Blockchain for Development

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Executive Summary

Blockchains are the class of distributed, decentralised ledger underpinning cryptocurrencies such as Bitcoin and Ethereum. More broadly these technologies provide the new economic infrastructure for a wide range of applications such as identity, trade, property registration, economic organisation and self-governance in civil society.

Institutional cryptoeconomics is the study of the economic possibilities of blockchain as a governance technology that competes with firms, markets and governments. This emerging field draws on transaction cost economics to provide a map of how economies can adopt, and adapt to, distributed ledger technologies. Institutional cryptoeconomics helps us predict what happens to economies and societies when blockchains can govern cooperation and coordination.

Developing economies, such as Papua New Guinea, might realise significant opportunities from blockchain technology. Blockchain technology is poised to rapidly and effectively build more sustainable, resilient and robust forms of governance in the developing world. In this report we outline four main applications of blockchains:

1. For managing information in supply chains. Blockchain applications in this area might better integrate people into the global economic system and over the longer-term may re-distribute economic power towards primary producers.
2. For the provision of registries (such as property titles and intellectual property). Blockchain might improve the enforcement and transparency of property rights in the developing world, enabling people to invest and act entrepreneurially confidently.
3. Managing information relating to identity (such as education credentials or official identity information). A secure and trusted identity is demanded to interact with government, as well as to enable economic mobility by engaging in wider economic exchange.
4. Tracing funds that move through civil society organisations (such as foreign aid). Blockchain applications in civil society might help to ensure the integrity and reduce fraud, potentially increasing the effectiveness of aid.

What can governments do? There are a number of policy barriers to blockchain adoption in developing economies, and more challenges are likely to arise as the technology develops. Governments should acknowledge that physical infrastructure (such as internet connectivity) and institutional infrastructure (such as blockchain applications) are complementary goods. Both are necessary for the process of economic development and prosperity. Therefore governments should be encouraging and enabling entrepreneurs to build institutional infrastructure using blockchain. Governments should seek to discover and apply world's best practice in crypto-friendly policy settings, encouraging investment inflows and entrepreneurial testing in a globally competitive environment of mobile labour and capital.

1 Introduction

Most famous for enabling cryptocurrencies such as Bitcoin and Ethereum, blockchain is a governance technology for updating and securing decentralised ledgers of information.[1] Blockchains and other distributed ledger technologies are now being applied across industries including finance, supply chains, digital voting, health records and identity. In this report, we examine the potential of blockchain for developing economies, with a focus on Papua New Guinea. We introduce and draw on the new field of institutional cryptoeconomics, arguing that blockchain acts as new economic infrastructure that might lift millions of people out of poverty and dramatically improve their quality of life. However, the application of blockchain must be coupled with an effective understanding by governments. Therefore we also examine the role of governments in the burgeoning blockchain industry, introducing the notion of 'crypto-friendliness' and explaining its importance in blockchain adoption.

Blockchain is not just a new general purpose technology or information communications technology—blockchain is a technology for creating and maintaining new decentralised institutional forms of *governance*. This means that blockchain competes with other forms of governance and economic organisation, such as hierarchies and markets. By creating immutable, decentralised and digital ledgers of information, entrepreneurial application of blockchain creates the infrastructure for people to more easily cooperate and coordinate. For instance, the application of smart contracts—contracts governed by code that automatically execute—means that people can contract in potentially hostile environments. Smart contracts also facilitate entirely new forms of economic organisation, including the potential to democratise and tokenise investment.

From an institutional cryptoeconomics perspective, blockchain is *new economic infrastructure*. It is unusual to see technologies that are native governance technologies. The effective application of blockchain is where it acts as a foundation on which people can better govern their interactions and instances of exchange. The institutional cryptoeconomics view also suggests that blockchain will interact with other new technologies—such as the Internet of Things (IoT) and Artificial Intelligence (AI)—to manage the data inputs and outputs of those processes. However, what does all of this mean in practice-both for developed and developing economies? There are vast opportunities for improvements to peoples' lives.

Why is blockchain technology relevant for developing economies? What is different about the application of blockchain compared to previous technologies to stimulate economic growth? These questions should be answered in the context of the past half-century of development economics. Through time, development economics has increasingly realised the importance of *governance* and

[1] The authors thank the input of RMIT Blockchain Innovation Hub colleagues Aaron Lane, Alastair Berg, Professor Jason Potts, Professor Sinclair Davidson and Dr Mikayla Novak.

entrepreneurship to the process of economic growth.[2] Governance refers to the institutional rules and procedures within which people exchange and interact. Interpreted broadly, governance ranges from both formal laws and regulations to the way that individuals self-govern their lives.[3] The continuing resurgence and expansion in schools of economic thought such as transaction cost economics and Austrian economics have changed the view of where growth comes from. Early analyses of development emphasised savings, investment and the accumulation of capital. Modern analysis of development increasingly emphasises institutions such as property rights and the rule of law, and how these institutions shift the way that entrepreneurs act. Given our understanding of blockchain as an institutional governance technology, we have a clear motivation to examine the impact of blockchain on the institutional structure and entrepreneurial activities in developing economies.

How does blockchain change governance in a developing economy? How might blockchain facilitate more robust, resilient and stable forms of governance? How do we answer these questions in the real world? Moreover, importantly, how can the governments of developing economies help? In this report, we explore the potential of blockchain to catalyse growth within developing economies, and some of the policy challenges that will arise. In particular, we focus on blockchain as a solution to some common governance challenges: integrating people into global trade networks to realise the gains from exchange, securing property rights so that people can act entrepreneurially and invest, the management of identity so that people can exchange and be economically mobile, and the provision of effective civil society organisations so that foreign aid is effectively utilised. Can blockchain-based institutions better solve these problems than legacy solutions?

The specific application of blockchain institutions will occur over time and will be primarily driven by the private sector. Nevertheless, there is an important role for government in providing accommodative regulatory settings, assisting entrepreneurs interacting with government services, and generally providing a 'crypto-friendly' policy sentiment. Entrepreneurs must be allowed to test and experiment with, blockchain solutions to create new institutions for the developing world. This is not to say that governments should directly fund blockchain entrepreneurs, but rather develop a policy environment that is conducive to entrepreneurial activities. Particularly relevant for governments in developing economies is the notion that the provision of physical infrastructure—such as communications technologies like the internet—are *complementary* to the institutional infrastructure that new blockchain and distributed ledger technologies provide. Together these

[2] See, for instance, Acemoglu and Robinson (2010, 2012); Bauer (1976); Boettke et al. (2008); Easterly (2006).
[3] On institutions see North (1990). For the important distinction between legislation and law see Hayek (2012).

forms of infrastructure might lay the foundations for more dynamic and prosperous developing economies.

Our report proceeds as follows. In Section 2 we examine the nature of blockchain technology. We provide an analysis of the nature of blockchain and distributed ledger technologies as governance technologies. We also introduce the emerging field of institutional cryptoeconomics. In Section 3 we cover the history of development economics. The upshot is the importance of blockchain in securing stable, robust and trusted institutions for coordination and exchange. We also sketch a potential new path in economic development—what we term decentralised development—where blockchains are used as economic infrastructure to democratise the funding of physical infrastructure. Section 4 outlines some applications of blockchain: supply chains, property rights, identity management and civil society. We focus particularly on blockchain for supply chains, which we believe holds widespread opportunities for developing economies' economic integration, and the economic mobility of their people. In Section 5 we propose 'crypto-friendliness' as the broad policy stance that will facilitate blockchain adoption. Section 6 summarises and concludes.

2 What is blockchain?

2.1 The origins and basics of blockchain technology

Blockchain technology was invented by Satoshi Nakamoto in 2008 as a technology to support the first decentralised digital currency, Bitcoin.[4] Digital currencies are vulnerable to what has been described as the 'double spending problem'. Equivalent to the counterfeiting problem with fiat currencies, it is simple to make exact copies of digital assets. Preventing units of digital currencies from being copied has been the longstanding problem faced by entrepreneurs and developers when trying to develop a native internet 'money'.

Previous solutions to the double spending problem relied on a central authority—such as a firm or bank—providing a validation service that ensured currency units being used in any given transaction were not double spent. However, central authorities can create problems. First, they can potentially be vulnerable to digital attack or infrastructure failure. Second, they can exercise authority over the network and (potentially) censor certain transactions. Up until 2008, there was no real coherent decentralised solution to these problems.

Bitcoin does not rely on a central authority—the double spending prevention is provided by a *blockchain*. At their simplest, a blockchain is a continuous record of transactions—a *ledger*—sequentially grouped into blocks. That ledger is shared between computers and devices across a peer-to-peer network, without a central authority. Rather than a central authority, blockchains require a 'consensus mechanism' to allow devices on the network to update the ledger (that is, announce and receive information about new transactions) and validate that updates do not violate the double spending restriction.

How do those ledgers come to agreement—that is, *consensus*—over the correct state of the ledger at any given point in time? The Bitcoin blockchain uses a 'proof of work' consensus mechanism that requires 'miners' to solve a computationally difficult puzzle for the right to create new blocks and update the ledger. When Satoshi Nakamoto developed the bitcoin protocol, they incorporated economic invectives for miners to validate all transactions and maintain the distributed ledger (miners have a chance of winning newly minted bitcoins). The mining mechanism ensures the network is secure as long as 51 per cent of miners are honest. As the network grows and more nodes are partaking in mining activity, the network becomes more secure—it simply becomes too expensive for someone to hack the network and change the history of transactions.

Proof of work, however, is not the only consensus mechanism. Alternative consensus mechanisms include proof of stake (where validators stake blockchain tokens for the right to validate the ledger),

[4] For the original bitcoin whitepaper see Nakamoto (2008).

delegated systems (where holders of cryptocurrencies vote on validators) and private or consortia blockchains, where a small number of validators are nominated ahead of time. Each of these approaches offer blockchains different characteristics of decentralisation, which is an active area of study in blockchain research.[5] Consensus mechanisms differ in terms of speed, security and scalability. Each mechanism is likely to be employed in different scenarios to solve different types of governance problems. There is not one single blockchain—or even one type of blockchain—but rather a constellation of thousands of blockchains, each of which can be understood as their own unique governance system.[6]

As a technology, blockchains are best seen as distributed ledgers (or databases), rather than as cryptocurrencies. While invented for the purpose of digital currencies, blockchains provide an immutable, updateable ledger of information shared between multiple parties without a central authority. Cryptocurrencies are the first application of blockchain technology, but they are not necessarily the most significant. At the level of the mechanism, cryptocurrencies are merely a valued token used to incentivise good behaviour within the network (and penalise bad behaviour). Cryptocurrencies provide the incentive for a distributed network to come to a consensus over the true state of the ledger. Private blockchains such as R3's Corda and Hyperledger's Fabric—where there are restrictions on who can participate—do not require tokens to operate.

Consequently, from the perspective of information management, blockchains compete as a technology against alternative and potentially distributed database systems. The formal decentralisation in blockchain technology is costly. While there has been some rapid development and innovation in the blockchain field since the 2008 Bitcoin whitepaper, it is still the case that blockchains can be slow, expensive, and (as an experimental technology) risky for enterprise deployment. Some attempts to resolve these limitations trade-off key blockchain features (such as openness or decentralisation). Any shortcomings of the technology, however, must be understood within the context that blockchain is still a nascent technology.

Databases are for the most part back-office tools, and until now have offered little intrinsic economic or political interest. However, decentralisation—and the consensus mechanisms that have been developed to offer decentralisation characteristics—gives blockchains complex economic characteristics that make them not only suitable for exchanging valued tokens but operate as an alternative and entirely new institution to govern economic activity and economic coordination. In this way, blockchains are a new form of *economic infrastructure* that enables people to coordinate, cooperate and exchange in new ways.

[5] See Berg and Berg (2017).
[6] See Allen (2017, Forthcoming).

2.2 Blockchains as economic infrastructure

Catalini and Gans characterise blockchain technology a new *general purpose technology* (GPT).[7] A GPT is a technology that provides an input into a large array of production processes, the result being an increase in productivity across the economy. GPTs begin as crude but develop into highly sophisticated technologies, are widely used throughout the economy, have multiple uses, and have many technological complementarities.[8] Common GPTs include electricity, semiconductors, railroads and the internal combustion engine. GPTs do not have to be discrete, physical technologies, but can also be business innovations and processes, such as the factory system, interchangeable parts, and just-in-time ('lean') manufacturing.

However, are blockchain and other distributed ledger technologies best viewed as just another GPT? In this view, blockchains make production more efficient by removing middlemen and reducing the costs of complex process coordination. This accords with the idea that blockchains are a database with unique and significant characteristics that are likely to make it a pervasive feature of the economy of the future. However, this perspective—that blockchains are an input into production processes—misses some of the core features and disruptive potential of the technology. From the view of *institutional cryptoeconomics* blockchains are better seen as an *institutional technology*.[9] Rather than an input into production, blockchains are a governance framework to coordinate economic activity.

Institutional cryptoeconomics draws on the transaction cost and institutional scholarship of Ronald Coase, James Buchanan, Friedrich Hayek, Oliver Williamson and Elinor Ostrom.[10] Institutional cryptoeconomics examines blockchains as an economic institution that competes and complements with firms, markets, relational contracts, governments, commons and clubs.[11] Blockchain enables entrepreneurs to create new rule systems to organise the way we interact and exchange.[12] Blockchains are not simply applied within firms, markets and governments—the institutions that underpin a modern global economy—but rather competes with those institutions as a way to organise society. The study of blockchain technology, therefore, is always comparative: what form of governance solves an economic problem more effectively—firms, markets, governments, *or blockchains*?

[7] Catalini and Gans (2016). See also MacDonald et al. (2016).
[8] Lipsey et al. (2005).
[9] Davidson et al. (2018).
[10] For the some relevant works of these scholars see Buchanan and Tullock (1962); Coase (1937); Hayek (1945); Ostrom (1990); Williamson (1985).
[11] For scholarship in institutional cryptoeconomics see Allen et al. (2018b); Berg (2017); Berg et al. (2017a, 2017b); Berg et al. (2018b); Davidson et al. (2018); MacDonald et al. (2016).
[12] Markey-Towler (2018).

The foundation of this comparative claim pivots on the relationship between a 'ledger' and who has the authority—and incentives—to update a ledger. Ledgers are a foundational technology of human coordination. Berg, Davidson and Potts describe ledgers as maps of property and other relations and underline that ledgers (whether 'real' or 'virtual') are necessary for exchange.[13] Ledgers allow social institutions (such as the legal system) to prohibit or penalise opportunistic behaviour from third parties who might assert ownership over an asset that they have not lawfully acquired. Many of our social institutions—governments, firms, and other hierarchical organisations—have evolved to create and update ledgers, and many GPTs (e.g. language, writing, computers) were first used to organise ledgers. Given the significance of ledgers, the ability to decentralise their management is potentially revolutionary.

Firms, markets and governments are familiar forms of economic infrastructure. Since 2008 we now have a new type of economic infrastructure—blockchains and other distributed ledger technologies—that allow us to coordinate and exchange in novel ways. There has been a lot of commentary about the breadth of blockchain use cases, some of which we cover in Section 4 below. Institutional cryptoeconomics generalises these observations to argue that much economic activity that occurs in firms, markets and governments can potentially occur through blockchains. The boundaries at which these shifts occur will be an entrepreneurial discovery process over comparative institutional costs.[14] Indeed, to the extent that 35 per cent of the workforce of an economy is involved in the process of trust-creation—such as accountants and lawyers—there are a potentially enormous array of blockchain applications.[15] We can now turn to the application of blockchain in the context of developing economies.

[13] Berg et al. (2018b).
[14] There are trade-offs along multiple dimensions of whether to integrate blockchain technology within existing solutions, or to cryptosecede and to exit. See Allen (Forthcoming).
[15] Novak et al. (forthcoming).

3 The economics of development and governance

3.1 From old to new development economics

The economics of development is fundamentally about how societies grow. A market economy progresses through the constant process of entrepreneurial discoveries and productivity improvements, bringing new products and technical advances to market. This is what economist Joseph Schumpeter called the 'gale of creative destruction'.[16] However, over time the precise drivers of this economic growth—including in the context of developing economies—have remained a contested topic. Only through a modern conception of development economics—that economies are propelled through entrepreneurs in a favourable institutional environment—is blockchain a potentially remarkable tool for economic development. In this section, we begin by examining the history of development economics before proposing a future path of decentralised development, enabled through blockchain and other distributed ledger technologies.

Development economics emerged as a sub-discipline in the mid-twentieth century.[17] The focus was on how resources—such as land, labour and capital—were invested in and allocated across a developing economy. This approach emphasised how an economy accumulated and allocated resources to their best use. Such an economic analysis aligned closely with the economic orthodoxy of the time. Early theories of development focused on how it was important for economies to build up savings so that they could invest. The key to economic development was seen as filling the 'savings-investment' gap that left economies in a poverty trap. Economies needed investment in physical resources, such as roads and ports, but they lacked the savings to fund that investment.[18] This understanding of a savings shortfall acted as a primary rationale for rapid increases in foreign aid.

Building on this understanding of a poverty trap and the need for foreign aid, the 'big push model' argued for coordinated state-led investment across a number of interlinked sectors.[19] The big push theory emphasised that gradual and marginal investments were not enough to pull an economy out of a poverty trap. Rather, governments needed to drive investment across a number of sectors simultaneously. A number of reasons for the necessity of the 'big push' were put forward, including the potential complementarity of different forms of demand, and that some investments were complementary to other investments.[20] From this perspective development not only required foreign

[16] See Schumpeter (1934).
[17] See Engel (2010).
[18] See Chenery and Strout (1966).
[19] See Jomo and Reinert (2005); Murphy et al. (1989); Rosenstein-Rodan (1961).
[20] One argument for the complementarity of investments came through pecuinary externalities (that operate through the price mechanism).

aid to overcome the savings-investment gap, but also simultaneous and centrally planned investment across multiple sectors.

The above analysis can be contrasted with the emergence of a 'new development economics', which focuses on institutions and entrepreneurship. New development economics emerged in part as critiques of the development economics of the time.[21] How was the big push of investments to be coordinated and allocated to efficient use? With the resurgence of institutional economics, the focus of development shifted from the centralised allocation of investment to incorporate the importance of governance and institutions. Investment, allocation and planning are not the sole drivers of development. Institutions and governance are important too. Indeed, this understanding is not new to economists more broadly, being applied relatively consistently through the mainline of economic thought.[22]

Institutions are important because they are the rules of the game within which people make choices and engage in productive economic activity.[23] This is why developing economies require an effective rule of law and court system, a stable and trustworthy enforcement and recognition of property rights, and a range of other institutions necessary for voluntary and peaceful exchange. As outlined by Daron Acemoglu and James Robinson, institutions should be 'inclusive' rather than 'extractive' to stimulate productive activity.[24] Indeed, the way that the rules of the game are structured changes the potential choices that entrepreneurs will make, whether productive, unproductive or destructive.[25]

However, how are effective institutions in a developing economy created and maintained? One of the challenges is the path dependence of existing institutions and the potential for corruption. To overcome this, there has been an expansion in special economic zones, private cities and charter cities.[26] These new jurisdictions break the path dependence of 'extractive' institutions that exist within a developing economy. They might establish more 'inclusive' and effective institutions that protect property rights and facilitate cooperative exchange.

As economists Peter Boettke and Peter Leeson note, we can conceive two broad types of entrepreneurship within developing economies.[27] The entrepreneurship that is often cited is *productive-tier* entrepreneurship. This is entrepreneurial discovery of new business models within

[21] For instance, economist William Easterly (2006) referred to the big push model as a "legend".
[22] See Boettke and Mitchell (2017) on the mainline of economic thought, which stretches through Adam Smith, Ronald Coase, Friedrich Hayek, Oliver Williamson and Elinor Ostrom.
[23] Coyne and Boettke (2006).
[24] Acemoglu and Robinson (2012).
[25] Baumol (1990).
[26] See Bell (2017) for a recent extensive analysis of the rise of other forms of organisation rather than nation states.
[27] See Leeson and Boettke (2009).

existing rules of the game (i.e. institutions). To be sure, productive-tier entrepreneurship is critical for the development and application of new technologies to meet human needs. However, there is also a higher level of entrepreneurship that may be particularly important in developing economies: *protective-tier* entrepreneurship. Protective-tier entrepreneurship involves the discovery of institutions themselves.[28] This is where institutional entrepreneurs create new rules, customs and norms to protect property rights and facilitate cooperative exchange. As a governance technology, blockchain is a new potential tool for these protective-tier institutional entrepreneurs.

Blockchain enables citizens to develop new private governance rules to protect property rights and facilitate cooperative exchange. The unique potential of blockchain and other distributed ledger technologies is that they enable individuals to undertake institutional protective-tier entrepreneurship. These technologies make it more viable for groups of people to collectively develop new institutions. Furthermore, these institutions can be implemented in parallel with existing state-enforced institutions. Citizens of developing economies then have the institutional choice between different sets of institutions without requiring wholesale change. This approach might also be more conducive to discovering effective institutions in a developing economy context through trial and error. However, before we examine some more specific applications of blockchain to create institutions within developing economies (in Section 4), below, we introduce the concept of decentralised development.

3.2 Towards decentralised development

The application of blockchain technology within developing economies is interesting because it represents a step-change in the way policy change is achieved. Over the past few decades, there has been a resurgence in the literature on charter cities and private cities. These effectively provide for new territorially-based breaking of path dependence of institutional constraints. That is, through government action—or by slipping through the cracks—entrepreneurs build new constitutional rules for individuals.[29] Those individuals and businesses who wish to operate under the new institutions move their operations into that territorial area.

Blockchains allow for what we conceptualise here as a new approach to development: decentralised development. Decentralised development exploits the opportunities offered by distributed ledger technology to finance and provide public goods without necessarily affecting the underlying institutional structure. One critique of the new development economics is that it provides developing countries with few tools to resolve problems with existing institutions. Blockchains allow for institutional layering—the creation of alternative institutional structures on top of (and without affecting) existing institutions.

[28] Boettke et al. (2008); Coyne and Boettke (2006).
[29] See, for instance, Allen (2015); Rajagopalan and Tabarrok (2014).

The possibilities for such institutional layering are two-fold. The old development economics school was correct to note that a major barrier to development is the financing of large-scale infrastructure. Their solution was, however, to directly finance this through foreign aid or foreign government-backed loans (including through a potentially centrally planned 'big push'). The new development economics approach is to reform regulatory, legal and political systems to open up space for entrepreneurs to develop infrastructure projects. One of the obvious challenges with such a private-sector entrepreneurial approach, however, is that there might be a lack of either incentives or visibility for entrepreneurs to provide those goods. This is an institutional governance problem.

Blockchains provide an alternative financing apparatus by which infrastructure can be tokenised. That is, blockchain can solve the challenges of economic development as perceived by both the old development economics and the new development economics by enabling peaceful funding of infrastructure investment and acting as a new economic infrastructure for exchange. While the idea that large-scale physical infrastructure projects might be financed through a new technology might seem farfetched, there are a number of lower-level blockchain use cases being applied currently across the developing world. We turn to a number of these use cases in the following section.

4 Blockchain use cases

In what industries and in what ways can blockchain act as a new economic infrastructure for developing economies? In this section, we introduce four potential use cases. Our focus is on the economic problem that blockchain might solve, explore some examples of solutions that are currently being developed, and finally outline some of the barriers that we propose will arise. We focus in particular on the potential of blockchain to govern the information of global supply chains because we believe the application of blockchain to trade provides fundamental benefits to developing economies, are likely to be applied in the coming years and has some clear policy implications for governments seeking to incentivise blockchain adoption.

4.1 Governing supply chains

Increasing trade networks, and fairly distributing rents between people along a supply chain is one of the central barriers to economic development. In this section, we propose that blockchain might act as new economic infrastructure for governing the information of supply chains.[30] This is no longer a radical argument—there have been a number of substantial trials by major multinational companies.[31] More efficient supply chain governance is particularly important for developing economies because mutually beneficial trade is critical to economic development. Better supply chains within, and connected to, developing economies not only promotes peace and stability but may re-distribute the value of rents back towards primary producers (rather than to intermediaries). In this view, more effective supply chains are a path to more 'inclusive growth' for developing economies.[32]

The economic problem of supply chains is not only the costs of transportation—or other direct regulatory costs such as tariffs—but is increasingly information costs about goods. This information is demanded by consumers, to the extent they want to know about the products they are purchasing. Moreover, this information is sought by governments, who need information about whether goods comply with domestic regulations. Most generally it is information about the characteristics, production technologies and quality of goods and services. It is costly to produce and maintain trusted and verified information across the multiple actors in supply chains. This is a governance problem. What institutions should be used to minimise the cost of supply chain information? Using institutional cryptoeconomics we can analyse the comparative ability of firms, markets, governments or blockchains to solve this problem.

[30] See Allen et al. (2018a).
[31] For example, Walmart recently announced that all suppliers of leafy green vegetables are required to upload their data to a blockchain. See Miller (2018).
[32] See Niforos (2017).

Currently minimising information costs of supply chains occurs through an inefficient and complex system of hierarchies. Firms along a supply chain are regularly tasked with vouchsafing information about a good before moving it to the next person. This raises the potential not only for errors and inefficiencies but also for fraud. A blockchain-based solution to supply chains may help to overcome some of these challenges. Blockchain or other distributed ledger technologies could provide a tamperproof public record of the history of products. This information would not be contained within the siloed hierarchies along a supply chain, but more broadly visible across the entire supply chain.

Many developing economies have challenges with domestic production and therefore must import products. These products may be counterfeit or of poor quality. For example, in PNG and other developing economies, there is often fraudulent behaviour in pharmaceutical supply chains. The World Health Organisation has noted that PNG has chronic shortages and challenges with medical products.[33] There are also a number of problems with food fraud and safety.[34] A blockchain solution might reveal information for consumers who want to know the quality of products, and also for governments who need to know whether imported goods are compliant with domestic regulations.

Producers who export goods from developing economies also face supply chain information costs. Producers are often many steps removed from the final consumer in another country. They lack information about their market demand and are placed in a weak bargaining position by intermediaries. If a blockchain-based solution can provide better and cheaper information about final consumers, then there is the potential for producers to receive a better premium for their product by cutting out some intermediaries.

One recent example of blockchain supply chains is Token, who seeks to bring transparency and efficiency to coffee supply chains, as well as equality of rent distribution (by showing who earns what along the supply chain).[35] AgriLedger also aims to aid farmers and cooperatives access markets using blockchain traceability.[36]

Consumers might lack visibility about the characteristics of goods, such as their provenance and quality. At present, we solve the problem through certifications, such as certifications of products as Fair Trade or organic. These are centralised solutions to the supply chain information problem and are known to have had concerns raised over their integrity. A decentralised blockchain solution to the same problem does not require a centralised intermediary. It could either rely on time-stamped data of stakeholders along a supply chain, or through leveraging other technologies including the IoT.

[33] See World Health Organisation (2018).
[34] See Tian (2016).
[35] See Token (2018).
[36] See AgriLedger (2018).

There are a number of developing economy specific challenges to blockchain applications. There is often a lack of internet access. We are optimistic that this will be solved through time—either through the expansion of physical communications infrastructure and communications technology or through other solutions such as SMS blockchain-based transactions that are later updated on a blockchain. This challenge is also closely connected with problems of the pervasiveness of mobile phone technology. Another potential solution to this was covered in Section 3.2—blockchain might fund the investment and deployment of these information communication technologies through tokenisation. Blockchain can act not only as new institutional, economic infrastructure for exchange but also as a mechanism for the funding of new projects.

There are also questions relating to the on-boarding of information. This is essentially a problem of discrepancies between blockchain data and the state of goods in the real world. The information that blockchain can carry along a supply chain must either be inputted by a person—who faces all of the challenges of fallible human actors including fraud and opportunism—or through the use of other technologies such as IoT. In the latter approach, sensors could be attached to a shipping container or product that automatically uploads information to a decentralised distributed ledger. This takes away the potential for a wide range of human opportunism along the supply chain.

As we discuss further in Section 5 below, there are a number of policy questions for governments relating to the application of blockchain supply chains. First, will governments recognise blockchain-based solutions? For example, will customs authorities accept blockchain-based information relating to biosecurity regulations? Moreover, how will governments engage with industry to develop open standards for the structuring of information? We have proposed elsewhere that governments should be involved in international policy coordination to devise open standards.[37]

4.2 Enforcing property rights

The recording and enforcement of property rights in developing economies is a long-standing challenge. Registries of property rights are often untrustworthy and contradictory across a number of different sources. These challenges are compounded by a lacking rule of law, corruption, and a failure of enforcement. At the same time, transparency and enforcement of property rights are well-known as foundational to growth. Property rights enable individuals to care for their property, trade, invest, and act entrepreneurially. Economist Hernado de Soto estimates the level of 'dead capital'—assets that cannot easily be bought or sold—sits in the tens of trillions of dollars.[38]

Blockchain could potentially solve some of the challenges relating to property rights in the developing world. As a governance technology, blockchain could be used as the infrastructure to

[37] See Allen et al. (2018a)
[38] De Soto (2000)

store information about property titles—including not only ownership but specific details about the property—in an immutable and tamper-proof ledger. Rather than relying on opaque databases maintained by governments, individuals can transfer property rights directly with each other using blockchain technology. This is essentially the same economic problem as we saw with money—the need to come to consensus over a distributed ledger of information.

How would blockchain-based property registries work in practice? The most basic approach would be a public blockchain where individuals use unique identifiers—using public key cryptography—to transfer digital assets (that represent the underlying physical property assets) to others. This could radically reduce the cost of transferring property and ultimately enable a more frictionless property market. Other decentralised—and perhaps messier—approaches might be more decentralised, where individuals in a locality attest to the ownership of a property title. This more closely aligns with the concept of common property resources as outlined by Nobel Laureate Elinor Ostrom, and can be broadly be termed a Web of Trust model.[39]

Precisely what form a blockchain-based property registry takes will be discovered over time and will differ depending on the economy. There are a vast range of countries experimenting with solutions now, including Bermuda, Georgia, Honduras and India:

- Bitfury and the Republic of Georgia are testing distributed ledger technologies for more transparent access to reliable data on land titles. Over 100,000 land titles have been registered on the platform.[40] They also aim to provide this for other types of asset registries, such as Intellectual Property.
- The government in Bermuda has signed an agreement to incorporate blockchain into their land registry system.[41] This agreement is also with Bitfury.
- Two Brazillian municipalities, Pelotas and Morro Redondo, are looking to overhaul their land registry offices by embedding the information into the Bitcoin blockchain.[42]
- The Rwanda Land Registry is being digitised to ensure control of authenticity.[43] Bitland also operates in Ghana, attempting to survey land and record title deeds to prove a permanent and auditable record.[44]

There are also a number of hurdles to implementing blockchain-based solutions to land registries. Similar to supply chain governance, one of the issues is on-boarding. Property title data that is placed on the blockchain must be accurate and accepted in the first instance. This is a particular

[39] Ostrom (1990, 2010)
[40] https://eurasianet.org/georgia-authorities-use-blockchain-technology-developing-land-registry
[41] See Milano (2018).
[42] See Keirns (2017).
[43] See Tobor (2017).
[44] See Aitken (2016).

problem for developing economies, where there may be lacking or untrustworthy existing data sources. Placing inaccurate property title records on a blockchain may only compound issues given its immutability properties. Implementing blockchain-based property registries may face political or regulatory resistance. That is, if those who are corrupt are in power there may be concerted efforts to slow the pace of blockchain development. These challenges, however, have a number of potential upshots. The nature of blockchain as a decentralised technology may more closely align with the customary norms of property ownership. That is, a blockchain, depending on the underlying consensus mechanism, is effectively a community-based form of self-governance where individuals attest or verify the status with the community. It is a much more community-like or tribe-like application of registries.

4.3 Verifying identity

Many people in developing economies have insufficient identity verification. Identity is a good that is currently co-produced by both the private sector (e.g. utility bills) and by governments (e.g. passports or drivers licences). Government records of identity are regularly lost or are simply never created. This problem particularly affects displaced people such as refugees. A secure identity is necessary because a unique identity is a foundational tool for:

- accessing or purchasing services including education and healthcare.
- participation in democratic governance.
- as an input into economic exchange, and therefore economic mobility.[45]

Indeed, the Sustainable Development Goals include the aim to achieve effective legal identity for all people.[46] There are also groups who are attempting to solve the multi-faceted problem of identity management, such as ID2020.[47] A person's identity includes not only citizenship and other basic data, but also credentials of, for instance, educational achievements and medical records.

Identity is an economic problem of governance in the face of uncertainty and transaction costs. How can everyone agree that someone's identity is trustworthy and hasn't been tampered with? How can a refugee who moves countries maintain records of their identity when they cross national borders? For these reasons, there have been a range of centralised digital identity solutions provided by government.[48] However, one of the problems with centralised digital identity solutions is privacy over a centralised digital database of potentially sensitive information. As a tool for institutional governance of ledgers, blockchain technology holds potential for the creation of a

[45] See Berg et al. (2018a); Berg et al. (2018b).
[46] See United Nations (2015, p. 30): "By 2030, provide legal identity for all, including birth registration."
[47] Including Accenture and Microsoft, ID2020 aims to build a digital ID network using blockchain.
[48] For instance, there are applications in Canada, Estonia and India.

decentralised digital identity framework to assist people in developing nations, enabling them to engage within the economy and society more broadly.

Blockchain could be used a mechanism to solve the identity problem. There a number of ways this could occur. Many efforts are emerging under the banner of 'self-sovereign identity'. In this approach, private solutions emerge so that individuals control their identity data. Blockchains enables people to have a unique digital identifier that they use to engage with others. Here individuals effectively store attestations of correct data from other third parties, cutting down on the need for that data to be validated each time. This information cannot easily be altered, and it is more widely used when individuals move across jurisdictions. Some examples of identity solutions using blockchain technology are outlined below.

- IDbox has been tested in Lalaura, Papua New Guinea.[49] This is a solar powered unit which creates a unique ID allowing users to access micro-finance and insurance.
- Building Blocks has integrated biometric authentication—a technology that allows people to identify themselves using their iris—with a private permissioned blockchain.[50] In January 2017 there was a proof of concept in Jordan and Pakistan.
- In India the state of Andhra Pradesh has announced plans to launch blockchain pilots, including a proof of concept to secure citizen data on a blockchain platform.[51] This is in collaboration with cybersecurity firm WISeKey.

There are a number of challenges to implementing a blockchain-based system of digital identity, including social barriers, complexity, interoperability, and government regulations. There are likely to be challenges relating to cultural norms, perhaps leadings to problems with adoption. In particular, there are likely to be concerns about privacy. While not a blockchain-based solution, Aadhar in India was a centralised digital identity system that was hacked.[52] Citizens of developing economies might also have challenges managing cryptographic keys. The nature of government regulations and uptake might also constrain identity applications. The creation of a useful self-sovereign identity system is likely to require significant government adoption, in particular as it relates to domestic regulations such as Know Your Customer.[53]

One of the unique features of blockchain applied to developing economies, however, is that it enables the organic growth of institutions from the bottom-up. Those new institutions can theoretically be tailored and better map to the specific norms and cultural values of the people. This sits in contrast with a more centralised imposition of institutions from the top-down. We suggest

[49] See Loop Technology (2018).
[50] See World Food Programme (2018).
[51] See Das (2017).
[52] Khaira et al. (2018).
[53] See Pisa and Juden (2017, p. 27).

that this enables a more peaceful and seamless transition towards pro-growth institutions that understands the complexities of institutional analysis.

4.4 Enabling civil society

Australia gives over $500 million per year in foreign aid to Papua New Guinea. One of the major problems facing governance of civil society funding and aid is the trust, visibility and transparency of funds as they move. The economic problem of aid is effectively a supply chain problem: money moves from one place, often through an intermediary, to produce goods or provide services within a developing economy.

The funds that move through civil society must often be traced through a number of siloed hierarchies and banks, leading to loss of data. Why do we need transparency of funds through civil society organisations? The first reason is that donors want to know if funds are being used for their intended purpose. This both relates to the wasting of funds through inefficient bureaucracies, and whether funds are being fraudulently syphoned. The second reason is that better information about how funds are used provides the data for determining the effectiveness of the particular development approach.

By acting as the economic infrastructure on which the data of civil society flows, blockchain technology helps to minimise these information costs. We expect that better and deeper information about the flows of foreign aid will incentivise people to provide those funds in the first instance. That is, blockchain might not only ensure that current levels of foreign aid are better spent, but incentivise donors to give more funding. Furthermore, the process of decentralised development we described above might lead to a new wave of funding for infrastructure projects that is more democratised. There are currently a number of attempts to solve some of these traceability problems using blockchain technology.

- Disberse aims to make aid delivery more transparent and effective using a permissioned blockchain system.[54] The company liaises with the people and organisations along the donor supply chain, to determine objectives and funds for a project.
- Alice is a platform that tracks and runs projects transparently.[55] The platform makes the performance of past projects available publicly.
- Chian aims to implemented blockchain as part of the government's charity tracking system, representing a government-based application of blockchain to civil society functions.[56]

[54] See Disberse (2018).
[55] See Alice (2018).
[56] See Suberg (2018).

5 Policy implications

The blockchain use cases we explored above are only the first stages in the application of blockchain technology for economic development. Over time there will be an evolutionary process through the testing and trialling of new solutions. In this process, some blockchain institutions will outperform existing solutions, such as firms and governments, while others will demonstrate the shortcomings of applying blockchain, such as privacy or speed, and we will remain with legacy centralised systems. The faster this evolutionary process occurs—and the more effectively entrepreneurs can test and trial applications in market settings—will propel economic growth and facilitate the process of economic development. While we suspect that much of the effort for blockchain development will come through private industry, questions remain over the role of government. In this section, we suggest a number of recommendations governments of developing economies should embrace. These recommendations revolve around a concept of crypto-friendliness—a notion developed at the RMIT Blockchain Innovation Hub—and the current state of rapid global investment in blockchain technology. Our recommendations do not seek to be prescriptive in the sense of providing a step-by-step guide for developing economy governments. Rather, we seek to provide the intellectual framework and understandings that policymakers should have front of mind when making regulatory decisions.

The blockchain industry is currently facing a rapid process of investment into a wide range of applications. The critical understanding for governments is that this process is occurring in a globally competitive environment and across a wide range of potential jurisdictions. Entrepreneurial action is not limited to decisions over business models—they must also choose the jurisdiction and rules within which they operate. This leads to global competition over the regulatory settings and rules of the game of different economies. What rules are most conducive to the needs of entrepreneurs? This process is clear in the blockchain industry, where some particular jurisdictions such as Switzerland, Singapore and Estonia are widely considered good jurisdictions for blockchain investment—that is, crypto-friendly. However, what does it mean to be crypto-friendly?

Crypto-friendliness is a multi-faceted concept.[57] Blockchain entrepreneurs are seeking quality institutional governance within which they can invest. These institutions include stable government, property rights, low taxation, and limited over-regulation. There is an inherent trade-off in determining precisely what these institutions are, however. First and foremost entrepreneurs require the freedom to set up businesses and to test and trial new ideas.

The concept of 'permissionless innovation'—where the default setting is to enable innovation—sits in contrast with the 'precautionary principle', where governments systematically overweight the

[57] For a comprehensive analysis of crypto-friendliness see Novak (2018).

potential harms of new technology, while not taking into account the benefits.[58] On the other hand, it is also true that entrepreneurs seek stability and certainty: entrepreneurs take into account the potential that a government may later change a decision, or that they may radically shift how a particular technology is treated. Crypto-friendliness trades-off these understandings: freedom and certainty.

As we saw in Section 2.2, blockchain is an institutional technology. Given the process by which blockchain will compete with existing forms of governance—many of which, including governments, may be deeply entrenched in regulations—one key aspect of crypto-friendliness is the willingness for regulatory frameworks to be adaptive. Will governments be willing to shift existing regulations that might hinder 'protective-tier' blockchain entrepreneurship? Both setting prescriptive rules for blockchain technology today, and failing to reform existing ones, may restrict innovative behaviour in the future. For instance, governments might need to quickly clarify the tax status of a particular blockchain-based asset or to reform existing regulations that are no longer considered minimally effective regulation when there are new forms of blockchain governance that solve a similar economic problem.

This must be a constant and dynamic process of learning and development of best practice—with a particular eye on the actions of other jurisdictions. To be sure, governments in developing nations must also be careful not to implant policy solutions from other nations without taking into account context, but there will inevitably be a process of learning and discovery across jurisdictions. Furthermore, as blockchain technology develops, and is combined with other new technologies such as Artificial Intelligence and IoT, the effective state of regulation will shift through time.

If it is difficult for governments to change their existing regulations for whatever reason—for instance, entrenched interests—then the notion of developing a separate territorial, economic zone for blockchain implementations could be an effective approach. This is an acknowledgment both that (1) there is a process of discovery of effective institutions over time; and (2) it is often difficult to achieve political change. For instance, PNG, together with blockchain firm Ledger Atlas, is looking to take this approach, implementing a blockchain-focused special economic zone.[59] This may be a useful path to stimulate investment and attract entrepreneurial activity.

One fundamental understanding for the governments of developing economies will be the relationship between physical investments in infrastructure—such as communications infrastructure that enables blockchain technology to operate—and the economic infrastructure that blockchain potentially provides. These investments such occur simultaneously. For instance, in PNG there is currently a project for a submarine internet cable to Australia to increase internet connectivity. While

[58] See Allen and Berg (2018); Thierer (2014, 2016).
[59] See Oxford Business Group (2018).

we are optimistic that blockchain solutions will eventually evolve to be more effective without reliable internet, it should be recognised that there is a place for the developing economy governments to be investing in the physical and communications infrastructure necessary for blockchain to be applied. As we noted in Section 3.2, however, the physical infrastructure itself could be funded using blockchain technology: democratising the process of aid funding and providing a more crowd sourced approach to the building of infrastructure.

There are three further roles of government that we wish to touch on briefly in this report:

- Engage in efforts to develop blockchain open standards—particularly for supply chain information. Developing economies should seek to engage in efforts to develop open international standards for the application of blockchain to global supply chains. We believe there is significant potential for the developing world to take advantage of the benefits that more trustworthy and cost-effective supply chain information will bring.
- Digitise existing government records. Much of the role of modern governments is acting as a trusted third party to maintain ledgers of information such a property titles, intellectual property protections, and births, deaths and marriages. For entrepreneurs to build solutions off existing records, governments should seek to provide these records in a digital form. The main reason for this is because of the nature of cryptographic hash functions (even a minor change in the underlying data being verified will make hash functions ineffective at verification). Given privacy concerns, governments should begin with records that are already public.
- Recognise blockchain information. One of the basic roles for government in the future application of blockchain technology is in being open to recognising solutions to blockchain problems. This is clear in the case of blockchain supply chains: will customs and port authorities treat blockchain information solutions as true and correct? Furthermore, will governments recognise blockchain-based information about identity, such as education credentials? It is unclear at precisely what margins these challenges will arise—but we suggest that governments are open to these challenges.

We have presented here a wide-ranging scope of activities and roles of government within the blockchain space. This is the nature of a government being adaptive to technological change.

6 Conclusion

In this report, we examined the potential of blockchain technology as an institutional tool for economic development. Blockchain technology, invented in 2008 in its first application as Bitcoin, is a technology for creating and maintaining distributed ledgers of information. Its applications range far beyond cryptocurrency to include supply chain governance, democracy and new forms of organisation. Ultimately blockchain is a governance technology—alongside other forms of organisation such as firms and markets—and might lead to a radical shift in the way we govern exchanges and interactions. The study of the way blockchain competes with other institutions is institutional cryptoeconomics, drawing on the institutional and transaction cost school of economics.

Blockchain is relevant for developing economies precisely because of the potential it provides for innovative forms of governance. Indeed, over time analytical focus of development economics has shifted from accumulation and allocation of capital towards an understanding of the importance of governance and institutions. Blockchain provides the tool for institutional entrepreneurs to develop new ways to govern human exchange and cooperation, including the protection of property rights. We propose that blockchain might even bring a new phase in development—decentralised development—which comes through the parallel implementation of blockchain-based institutions alongside legacy institutions. An evolutionary process will then determine the comparative efficacy of distributed blockchain solutions compared to existing centralised institutions.

We focused in particular on the possibility of blockchain applied to the information problems of supply chains, as well as for property title registries, the management of identity and the tracking and transparency of civil society organisations. This shows that blockchain provides a potential solution to many of the challenges common across developing economies. To be sure, there are a range of challenges to be overcome—and we expect many solutions to these challenges to be developed by private industry. However, we also draw a number of implications for governments. Governments should seek to implement ‘crypto-friendly’ policy settings that are accommodative to the needs of entrepreneurs. The building of physical infrastructure is complementary to the building of economic and institutional infrastructure. The role of government, therefore, incorporates how they can provide the necessary public data to build blockchain-based solutions, and provide recognition of solutions once they are discovered.

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