumers to make more subjective value perceptions.

Electronic copy available at: https://ssrn.com/abstract=3299725
4. New proxies of quality for economic agents—as distinct to that derived simply from production within national borders—and therefore a closer match between comparative advantages and production.

We proceed as follows. First, we introduce blockchain as an institutional governance technology, the field of institutional cryptoeconomics that studies it, and examine how blockchain might overcome some of the frictions in global trade networks. Second, we model the incentives under which participants would adopt a blockchain-based smart contract supply chain infrastructure. Assuming this infrastructure is built, in the third section we draw on economic theory to make predictions about how blockchain transforms supply chains. Finally, we outline policy implications for governments to enable entrepreneurs to test and trial these concepts.

2. **Blockchain as an institutional technology for supply chain infrastructure**

Blockchain technology underpins cryptocurrencies such as Bitcoin, Litecoin and Dogecoin. Blockchains are a type of distributed ledger which does not rely on any central authority to maintain their integrity. In general, blockchains use asymmetric (public-key) cryptography, peer-to-peer networking and economic incentives to achieve consensus over shared facts in the presence of malicious actors and network latency (Antonopoulos 2017). Blockchain technology allows for distributed, tamper-resistant and publicly auditable ledgers. Using blockchain and other distributed ledger technologies, people can transact value over the internet without reliance on traditional intermediaries. The technology has been especially useful for individuals who use cryptocurrencies like Bitcoin as a store of value, as a speculative investment (Lo and Wang 2014) and who use Bitcoin to escape capital controls in countries where the domestic currency has dropped in value substantially (Brito 2013). Since 2008, when the Bitcoin whitepaper was released (see Nakamoto 2008), the use cases of
blockchain technology have been identified to include identity access and management (see Berg et al. 2017a), civil society (see Novak 2018) and data markets.

When described simply as a new type of ledger, blockchain technology might seem to be little more than accounting technology. However, such innovations can have a profound impact on an economy’s institutional structure. The ledger-centric view of the economy argues the importance of ledgers in mapping property ownership and relationships, along with other rights and responsibilities which underpin economic and political exchange (see Berg et al. 2018a). Changes to the nature of ledgers have long been associated with changes in institutions. The emergence of literacy and systems of accounting in the ancient Near East allowed for the emergence of simple ledgers which aided in the administrative necessities of large scale empires (Scott 1998). Mustering the vast resources necessary to control large territories throughout Mesopotamia and Egypt required detailed records related to taxation and expenditures. The next big change in ledger technology—double entry bookkeeping—contributed to the emergence of capitalism. Double entry bookkeeping enabled distributed ownership of enterprise, the spread of risk, and contributed to the emergence of multinational corporations (Sombart 1902). Tracking inventories and ownership rights throughout complex organisational structures requires robust ledgers which can be reconciled and audited with relative ease. The nature of ledgers matter, because the propensity to exchange is closely correlated with the ready verification of property rights, along with a system of courts and law to enforce those rights (Commons 1924).

Following Commons (1932), the existence of and nature of transactions costs have been used to account for organisational variety. Coase (1937) and Williamson (1975) sought to explain

---

2 See also Berg (2017) on the relationship between blockchain and diplomacy in the Ancient Near East.
why some transactions occur within a firm, and why some take place in the market.\textsuperscript{3} The institutional logic here is that different institutions are alternate organisational structures to transact, and the choice of institution depends on several behavioural assumptions and key constructs. For instance, actors exhibit cognitive limitations (e.g. bounded rationality) and do not always act benevolently (i.e. opportunism).\textsuperscript{4} To give the framework predictive logic, transaction cost economics also defines transactions as exhibiting different types and degrees of asset specificity, uncertainty and frequency of exchange. Asset specificity refers to the degree upon which a transaction specific asset can be redeployed to some other use with little or no loss of productive value (Williamson 1985, 1991).\textsuperscript{5} Uncertainty over the future state of the world exists both due to bounded rationality and exogenous shocks (e.g. unforeseen events), necessitating the development of contractual safeguards (Williamson 1996). The frequency of exchange plays a role in dictating contractual governance arrangements. For instance, an economic actor is more likely to make significant investments to fulfil contractual arrangements which are likely to recur, rather than to fulfil one-off spot market transactions.\textsuperscript{6} Together, the characterisation of transaction costs and governance structures enables us to make predictions about the transaction cost economising structure for various transactions, including those situated along a supply chain (see below).

\begin{itemize}
\item Transactions costs in general refer to the ‘friction’ inherent in exchange (Williamson 1985), and are the “costs of running the economic system” (Arrow 1969, p. 501).
\item Bounded rationality was first proposed by Simon (1957) and refers to the cognitive and language based limits of rationality; economic actors are “intendedly rational, but only limitedly so” (Simon 1961, p. xxiv). Opportunism in contrast refers to the way in which economic actors are generally guided by self-interest, and may act to selectively reveal, obfuscate, or otherwise manipulate information to their advantage; opportunism is what Williamson (1985, p. 47) refers to as “self-interest seeking with guile”.
\item For instance, asset specificity ranges from uniquely idiosyncratic investments where those investments would be lost if the relationship was to be severed, to more general purpose investments that are more easily redeployed to other uses.
\item Frequent and similar transactions are “often associated with internalization of economic activities” (Kulkarni and Heriot 1999, p. 45) in a hierarchical governance structure like a firm such that establishment costs can be amortised.
\end{itemize}
Blockchains ‘industrialise trust’ by reducing the transaction costs which economic actors might otherwise face (Berg et al. 2017c). Institutional cryptoeconomics uses the transaction cost economics framework to explain how blockchain technology shifts the comparative efficacy of firms, markets, governments, civil society to solve economic problems (see, for example, Allen et al. 2018a; Allen et al. 2018b; Berg et al. 2017a; Berg et al. 2017b). Our focus here is on the application of blockchain technology in supply chains. When goods move along supply chains, trusted information about those goods must also move with them. That information must be produced and maintained through economic organisation—which is costly. More broadly there are three main types of trade costs that act as frictions in supply chains: transportation costs, political or regulatory costs, and information costs (Petropoulou 2005). Transportation costs have been lowered through transportation technologies including the shipping container (Hummels 2007; Levinson 2016), while political and regulatory barriers such as tariffs have been reduced through global coordination bodies (Goldstein 1998). Our focus here is on the information costs underpinning trade, that stem from demands from consumers, producers and governments.

Consumers demand information in terms of the legitimacy, quality and provenance of a product. That information enables consumers to differentiate products and therefore to determine their subjective valuations. Governments demand information about goods because when goods cross borders they must comply with domestic regulations. For instance, biosecurity restrictions, minimum labour or ethical standards and sanctions compliance. Producers demand information about goods after they have sold them, including information about their final market consumers as well as the rents and actions of others along the supply chain (e.g. transport companies).

These problems are exacerbated as organizational distance increases (Banet 1976). Goods have characteristics that are the product of production, financing, delivery, warehousing, regulatory procedures and a myriad of other processes in a supply chain. Except for in the
context of a supply chain located wholly within a vertically integrated organisation, these processes might occur across tens, hundreds, or even thousands of discrete organisations. For instance, Apple has 785 suppliers, across 31 countries (Clarke and Boersma 2017); their products are (officially) available for sale in most countries, apart from those subject to US sanctions such as North Korea and Syria, or where there is little demand, like in Afghanistan and Yemen (Linshi 2014). As supply chains become longer and more complex, information changes hands more often and across more relationships (Awaysheh and Klassen 2010), potentially leading information loss or fraud.

The production and maintenance of trusted information about goods, however, is not costless. Individuals create private orderings such as firms, to produce the information, ensure its integrity, and communicate that information between relevant parties. Some supply chain information is produced through brand reputation, “repeat transactions ... and social norms that are embedded in particular geographic locations or social groups” (Gereffi et al. 2005, p. 81). Siloed hierarchies along a supply chain communicate information—for example through paper-based bills of lading—between each other to maintain and update ledgers of information. Estimates to the administrative cost of this paperwork varies from 15 per cent of the value of goods shipped (Groenfeldt 2017) to being equal to the cost of physically moving those goods (Popper and Lohr 2017). The complexity of global supply chains also means that shipping goods involves a multitude of organisational interactions; Maersk found that a single shipment of refrigerated goods in 2014 from Africa to Europe involved 30 different individuals and organisations, with 200 separate instances of interaction (IBM 2017). This process is not only costly, but due to the complexity and multiple interactions it is error-prone and open to fraud (Hackius and Petersen 2017). Actors along a supply chain are ultimately limited in their “ability to receive, store, retrieve and communicate information without error” (Grover and Malhotra 2003, p. 459) due to transaction costs. What institutional solutions can ameliorate these transaction costs is
constrained by available technologies. Blockchain and other distributed ledger technologies open up new potential governance solutions to economise on information costs.

There is substantial interest from the private sector and from governments to develop blockchain-based economic infrastructure for global supply chains. This includes using the technology to validate the legitimate ownership of goods traded (Underwood 2016), identifying counterfeit medicines (Apte and Petrovsky 2016; Mackey and Nayyar 2017), tracking the trade of protected species (Sutherland et al. 2017) and managing food safety incidents (Tian 2016). Significantly, blockchain technology is being adopted by firms including IBM, Maersk and Walmart as the economic infrastructure to achieve greater levels of assurance over the nature and provenance of goods as they move along supply chains. In 2017 IBM and Danish shipping company Maersk announced their TradeLens blockchain solution to facilitate “the real time exchange of original supply chain events and documents” (IBM 2017). Walmart has since announced their intention to use the IBM Food Trust platform to facilitate the sharing of provenance information by their leafy green suppliers in the wake of an E. coli outbreak (Walmart 2018).

Blockchain can be used to store transparent and tamper-resistant information about goods. Relevant information could include that related to ownership, location, environmental impact, in addition to location and time stamping data (Abeyratne and Monfared 2016). The use of blockchain technology might be readily considered in the context of food safety and traceability, where provenance information stored on an immutable, transparent and distributed ledger can be consulted in real-time by consumers and regulators (see, for instance, Tian 2016). Blockchain supply chains are likely to emerge in concert with a range of other technologies. The simplest form could involve a permissioned network of actors who hold a QR code scanning technology, perhaps through a smart phone, that updates information on a private distributed ledger. This approach, however, faces many of the challenges of human involvement. Questions form over the legitimacy of the data entered in
the distributed ledger—the ‘garbage in-garbage out’ or the ‘oracle’ problem. Blockchains are unable to autonomously interact with real-world individuals or events and hence rely on ‘oracles’ to transmit data about temperature, contractual performance and so on (De Filippi and Wright 2018). The role of the distributed ledger here is mainly to provide transaction cost efficiency gains, rather than any new fundamental security (except to the extent that the transparency of the ledger itself prevents people from committing fraud in a game theoretic sense).

Another approach to deploying blockchain supply chains will leverage more complex technologies in an attempt to input information via sensors (Kim and Laskowski 2018). One example of this is the development of ‘smart containers’ based on the Internet of Things (IoT) where a number of sensors record information—such as temperature and GPS data—that is then uploaded to a blockchain-based distributed ledger. This represents a shift away from human-centred data input towards technology-centred data input, and might even see the dynamic adjustment of shipping routes and prioritisation based on the attributes of the goods shipped, a product’s ‘health’ for instance (Mohan et al. 2018). Another potential application of this is the use of Proof of Location protocols, which provide for robust geographic information about users or things without relying on a central authority to verify that information (Brambilla et al. 2016). This includes protocols such as FOAM, where a physical infrastructure is built that detects and uploads information about location to a blockchain-based system (Kohut 2018). That information may also be leveraged to execute smart contracts between supply chain parties.

The precise nature of how blockchains will be applied within supply chain governance is uncertain. Blockchain-based supply chains might require significant infrastructure upgrades or investments in new technologies and those upgrades might need to occur across the entire supply chain. This will be necessarily in particular for the execution of smart contracts along an entire chain. Indeed, the various institutional possibilities that emerge will be discovered
through an evolutionary process of learning by entrepreneurs. In the following section we examine some of the economics of why producers might be willing to adopt this supply chain infrastructure through smart contracting technology. Put simply, what are the incentives for actors in a supply chain to adopt blockchain-based smart contracting supply chain infrastructure?

3. **Incentives to develop blockchain-based supply chain infrastructure**

In this section we examine the necessary conditions or incentives that supply chain participants must meet for a blockchain-based supply chain to be adopted. This precedes our predictions of how deeper and more certain information about goods as they move might make more fundamental changes to supply chain governance, rather than a simple efficiency switch between legacy centralised information verification and decentralised verification and smart contracting.

The central institutional innovation for understanding blockchain-based supply chains is the “smart contract”. Proposed by Szabo (1997), the smart contract is an algorithm which executes the provisions of a contract automatically upon the realisation of some state of the world. We could conceptualise a smart contract as follows. Upon the provision of some good or service $x_{ij}$ by $j$ to $i$, a smart contract executes automatic payment of some medium of exchange $p_{ij}(x_{ij})$, such as a cryptocurrency which is conditional that good or service

\[
p_{ij}(x_{ij}) = \begin{cases} 
    p^N_{ij} & \text{if } x_{ij} = \{t_1 \ldots t_N\} \\
    \vdots & \vdots \\
    p^1_{ij} & \text{if } x_{ij} = \{t_1\} \\
    p^0_{ij} & \text{if } x_{ij} = \emptyset
\end{cases}
\]

with the property that $p^N_{ij} \geq \ldots \geq p^1_{ij} \geq p^0_{ij}$.

Electronic copy available at: https://ssrn.com/abstract=3299725
We define goods and/or services \( x_{ij} \) to be delivered as bundles of attributes \( \{ t_1 \ldots t_N \} \) in the style of New Consumer Theory (Ironmonger 1972; Lancaster 1966), although defined more broadly than physical attributes to potentially include information about the goods and/or services such as time and location of provision as well as state of provision. Once a smart contract is struck in a blockchain-based supply chain system, it is broadcast to the network of nodes holding the blockchain and validated once it is included in a block on which consensus is achieved by the network. When the conditions for its execution (the provision of \( x_{ij} \)) are broadcast to the network by whatever means, the contract is then executed. The blockchain on which a supply chain is implemented thus takes the form of a ‘smart ledger’, not only of static entries, but of smart contracts ready to be executed upon the realisation of various states of the world.

Davidson et al (2018) discuss how, from a network of such contracts between \( i \) and \( j \), we observe the emergence of the “decentralised autonomous organisation”—a network of economic interaction which emerges from the striking of smart contracts, and operates through their execution. Obviously, such decentralised autonomous organisations can take the form of supply chains where they are organised around the provision of goods and services to meet some consumption end. Such supply chains are thus implemented over an Internet of Things when they are based on blockchains.

So it is possible indeed for supply chains to be implemented over blockchain. The question is: under what conditions is there an incentive for \( i \) and \( j \) to implement their portion of a supply chain with smart contracts recorded and validated within a blockchain? The question, of course, comes down to the value that smart contract provides to those parties compared to legacy systems. Smart contracts are costly to write and require specialised technical knowledge, so we would expect the emergence of organisations—consulting technology companies with a speciality in cryptolaw—which specialise in writing them (see V-form network in section below). Obviously an incentive has to be provided to the consulting firm
to do so, which we denote as \( c_{ik}(p_{ij}(x_{ij})) \) and \( c_{jk}(p_{ij}(x_{ij})) \), the price \( i \) and \( j \) respectively pay to \( k \) to write the smart contract containing the protocol \( p_{ij}(x_{ij}) \) for them. Supposing that \( c_k(p_{ij}(x_{ij})) \) is the opportunity cost of writing this contract, the consulting firm has an incentive to provide the smart contract as long as

\[
c_{ik}(p_{ij}(x_{ij})) + c_{jk}(p_{ij}(x_{ij})) \geq c_k(p_{ij}(x_{ij}))
\]

Let us suppose that the value that would be realised by \( i \) were \( j \) to provide them with the goods and/or services \( x_{ij} \) can be represented by a number \( v_i(x_{ij}) \) (for instance, marginal profit). In that case, given a distribution of beliefs \( \beta_i(x_{ij}|p_{ij}, \delta^b) \in [0,1] \) about the provision of \( x_{ij} \) by \( j \) conditional on the provisions \( p_{ij} \) of the smart contract and an information set \( \delta_j^b \) about \( j \) contained within the blockchain (such as satisfaction metrics and so on), and assuming a von-Neumann-Morgenstern incentive structure, the expected value obtained by striking the smart contract on a blockchain is

\[
\sum_{x_{ij}} \beta_i(x_{ij}|p_{ij}, \delta^b)[v_i(x_{ij}) - p_{ij}(x_{ij})] - c_{ik}(p_{ij}(x_{ij}))
\]

Were we to imagine that the cost to \( j \) of providing \( x_{ij} \) to \( i \) to be \( c_j(x_{ij}) \), and assuming a perfect correspondence between cost incurred and outcome in terms of provision we could say that the value to \( j \) of striking the smart contract and providing \( x_{ij} \) to \( i \) is

\[
p_{ij}(x_{ij}) - [c_j(x_{ij}) + c_{jk}(p_{ij}(x_{ij}))]
\]

Now suppose that the same provisions \( p_{ij}(x_{ij}) \) would apply in an off-blockchain contract, that the same values \( v_i(x_{ij}) \) would obtain for \( i \) upon receipt of \( x_{ij} \), and that the same costs \( c_j(x_{ij}) \) would be incurred for \( j \) to provide it. Suppose further that a distribution of beliefs \( \beta_i(x_{ij}|p_{ij}, \delta^b) \in [0,1] \) exists for \( i \) about the provision of \( x_{ij} \) by \( j \) conditional on the provisions \( p_{ij} \) and an information set \( \delta_j^b \) available to \( i \) about \( j \). To execute the contract, \( i \) and \( j \) have to incur a cost of verifying that \( x_{ij} \) has been provided which we call \( c_i^T(x_{ij}) \) and
$c_j^T(x_{ij})$, and we assume that there is a perfect correspondence between the incurring of this cost and verification. This cost is variously the cost of compensating management hierarchies for providing third-party verification in firms, or the cost of verification by third parties in markets (Williamson, 1985). In markets we would imagine that these costs fall on $j$ most heavily as they concern brand building and guarantees of various kinds to convince $i$ that $x_{ij}$ has been provided such that they ought to execute payment $p_{ij}(x_{ij})$ within the contract.

We will therefore find that there is an incentive to adopt blockchain-based supply systems if three conditions are simultaneously met:

$$\sum_{x_{ij}} \beta(x_{ij}|p_{ij}\ \delta_j)[v_i(x_{ij}) - p_{ij}(x_{ij})] - c_{ik}(p_{ij}(x_{ij}))$$

$$\geq \sum_{x_{ij}} \beta(x_{ij}|p_{ij}\ \delta_j)[v_i(x_{ij}) - p_{ij}(x_{ij})] - c_i^T(x_{ij})$$

$$p_{ij}(x_{ij}) - [c_j(x_{ij}) + c_{jk}(p_{ij}(x_{ij}))] \geq p_{ij}(x_{ij}) - [c_j(x_{ij}) + c_j^T(x_{ij})]$$

$$c_{ik}(p_{ij}(x_{ij})) + c_{jk}(p_{ij}(x_{ij})) \geq c_k(p_{ij}(x_{ij}))$$

Now the third condition requires no further interpretation—it is very simple. We will observe incentives for consulting companies to adopt blockchain technology and begin writing smart contracts if their opportunity costs are adequately compensated. However, the first two conditions require a little more interpretation. If we rearrange them we find that $i$ has an incentive to adopt blockchain-based supply systems if

$$\sum_{x_{ij}} [\beta(x_{ij}|p_{ij}\ \delta_j) - \beta(x_{ij}|p_{ij}\ \delta_j^i)][v_i(x_{ij}) - p_{ij}(x_{ij})] \geq c_{ik}(p_{ij}(x_{ij})) - c_i^T(x_{ij})$$

while $j$ has an incentive to adopt blockchain-based supply systems if

$$c_j^T(x_{ij}) \geq c_{jk}(p_{ij}(x_{ij}))$$
The second—the conditions under which $j$ will be incentivised to adopt blockchain-based supply systems—is a very simple condition. If they are going to achieve similar compensation relative to costs for supplying $x_{ij}$ in either blockchain-based or firms/market supply chains, the question of their incentivisation to adopt blockchain-based systems comes down to the differential costs of verification in the two systems—by smart contract or third party. If verification costs that $x_{ij}$ has been provided are lower in blockchain-based supply chains, there is an incentive to adopt them.

The first condition—the conditions under which $i$ will be incentivised to adopt blockchain-based supply systems—is a little more involved as it involves, in particular, the differential beliefs $\beta(x_{ij} | p_{ij} \delta_j^b) - \beta(x_{ij} | p_{ij} \delta_j^i)$ held about the delivery of $x_{ij}$ in its various forms. Any increase in the transaction costs $c_{ik}(p_{ij}(x_{ij})) - c_i^j(x_{ij})$ caused by the expense of writing a smart contract must be compensated for by an increase in the expected value to be brought about by this contract. If the provisions of the contract itself do not change, then that increase in the value expected to arise from the contract comes from the increased beliefs about the net positive values ($v_i(x_{ij}) - p_{ij}(x_{ij}) > 0$) and the decreased beliefs about the net negative values ($v_i(x_{ij}) - p_{ij}(x_{ij}) < 0$) that may be realised by a supply chain based on a blockchain. That, naturally, is brought about by the range of information $\delta_j^b$ that is available within a blockchain about $j$ upon which beliefs can be formed relative to the range of information $\delta_i^i$ that is available to $i$ within a market/firm context.

We have good reason to believe that these two conditions for incentivising the adoption of blockchain-based supply systems will become increasingly easy to satisfy over time, especially with respect to $i$, the “buyer” in this supply chain. In particular, we can expect that the cost of writing smart contracts will decrease markedly as consulting firms move down the learning curve and develop base templates. Moreover, such costs only need be incurred once when the smart contract needs to be written in the first place or altered, whereas verification costs
must be incurred for each transaction in a market/firm setting. But it is in the wealth of information that is stored in a blockchain upon which to form expectations about the likelihood \( x_{ij} \) will be provided that we really see that incentives will emerge to adopt blockchain-based supply systems. Blockchain is *designed* to store information and validate it, which means we are very likely to see a better basis for more accurate beliefs to form about the provision of \( x_{ij} \) in various states by \( j \) within blockchain-based supply chain systems.

### 4. Predictions for the future of supply chain governance

#### 4.1. New forms of economic organisation

Even if supply chain actors are incentivised to adopt blockchain-based infrastructure, this adoption process is likely to require significant coordination and cooperation across multiple actors. The evolutionary change from the current, and often paper-based, system towards a more digitised blockchain-based system requires technical and economic coordination between supply chain actors, and it is unclear how this process will occur. On one hand adoption could occur through forced adoption down the supply chain due to some market power (e.g. Walmart). Alternatively, third parties, such as consulting firms, might be required to coordinate and supply the technology necessary. Following the latter path, here we propose a new form of organisation to facilitate supply chain coordination, the V-form organisation.

The V-form organisation is an “outsourced, vertically integrated organisation tied together not by management and corporate hierarchy but by a shared, distributed and decentralised ledger – a blockchain” (Berg et al. 2018c). Rather than a multidivisional (M-form) company where operations are divided into self-contained business units and overarching corporate hierarchy (à la Chandler 1962; Williamson 1996), the V-form organisation is a new form of decentralised organisation where fully independent companies (1) coordinate and audit their
activities through a decentralised blockchain ledger; and (2) have a common coordinating third party, such as a consulting firm or technology company, who brokers that collaboration (see also Berg et al. 2018d).

The institutional possibility of a V-form organisation represents a step-change of supply chain governance. Consensus over facts along a supply chain—including information about the attributes of goods—can now be achieved through outsourcing to a decentralised blockchain ledger, rather than relying on vertical integration. Previously supply chain trust has been provided by hierarchy in the form of the M-form organisation which economised on both bounded rationality and opportunism via a somewhat decentralised structure. Existing supply chain organisations now essentially face the problem of making trust (through vertical integration), outsourcing trust (through market exchange), or now achieving trust through outsourcing to a network (through a common distributed ledger).

How does the V-form organisation interact with existing political economic systems? We anticipate that there will be several issues relating to competition policy. How can competition or anti-trust policy deal with the problem of common protocols and consulting companies coordinating along lengthy and complex supply chains? While V-form organisations might facilitate adoption of blockchain, they may also generate later issues of market power.

4.2. *Shifts in economic power through reductions in information asymmetries*

One information problem facing producers and consumers is that they lack information visibility looking towards the opposite end of their supply chain. That is, information asymmetries exist along supply chains in both directions: producers lack information about where their goods are eventually sold, and consumers lack information about the provenance
of the good they are buying. Reducing these information asymmetries, we argue below, shifts economic power towards the polar ends of supply chains.

What is the nature of information that producers and consumers lack? Producers lack information over who the final market consumers are, the price(s) at which those goods are sold, the behaviour of actors along the chain, and how rents are distributed across the various actors. A coffee farmer in a remote area, for instance, might lack information other than the price at which they sell the coffee to an intermediary, including information about their consumers and final prices. This lack of information about goods as they move along a supply chain creates an asymmetric information problem that is particularly poignant for the primary producer because we would expect information asymmetries to increase as the distance between actors increases. Consumers might also lack sufficient or reliable information regarding the provenance of the product that they are purchasing. This receipt of this information may dramatically alter the value they place on those products. Currently this information is in part derived through proxies such as brand reputation and national borders (both of producers and retailers) (See below).

These information asymmetries persist for several reasons, some of which have been outlined above. Supply chain participants might lack incentives to produce and maintain information about goods as they move. Notwithstanding issues of fraud or error—for instance, bad actors profiting from withholding information—there are a range of coordination problems that prevent supply chain information from being produced. Transaction costs might make producing the information economically unviable. However, new technologies such as blockchain might better economise on these transaction costs as well as overcoming the incentive problems that cause information asymmetries to persist.

What would happen if blockchain-based supply chain infrastructure dramatically reduced information asymmetries? We would expect that better visibility along a supply chain would
shift economic power to the polar ends of the supply chain. Primary producers will have greater bargaining power because they can identify final market customers (potentially enabling them to develop new patterns of trade and lower the cut of intermediaries). They therefore might be able to find more direct paths to market by better economising on the structure of a supply chain. For consumers—including those who are buying products as inputs into production—reducing information asymmetries enables them to restructure supply chains, and potentially dynamically switch between supply chains. The greater information produced through blockchain trade infrastructure therefore might lead to greater competition between suppliers of similar goods regardless of existing trade relationships.

4.3. *De-commoditizing and disaggregating prices*

Many goods in a modern economy are effectively commoditized because of a lack of information to differentiate them from other similar goods. This suggests that the prices consumers attach to those goods are not fully reflective of their underlying (potential) value. Blockchain-based economic infrastructure—through providing not only more reliable information, but information that was previously unavailable—enables consumers to more effectively differentiate economic goods, thereby de-commoditizing them. As price signals better reflect the information that market participants possess we would expect this to have a positive effect on the coordinating ability of the market mechanism (Hayek 1945).

As outlined above, one way to define a good is by its vector of attributes. Consumers observe those attributes to make subjective perceptions of the value of goods. For instance, a perishable good that is fresher is theoretically worth more to consumers. Keeping all else constant, the higher perceived value of a fresher good would translate to a higher market price. Furthermore, the vector of attributes defining a good changes through time (e.g. the good is damaged in transit). However, information about attributes is shrouded in uncertainty and that information must be produced and maintained through different forms
of economic organisation. The uncertainty about the good is particularly high when the information is not easily verifiable through third party observation of the good before or even after it is consumed (for example, a credence goods).

It is unnecessary for a consumer to have the theoretically complete set of vector characteristics that define a good because some of those characteristics will be unrelated to the formation of subjective value. However, blockchain-based supply chain infrastructure means consumers might not only be able to access cheaper and more trustworthy information about the goods that they buy, but also more granulated and detailed information on previously unobservable characteristics. That is, information about the vectors of goods that were either not previously produced or not previously observable due to transaction costs might become possible.

There are several implications of blockchain-based supply chain infrastructure on the operation of market prices. First, we anticipate a de-commoditization of goods. Two products that were previously considered identical because of a lack of information about their differing vectors of characteristics might now be reliably differentiated. This suggests those products now fall into two different markets. The second order effect of this is potentially more granulated prices that are more closely reflective of the underlying physical good. That is, a disaggregation of prices, perhaps splitting existing markets into new markets of premium and non-premium segments. The precise margins at which additional trustworthy information will shift the price of goods will emerge over time, and will be directly related both to the subjective perceptions of consumers buying those goods, and the entrepreneurial efforts of people seeking to create the blockchain-based infrastructure that will produce and govern that information. Finally, to the extent that market prices represent the aggregation of distributed and contextual information of market participants (Hayek 1945), we would expect over the longer term more effective market coordination. That is, market participants
will be better able to observe and put to use Hayekian information to achieve their objectives.

4.4. *Less reliance on proxies to determine the characteristics of goods*

Consumers regularly rely on proxies of quality. These proxies range from production within national borders to brand association and reputation. As blockchain supply chain infrastructure is built, however, we would expect that consumers rely more on the underlying characteristics of the specific good they are buying—because of the fall in transaction costs of producing that information—rather than proxies.

As a transaction cost economising strategy, consumers regularly rely on proxies. For instance, a consumer seeking some minimum level of health and safety regulations, labour practices and food safety measures, may buy goods that are produced within *national borders* that have strict laws relating to those matters. The information that those proxies represent do not necessarily correlate directly with the characteristics of the product underlying it. This is not to say that either: (1) goods produced within those jurisdictions could possibly not meet those minimum standards; or that (2) producers in jurisdictions without those standards might decide to voluntarily take sufficient health and safety or other measures. This observation also applies to other proxies and desired attributes, such as brand reputation. One function of brands is to signal to consumers that an organisation has ensured the quality of that product—effectively confirming information about its vector of characteristics. These examples of national borders and brand reputation are examples of governance solutions to the problem of producing trusted information about the characteristics of goods.

While proxies might be economically efficient given some level of transaction costs—that is, where it is too costly to produce more detailed information about specific goods—blockchain-based supply chains might enable consumers to better understand underlying attributes of goods.
What is the ultimate impact of this on the structure and patterns of global trade? We should expect that as proxies are replaced by more specific information about goods, then consumers will shift their consumption patterns—purchasing goods that more closely fit the criteria they are seeking. In the longer run this may change the goods that producers in certain nations produce. Producers within economies who were previously held back by reputational problems—for instance, in developing economies which are beset by poor food safety reputations—might be better able to market their products to consumers using more detailed information. We would expect this to shift the production patterns of goods to more closely match the comparative advantages of economies.

5. Policy

Global commerce benefitted from two notable instances of reductions in trade costs across the twentieth century (Allen et al. 2018b). The introduction of the standardised shipping container dramatically reduced the physical costs of trade (Levinson 2016), while the General Agreement on Tariffs and Trade (GATT) significantly reduced political costs. Blockchain technology has the potential to substantially reduce the information costs related to moving goods through international supply chains.

The complexity of supply chain networks means that a significant number of stakeholders along the chain require access to, and must be able to interpret, various data about those goods contained within it. Any successful blockchain based protocol needs to define standards which will allow users to capture, filter, store and query relevant data pertaining to the provenance of goods which move throughout a supply chain. This may very well be best achieved through open standards. Open standards serve to achieve interoperability between systems, as well as foster innovation (Coyle 2002).

Open standards achieve the needs for interoperability between the myriad of systems involved in these supply chains, reducing the costs of communication across highly networked
inter-organisational and regulatory structures (Zhu et al. 2006). Similarly, such open standards in blockchain-based data formats would allow organisations the flexibility to reconfigure their supply chains based on business and market needs (Gosain et al. 2004). Ideally, these standards should also allow organisations to minimise the disclosure of proprietary or sensitive information. Open standards are also important in facilitating (unexpected) innovation. The growth of the commercial internet in the 1990s is one example of how open standards allow for an explosion of innovation by reducing barriers to entry and preventing vendor lock-in (Maxwell 2006). Open standards for the adoption of blockchain based supply chains may see a similar phase of widespread innovation in global supply chains, and may even see the introduction of new corporate forms (Berg et al. 2018d).

6. Conclusion

In this paper we have made several contributions. First, we have outlined the potential of blockchain technology as economic infrastructure for the production and governance of information across supply chains. Second, we have modelled the necessary conditions within which this infrastructure might be built. Third, using economic theory we propose that the building of this blockchain infrastructure might lead to new forms of economic organization such as the V-form network, a shifting of economic power to the polar ends supply chains due to reductions in information asymmetries, the de-commoditisation of goods and the disaggregation of prices that assist market coordination, and reductions in the use of proxies used by consumers to value goods. In this way blockchain-based supply chain infrastructure doesn’t just make existing supply chains cheaper and more efficient, but might fundamentally change the way that globalisation takes place. Finally we outlined the need for open standards to facilitate entrepreneurial application of blockchain to global trade networks.

7. References
Abeyratne, SA and Monfared, RP 2016, 'Blockchain ready manufacturing supply chain using distributed ledger', *International Journal of Research in Engineering and Technology*, vol. 5, no. 9, pp. 1-10.

Allen, DW, Berg, C, Lane, AM and Potts, J 2018a, 'Cryptodemocracy and its institutional possibilities', *The Review of Austrian Economics*, pp. 1-12.

Allen, DWE, Berg, C, Davidson, S, Novak, M and Potts, J 2018b, 'Blockchain TradeTech', paper presented to APEC Study Centres Consortium Conference (ASCCC), Port Moresby, Papua New Guinea, 14-15 May 2018.

Antonopoulos, AM 2017, *Mastering Bitcoin: Programming the Open Blockchain*, O'Reilly Media.

Apte, S and Petrovsky, N 2016, 'Will blockchain technology revolutionize excipient supply chain management?', *Journal of Excipients and Food Chemicals*, vol. 7, no. 3, p. 910.

Arrow, KJ 1969, 'The organization of economic activity: issues pertinent to the choice of market versus nonmarket allocation', *The analysis and evaluation of public expenditure: the PPB system*, vol. 1, pp. 59-73.

Awaysheh, A and Klassen, RD 2010, 'The impact of supply chain structure on the use of supplier socially responsible practices', *International Journal of Operations & Production Management*, vol. 30, no. 12, pp. 1246-68.

Banet, A 1976, 'Organizational Distance: A Concept for the Analysis and Design of Organizations', *Group & Organization Studies*, vol. 1, no. 4, pp. 496-7.

Berg, A, Berg, C, Davidson, S and Potts, J 2017a, 'The institutional economics of identity', *SSRN*.

Berg, C 2017, 'What Diplomacy in the Ancient Near East Can Tell us About Blockchain Technology', *Ledger*, vol. 2, pp. 55-64.

Berg, C, Davidson, S and Potts, J 2017b, *The Blockchain Economy: a beginner’s guide to institutional cryptoeconomics*.

---- 2017c, 'Blockchains industrialise trust', *SSRN*. 

Electronic copy available at: https://ssrn.com/abstract=3299725
2018a, 'Ledgers', SSRN.

2018b, Outsourcing Vertical Integration: Distributed Ledgers and the V-form Organisation, RMIT University Working Paper.

2018c, 'Outsourcing vertical integration: distributed ledgers and the V-form organisation', RMIT University Working Paper.

2018d, 'Outsourcing vertical integration: introducing the V-form network', Medium.

Brambilla, G, Amoretti, M and Zanichelli, F 2016, 'Using Blockchain for Peer-to-Peer Proof-of-Location', arXiv preprint arXiv:1607.00174.

Brito, J 2013, Beyond Silk Road: Potential Risks, Threats, and Promises of Virtual Currencies, Mercatus Center: George Mason University.

Chandler, AD 1962, Strategy and Structure: Chapters in the History of the Industrial Enterprise, M.I.T. Press.

Clarke, T and Boersma, M 2017, 'The governance of global value chains: Unresolved human rights, environmental and ethical dilemmas in the apple supply chain', Journal of Business Ethics, vol. 143, no. 1, pp. 111-31.

Coase, RH 1937, 'The Nature of the Firm', Economica, vol. 4, no. 16, pp. 386-405.

Commons, JR 1924, The Legal Foundations of Capitalism, Macmillan, New York.

2013, 'The problem of correlating law economics and ethics', Wis. L. Rev., vol. 8, p. 3.

Coyle, K 2002, 'Open source, open standards', Information Technology and Libraries, vol. 21, no. 1, p. 33.

Davidson, SR, De Filippi, P and Potts, J 2018, 'Blockchains and the Economic Institutions of Capitalism', Journal of Institutional Economics, pp. 1-20.

De Filippi, P and Wright, A 2018, Blockchain and the Law: The Rule of Code, Harvard University Press.

Gereffi, G, Humphrey, J and Sturgeon, T 2005, 'The governance of global value chains', Review of International Political Economy, vol. 12, no. 1, pp. 78-104.
Goldstein, J 1998, 'International institutions and domestic politics: GATT, WTO, and the liberalization of international trade', in AO Krueger (ed.), The WTO as an international organization, pp. 133-52.

Gosain, S, Malhotra, A and El Sawy, OA 2004, 'Coordinating for flexibility in e-business supply chains', Journal of management information systems, vol. 21, no. 3, pp. 7-45.

Groenfeldt, T 2017, 'IBM And Maersk Apply Blockchain To Container Shipping', Forbes, 5 March 2017.

Grover, V and Malhotra, M 2003, 'Transaction cost framework in operations and supply chain management research: theory and measurement', Journal of Operations Management, vol. 21, no. 4, pp. 457-73.

Hackius, N and Petersen, M 2017, 'Blockchain in logistics and supply chain: trick or treat?', paper presented to Hamburg International Conference of Logistics (HICL), Hamburg.

Hayek, FA 1945, 'The Use of Knowledge in Society', The American Economic Review, vol. 35, no. 4, pp. 519-30.

Hummels, D 2007, 'Transportation Costs and International Trade in the Second Era of Globalization', Journal of Economic Perspectives, vol. 21, no. 3, pp. 131-54.

IBM 2017, Maersk and IBM Unveil First Industry-Wide Cross-Border Supply Chain Solution on Blockchain, 5 March 2017, <https://web.archive.org/web/20170327205334/https://www-03.ibm.com/press/us/en/pressrelease/51712.wss>.

Ironmonger, DS 1972, New commodities and consumer behaviour, Cambridge University Press, Cambridge.

Kim, HM and Laskowski, M 2018, 'Toward an Ontology-driven Blockchain Design for Supply-chain Provenance', Intelligent Systems in Accounting, Finance and Management, vol. 25, no. 1, pp. 18-27.

Kohut, O 2018, 'FOAM — A Geospatial Proof of Location Protocol for Blockchains and DApps on Epicenter', viewed 5 December 2018,
Kulkarni, SP and Heriot, KC 1999, 'Transaction costs and information costs as determinants of the organizational form: A conceptual synthesis', *American Business Review*, vol. 17, no. 2, p. 43.

Lancaster, KJ 1966, 'A new approach to consumer theory', *Journal of Political Economy*, vol. 74, no. 2, pp. 132-57.

Levinson, M 2016, *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger - Second Edition with a new chapter by the author*, Princeton University Press.

Linshi, J 2014, 'Why U.S. Sanctions Mean Some Countries Don't Get Any iPhones', *Time.com*, October 16, 2014.

Lo, S and Wang, JC 2014, *Bitcoin as money?*, Federal Reserve Bank of Boston.

MacDonald, TJ, Allen, DWE and Potts, J 2016, 'Blockchains and the Boundaries of Self-Organized Economies: Predictions for the Future of Banking', in P Tasca, T Aste, L Pelizzon & N Perony (eds), *Banking Beyond Banks and Money: A Guide to Banking Services in the Twenty-First Century*, Springer International Publishing, Cham, pp. 279-96.

Mackey, TK and Nayyar, G 2017, 'A review of existing and emerging digital technologies to combat the global trade in fake medicines', *Expert opinion on drug safety*, vol. 16, no. 5, pp. 587-602.

Maxwell, E 2006, 'Open standards, open source, and open innovation: Harnessing the benefits of openness', *Innovations: Technology, Governance, Globalization*, vol. 1, no. 3, pp. 119-76.

Mohan, R, Patil, P and Rajesh, I 2018, 'PRIORITY ROUTING OF SHIPMENT USING IOT SENSOR DATA FROM SHIPMENT PACKAGES'.

Nakamoto, S 2008, 'Bitcoin: A peer-to-peer electronic cash system'.

Electronic copy available at: https://ssrn.com/abstract=3299725
Novak, M 2018, 'Crypto-altruism: Some institutional economics considerations', SSRN.

Petropoulou, D 2005, 'Information costs and networks in international trade', London, CEPR.

Popper, N and Lohr, S 2017, 'Blockchain: A Better Way to Track Pork Chops, Bonds, Bad Peanut Butter?', The New York Times, 4 March 2017.

Scott, JC 1998, Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed, Yale University Press.

Simon, HA 1957, Models of Man, Wiley, New York.

Simon, HA 1961, Administrative Behavior, 2nd edn, Macmillan, New York.

Sombart, W 1902, Der moderne Kapitalismus, Duncker & Humblot.

Sutherland, WJ, Barnard, P, Broad, S, Clout, M, Connor, B, Côté, IM, Dicks, IV, Doran, H, Entwistle, AC and Fleishman, E 2017, 'A 2017 horizon scan of emerging issues for global conservation and biological diversity', Trends in Ecology & Evolution, vol. 32, no. 1, pp. 31-40.

Szabo, N 1997, 'The idea of smart contracts', Nick Szabo’s Papers and Concise Tutorials.

Tian, F 2016, 'An agri-food supply chain traceability system for China based on RFID & blockchain technology', paper presented to Service Systems and Service Management (ICSSSM), 2016 13th International Conference on.

Underwood, S 2016, 'Blockchain beyond bitcoin', Communications of the ACM, vol. 59, no. 11, pp. 15-7.

Walmart 2018, In Wake of Romaine E. coli Scare, Walmart Deploys Blockchain to Track Leafy Greens, 24 September 2018, <https://news.walmart.com/2018/09/24/in-wake-of-romaine-e-coli-scare-walmart-deploys-blockchain-to-track-leafy-greens>.

Williamson, OE 1975, Markets and hierarchies, analysis and antitrust implications: a study in the economics of internal organization, Free Press.

---- 1985, The Economic Institutions of Capitalism, Free Press.
Williamson, OE 1996, *The Mechanisms of Governance*, Oxford University Press.

Zhu, K, Kraemer, KL, Gurbaxani, V and Xu, SX 2006, 'Migration to open-standard interorganizational systems: network effects, switching costs, and path dependency', *Mis Quarterly*, pp. 515-39.