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Government by Code? Blockchain Applications to Public Sector Governance

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Studies of blockchain governance can be divided into analyses of the governance of blockchains (such as rules and power dynamics within a given network) and governance by blockchains (such as how blockchains can be implemented to improve self-governance of community-based peer production networks). Less emphasis has been placed on applications of distributed ledgers to public sector governance. Our review clarifies that the decentralization and distributive features that enable blockchains to link up loosely connected private organizations and public agencies to improve efficiency and transparency of government transactions. However, most blockchain applications lack clear advantages over the conventional digital recording of information. In addition, our review highlights that blockchain applications in public sector governance are potentially vast, though in most instances, the existing applications have not extended much beyond limited-scale pilots. We conclude with a call for the construction of indexes of public sector implementations of blockchains, as none yet exist, as well as for additional research to understand why governments have not deployed blockchains more widely.

Keywords: polycentricity, public sector governance, legal institutions, public procurement, blockchains

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INTRODUCTION

Blockchains have been hailed as a building block for a new economy (Davidson et al., 2018). But does distributed ledger technology harken a revolution in public sector governance? The first generation of scholarship on blockchain governance debated to what extent blockchains replace governments. Crypto-anarchists, or techno-determinists, see distributed ledgers as unseating government (Atzori, 2015). However, others see a significant role for government alongside distributed ledgers in creating and preserving trustworthy records on evidence of rights, entitlements, and actions as distributed ledgers provide new ways to record information (Lemieux, 2019). Legal scholars have pointed out how law and legal infrastructure is useful for blockchain networks (Werbach, 2018), including for smart contracts (Cohney et al., 2019).

A second generation of blockchain governance research considers governance *of* blockchains and governance *by* blockchains (Rozas et al., 2021a). Studies of governance of blockchains recognize that the performance of any given blockchain network depends on rules internal and external to the network. The increase in confidence in operations of computational systems with blockchains depends on proper operation of the governance of the blockchain network, which requires trust in individuals with influence and authority within those networks (De Filippi et al., 2020). Beyond considerations of governance internal to and external to blockchains, research on governance of blockchains embraces that there are thousands of ways that these networks are organized that offer opportunities for comparative institutional analysis (Allen et al., 2021a) as well as how on-chain crises lead to changes in rules governing blockchains, such as changes resulting from The DAO crisis (Reijers et al., 2018). These studies infuse consideration of "invisible politics" of blockchains that occur within networks and which ultimately contribute to their performance (De Filippi and Loveluck, 2016).

Blockchains can also be used by organizations as part of their governance, which is the subject of current studies of governance by blockchains. Studies of governance by blockchains consider how self-governing communities, including peer-to-peer communities and self-governing communities seeking to manage commons on a global scale, use blockchains to improve their ability to self-organize and self-manage (Rozas et al., 2021b).

Our paper extends research on governance by blockchains by providing a stock-taking of the applications of blockchain to public sector governance. To date, surveys of blockchains for public sector governance have focused on single areas of implementation, without considering the broad applications of blockchains for public sector governance. Such domain-specific studies and reviews tend to understate the broad range of possibilities for blockchain use by the public sector. Thus, our review seeks to catalogue the possibilities for blockchains, as well as to consider systematically whether blockchains are living up to their promise.

Our stock-taking finds that blockchain can improve the public sector governance on several margins. Many of these applications are simply government implementing a superior database as far as security is concerned. For some types of public (permissionless) cryptocurrencies, blockchains offer an alternative to government-backed currencies, though for stablecoins, cryptocurrencies combine features of governments and new technologies. Thus, while blockchains create new opportunities for experimentation with democracy outside the normal challenges of government, cryptocurrencies reduce reliance on central banks, and smart contracts facilitate business relations through their links with Industrial Internet of Things applications (Berg, Davidson, and Potts 2019), our review suggests that blockchain networks often work synergistically with traditional governance, and we explore those synergies here.

Our review also finds that the deployment of blockchain technologies depends in part on the government's administrative capacity and capability to implement the technology. While blockchains are most useful when trust in government is low (as ledgers provide for greater accountability), the ability to implement blockchain solutions depends on a certain degree of administrative and technological capacity. The finding that Information and Communication Technologies and e-government applications confront barriers to scaling up in the Global South extends to blockchains (Zambrano, 2020). The digital divide between blockchain smart government "haves" and "have-nots" is an issue in the Global North (such as among local jurisdictions within wealthy countries) as well as within the Global South. For example, the United States is a technology leader, though blockchains have barely scratched the surfaces on American Indian reservations despite the low trust that reservations have in the federal government. The broadband divide (including "last mile" problems) and lack of government capacity to digitalize records thus serves as a constraint on the implementation of blockchain solutions by governments to improve public sector governance.

Significantly, our review concludes by noting that there is currently no widely available index of deployments of blockchains by governments and national and subnational levels. Thus, our review serves as a call for the development of such an index. To date, reviews have focused on technical aspects of implementations to a single realm (such as voting). Since the applications of blockchains are vast, an index that captures the diversity of applications is critical to understanding progress in implementation of blockchains for public sector governance. In addition, since many blockchain applications have not advanced far beyond proof of concept or limited-scale pilot implementations, further research is needed on the barriers to adoption of blockchains by public sector governments, including the aforementioned issues with the digital divide. Such research should consider "ordinary" political barriers to change in administrative structures, including hesitancy of public officials to adopt novel technologies.

Our review proceeds as follows. We begin this review by setting forth three broad perspectives on blockchains: as an alternative to predatory governments and corporations, as a polycentric enterprise, and as an improved database. Our review suggests that all three perspectives hold some explanatory power in considering blockchains and that the view that blockchains compete with the government tends to ignore that blockchains are in fact a better database that is, in most instances, a nested enterprise where the success depends on a favorable and effective regulatory and legal environment. We then consider two realms where blockchain can and already is improving public sector governance: the provision of public goods and the facilitation of economic exchange. We compare various government implementations globally. In the conclusion, we consider some of the ongoing challenges with adopting blockchain more broadly, including inequities in smart government using blockchains. Thus, while research is underway to understand how blockchains are governed that embraces the diversity of the hundreds, if not thousands, of ways these networks are organized (Allen et al., 2021a), this

paper speaks to some of the emergent applications in the public sector.

BLOCKCHAIN AS A TECHNOLOGY OF FREEDOM, POLYCENTRIC ENTERPRISE, AND NEW DATABASE

Considerations of blockchains for governance can be categorized as taking one or more of the following perspectives: blockchain as a technology of freedom; as a polycentric enterprise; or as a new form of database. Blockchains can potentially be all three, depending on the political, economic, social, and technological context, and so each perspective sheds some light on their potential for public sector governance. This section provides a brief overview of these three perspectives.

Blockchain as a Technology of Freedom

The perspective on blockchain that sees distributed ledger technology as a new technology of freedom implies a fundamental distrust in existing governance structures or a need to escape them. The transparency and immutability of blockchain make it especially useful in such contexts of distrust of government (De Filippi and Wright, 2018).

Blockchains, from this perspective, offer some freedom from an untrusted government by enabling an alternative confirmation of information. To governments that have already digitalized government services and enjoy high levels of legitimacy and a reputation for reliability and transparency, adopting blockchain may gain little due to the comparatively higher costs of maintaining blockchains. In the context of unreliable government, blockchains could be a new architecture of trust. Certain aspects of the crypto-democracy literature see blockchain in this way as an alternative means to establish new governments on a blockchain (Allen et al., 2018). Blockchains allow people to establish their own governance institutions, as well as offer—through forking—opportunities to create any given blockchain (Berg and Berg, 2020). In the currency realm, since central banks may collude or fail to establish effective monetary policies (Boettke et al., 2021), cryptocurrencies offer countries an opportunity for innovation.[1]

Blockchains can also reduce reliance or dependence on corporations. Large and powerful modern corporations and economic entities introduce systematic risks. Blockchain provides people with an alternative channel to self-organize besides governments and corporations to improve their welfare. In the currency realm, since central banks' monetary policies may not be transparent to the public (Boettke et al., 2021), cryptocurrencies offer countries an opportunity for innovation.[2]

[1]For example, in June 2021, in response to proposed G7 currency policies, El Salvador announced it was going to rely more heavily on cryptocurrencies.

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Blockchain as a Polycentric Enterprise

A second view of blockchain sees it as a polycentric enterprise (De Filippi et al., 2020). One of the novel features of blockchains is to use smart contracts to eliminate ex-post manipulation of the terms of contracts. This is because all provisions are coded into the contract, with execution triggered by real-world data that cannot be manipulated by the contracting parties (De Filippi et al., 2021). In this regard, blockchains promise complete contracting, especially with reference to permissioned (or private) blockchains (Alston et al., 2021). Distributed autonomous organizations (DAOs) further reduce reliance on traditional corporate governance or trusted third parties, as transactions recorded in the blockchain are typically immutable (Werbach and Cornell, 2017).

Despite these novel aspects, blockchains depend on external rules. Polycentric governance institutions are nested in higher levels of governance. Though early internet and telecommunications industries were often self-governing, law remained significant in the early days of the Internet (Benkler, 2004) and telecommunications (Werbach, 2004), with debates centered on what the law governing innovative technologies ought to look like. Smart contracts also frequently rely on third-party data processors such as oracles in order to adjudicate contract completion. In the peer-to-peer production and telecommunications realms, self-governance is significant, though the ongoing role of law and regulation makes the enterprise polycentric.

In addition to blockchain nesting within established or state-sponsored governance, blockchains involve governance dilemmas similar to any large organization, including those arising from uncertainty in contractual relations (Howell and Potgieter, 2021) and the necessity of rules to deal with the concentration of power (Alston, 2020), as well as blockchain-specific governance dilemmas, including the need to choose protocols (Cowen, 2019) and competitive dynamics among blockchains (Alston, 2021). There are also governance challenges that arise from reliance on oracles to bring data from the real world into the digital world (Poblet et al., 2020). Oracles are software interfaces trusted by contracting parties to translate real-world data into a form that can be used to determine whether blockchain's conditions are satisfied and are often needed to translate those events into the blockchain (Poblet et al., 2020). In addition, while smart contracts are self-executing, disputes over smart contracts still are resolved by flesh-and-blood lawyers in the context of traditional courts of law (De Filippi et al., 2021). Further evidence of blockchain's polycentric features is found by examining the evolution of law with these new kinds of ledgers. The shortcomings of oracles, for instance, have resulted in an evolving area of negotiation law (Allen et al., 2019b). Lawyers are useful, and perhaps necessary, to write contingencies into code.

Polycentricity is thus a general feature of blockchains (Alston et al., 2021). Any given blockchain network tends to be nested in higher levels of rules and regulations (Frolov, 2021). Evidence of the ways that blockchains can benefit from the law is informed by research on ways cryptocurrency regulations improve opportunities for users (Whitford and Anderson, 2021) and

analysis of the evolving body of negotiation and enforcement law for blockchains that parallels conventional negotiation law (Allen et al., 2019b). This polycentric view thus sees the performance of any given blockchain as depending on rules internal to a network, those external to it, and competitive pressures and exit options that arise from the overall environment within which blockchains are operating (Alston et al., 2022).

Not all agree with this synergistic view of blockchain, law, and regulation. Schuster (2020) argues that the law will not and has not embraced cryptocurrencies. However, state governments in the United States appear to be competing to provide a friendly environment for blockchain. Wyoming, for example, passed over a dozen laws from 2018 to 2020 to establish a framework for the law to embrace blockchain. Though Wyoming has been called a blockchain Wild West, these laws show that the government is regulating blockchain.[3] In addition, while it is true that blockchain has not lived up to its potential, including in areas such as real estate transactions (Arruñada, 2018), blockchains are being implemented for the registration of real property. Thus, it appears there is a demand for blockchain law and governments are supplying it.

Blockchain as a New Database

A third view is that blockchain is a new type of database. While it is clear that blockchain has a novel combination of affordances (openness, transparency, and immutability) compared to previous ledgers, it remains a database. Governments could also adopt blockchain to mirror their records, adding robustness to their system of managing information.

An important question in considering the database view in the context of public sector governance is what it means compared to previous databases. Public governance functions are distributed already, at least to some extent. Digitalization is also present and offers some advantages, without blockchain, compared to other recording systems. In information and record-keeping contexts, efficiency refers to security and, if desired, transparency and immutability. This combination of features provides constraints on certain types of costly behavior. From an economic perspective, efficiency considers the balance of these benefits against the costs in terms of running blockchain networks compared to more centralized arrangements. Blockchain networks are more effective at managing information in a distributive fashion but at a higher cost than centralized architectures. Thus, blockchains may be less efficient from an economic function even if those functions outlined above—security, transparency, and immutability—are considered desirable.

Our stock-taking illustrates that all three views hold some explanatory power. In some applications, blockchain can lead to contracting outside of government authority. Still, governments remain able to influence blockchain, and can in principle, ban these activities. Moreover, blockchain applications such as smart contracts often rely on government or third-party authorities to be successfully implemented and enforced. In addition, despite arguments that blockchain is a new institutional technology, it can also be thought of as a database that is, in some situations, a superior alternative to digitalization as a better record-keeping system, but one that is far from perfect. The latter view—blockchain as a better database—is especially significant in understanding the promise and challenges of blockchain for public sector governance, as well as one that invites consideration of digital divides in government capacity to implement new governance technologies.

BLOCKCHAINS FOR PUBLIC ADMINISTRATION

Personal Data

Governments record vast amounts of personal information. Through fraud or compromised access keys, hackers often target personal information to access the benefits associated with it. In situations where security is an issue or where governments cannot be trusted with the aforementioned information, blockchains promise opportunities for self-sovereign identity. This process of storing personal information promises more individual autonomy over personal data. Our review clarifies that in most instances, the role of government or a trusted party is necessary to authenticate the personal information stored in decentralized services. Such applications remain largely conceptual at this point.

One way that governments can use blockchain is to place personal information on a blockchain, including social security numbers and printed birth certificates. One security challenge with social security numbers is that they are used for minor identification checks and other purposes beyond direct government identification. It creates vulnerabilities for security, as well as mistakes in record-keeping (as humans remain a weak link). Though no encryption is certain, blockchain can provide greater security in these decentralized applications (e.g., opening bank accounts, verifying credit ratings, etc.) because the records can be verified by a distributed rather than centralized process.

Once governments digitalize personal information, that information can be used for any activity in the government's purview, including voting, opening a bank account, and receiving government services. Such systems could be a mirrored blockchain, which is one of several types of recording systems using a blockchain. In a mirrored recording system, records are placed on a blockchain, and the records on the blockchain can be compared to the original (digitized) records (Lemieux, 2017). The advantage here over "normal" digital identification is the combination of transparency and immutability, including superior ability to determine fraud, as well as redundancy. Verification also becomes much less costly, as the blockchain record can quickly and easily be compared to the original records. Consequently, governments may be able to offer greater security and portability than with conventional government-issued digital identification and storage of personal information. Such systems would be permissioned as well, or hybrid public-permissioned blockchains, to address privacy concerns on the blockchain, as restrictions on who has access to information are necessary. It

[3]https://www.coindesk.com/crypto-regulation-custody-wild-west.

may be costly to implement, and registration through a blockchain is not essential (as governments routinely do it), though for citizens concerned about privacy and fraud, blockchains have advantages over traditional digital recording of personal information, including identities.

Governments can also support people who use blockchain-based systems to store their personal information. In such instances, the service of placing information on a blockchain is provided privately, with governments supporting such efforts by verifying identity, for example. Blockchain networks already exist to secure personal information. Individuals are given a key to their personal information. Encryption on a blockchain platform like Ethereum provides security, and individuals can back up their keys on an app, such as a digital vault. Once their information is verified (they must prove who they are) and coded into the network, service providers can verify information via an individual's smartphone or another device. All of this can be linked to biometric data, thereby ensuring that anyone who loses their identification could easily prove their identity (and fraudsters would have an extremely hard time faking biometric data). Advantages of blockchain identification include data portability, decentralization, and relative security. In addition, digital identification is a key gateway to blockchain applications such as voting.

None of the above requires a government, though governments can support such entities—thus giving them legal recognition. There are several proof-of-concept applications with blockchain-based storage of personal information that involve governments, though the role of government is largely as an endorser or a trusted party. For example, Estonia's e-Residency program allows citizens to become e-Residents who can register their businesses and access business services in e-Estonia, provided they follow Estonian laws and regulations (Sullivan and Burger, 2017). The digital government of the Zug region in Switzerland is another example: citizens can have their government IDs issued through the blockchain and then use an app for voting in their direct democracy. (Zug, which has named itself Crypto Valley, is also accepting cryptocurrency for tax payments.) Painted Rock, a proposed city on a blockchain in Nevada, United States, has a similar model of establishing a new government. In each situation, individuals are establishing their identities on a blockchain, with the government offering the green light to do so.

There are also situations where a government is unreliable, and blockchains offer solutions. The UN has implemented programs that provide people with a digital identity that can be verified with eye scans and then allows individuals to receive funds and food (Juskalian, 2018). The UN's program sees recording identities digitally as the first step in improving the distribution of services. In that case, the UN serves as a trusted third party. In instances where a government is weak, as in refugee camps, trusted third parties—international organizations, such as the UN, USAID, or World Bank—can supply trust to the contracting process. The information recorded by these third-party international organizations can then be used by a governing body (Reinsberg, 2019).

Digital identification could be part of networked public services, enabling a seamless flow of information about an individual without any interaction with government agencies, thus mitigating data silos and bureaucratic jurisdiction blockages. Individual information could be recorded on a secure blockchain database. Cryptographic keys could be shared selectively to limit information only to relevant information for any particular interaction or entity. Since private transactions (and privacy of information) become more challenging on public blockchains, the technical solution for doing so is through public-private hybrid blockchains that balance openness and accessibility with privacy considerations. This approach has been piloted by He3Labs on the Crow reservation in Montana.[4] American Indian reservations have been excluded from many economic opportunities because of federal regulation. The blockchain system piloted by He3Labs used a novel public-private blockchain to balance privacy considerations with performance and accountability.[5]

Though blockchains offer possibilities for securing identifications with privacy and portability even in precarious situations, it is not certain that blockchains will be justified from the perspective that benefits exceed the costs. If privacy is a concern, then enabling individuals to place private information on a blockchain can occur through their personal choices, with government playing a supportive role. In situations where government is not available to record information, blockchain networks offer ways to store personal information and distribute services beyond recording of information. Of course, verification of one's identity will typically depend on a government or some other external validation since blockchains cannot ultimately verify who someone is.

Public Procurement

Combatting corruption in public procurement is another area where blockchains have been implemented and show promise for expansion. Governments increasingly contract out services in the hopes of increasing the efficiency and accountability of public spending. This rise in outsourcing creates additional opportunities for corruption. A plethora of international agencies has established frameworks to combat corruption, including the OECD Anti-Bribery Convention, the WTO's Government Procurement Agreement, and the UN Commission on International Trade Law, which together establish frameworks for auditing, accounting, public availability of procurement law, processes for bidding, and sanctions for non-compliance. Our review suggests that it is not clear whether blockchains have advantages over traditional e-procurement systems.

The World Economic Forum (WEF) initiated the *Unlocking Government Transparency with Blockchain Project* to reduce corruption and provide an effective mechanism in vendor

[4]https://www.he3labs.com/blog/2018/7/21/hybrid-blockchain-solutions-real-world-combinations-of-public-and-private-distributed-ledger-technology-dlt.

[5]https://www.he3labs.com/blog/2018/9/4/he3labs-demonstrates-blockchain-e-government-at-the-100th-annual-crow-fair.

selection in the public procurement process.[6] The WEF's Blockchain Project is informed by the consensus in the literature that corruption reduces economic well-being and reduces trust in government and e-procurement. To assess blockchains, WEF compared blockchain-based systems to e-procurement. E-procurement refers to the use of Internet technology to automate or integrate any or all parts of public procurement to improve efficiency, transparency, and accountability to the wider public. It also enables any or all aspects of procurement to be put on a blockchain—advertising, tendering, bidding, awarding, purchasing, ordering, contracting, invoicing. Here, the WEF again takes the lead from anti-corruption best practices established by the WTO and UN, along with the Open Contracting Partnership and Open Data Charter, which recommend that e-platforms be widely accessible, have adequate authentication/encryption/security, and have clear governance (mirroring best practices of non-e public procurement). The Blockchain Project highlights some of the limitations of existing e-procurement systems and outlines gains to be made over Internet-based procurement systems even without blockchains, as well as finds that blockchains can improve public procurement, such as by providing greater transparency and accountability than traditional e-procurement.

There have been some notable implementations of blockchains for public procurement. The US Department of Health and Human Services focused on project cost analysis. Seoul of South Korea focused on proposal evaluation. And, the autonomous community in Aragon, Spain, focused on public procurement vendor selection. The project implemented in Aragon employs blockchain to increase transparency, traceability, security, and integrity in vendor selection, with over 25 contracts since its launch in 2019. The solution is a hybrid blockchain architecture with the Ethereum public blockchain coupled with a Hyperledger Fabric permissioned blockchain to automate tender vendor evaluation that civil servants review.[7]

Ukraine's efforts in e-procurement are a useful example. In Ukraine, for example, ProZorro (which is an e-procurement system that is not on a blockchain) has been used to provide a public record of all public procurement decisions, in the process reducing corruption in public spending (Shapoval et al., 2017). The use of blockchain along with digital records of transactions provides an immutable record of spending, as well as bidding—another vector of corruption. By relying on blockchain, the Ukrainian government could reduce time spent in contracting, reducing fraud in the process. Other procurement systems are on blockchains in Ukraine, so the experience provides some opportunity for comparisons or "conventional" and blockchain-based e-procurement systems.

Based on two of the authors' experience in implementing ProZorro, a few observations are in order. ProZorro is not on blockchain but is widely trusted. One reason is that it is semi-distributed, with multiple front interfaces—privately-owned electronic marketplaces (Kyiv School of Economics and Marin, 2016)—that have access to the database and can monitor it. Access to the whole ProZorro database is publicly available through open API and dashboards with extensive tenders' analytics that allows for public monitoring of all actions by public buyers and private marketplaces. Trust in the system allowed it to be extended from public procurement to e-sales of non-performing loans for the amount comparable to 20% of the nominal GDP of Ukraine in 2016 (Mylovanov et al., 2017).

OpenMarket, a publicly owned e-sale system in Ukraine, is on a private blockchain but is widely considered corrupt. OpenMarket runs auctions for arrested assets including those of Asset Recovery and Management Agency (ARMA) obtained from criminal proceedings against President Viktor Yanukovych, overthrown by the Revolution of Dignity in Ukraine in 2013–2014. The reason for low trust in OpenMarket is that it lacks transparency and does not actually follow the principles of decentralization and openness of the blockchain technology, with all nodes with the imprints of the database being controlled by OpenMarket. It illustrates how blockchain, the technology itself, does not inherently improve outcomes and how their initial constitutional design influences their performance.

The theme of e-procurement offering promise, and avoiding overselling blockchain solutions, is a more general one. Overwhelmingly, (conventional) e-procurement tends to reduce corruption by publicizing contracts and criteria, reducing information asymmetries, preserving a history of previous arrangements, and limiting official discretion, as well as increasing vendor competition and government savings. Over 154 countries use some form of e-procurement, but only 24 legally mandate such measures. High-income OECD countries are leading the way in key issues such as electronic submission of bids and bid-opening, and much of the process is not fully transparent. Additional issues with e-procurement are technological, social, and legal barriers—low levels of internet penetration, inadequate training, laws that hinder e-procurement by mandating hard-copy documentation, etc., though such barriers are not inevitable.

There remain substantial challenges with blockchains. The example above shows that blockchains can be subjected to corruption or collusion, regardless of the technology used to implement procurement. Blockchain procurement can have additional challenges with privacy and scalability. In addition, digital divides are relevant—participants require access to technology, as well as know-how, and governments need resources to implement blockchains. The WEF noted the most promise in hybrid, or permissioned, blockchain implementations, which limit participants and offer a semi-centralized and transparent record of transactions. Thus, by implementing blockchain, governments may be able to reduce the challenges of fraud, corruption, and waste in procurement. As blockchain technology improves in scalability, these benefits are particularly relevant when there are large increases in spending because of crises. However, as these examples illustrate, there are few reasons to see blockchains as

[6]For a review of procurement and blockchain, see http://www3.weforum.org/docs/WEF_Blockchain_Government_Transparency_Report.pdf.

[7]See the appendix to the WEF Blockchain Report:

a revolutionary tool in public procurement, and in some instances, blockchains may prove more challenging to implement than conventional e-procurement.

Networked Government and Public Service Delivery

Governments routinely disperse grants, though such spending is often subject to inefficiency and, in some instances, corruption. Service provision can also be mired in paperwork, reducing the quality of services. These issues can become especially acute during crises, which can bring corruption (misuse of public funds for private gain) and fraud (theft by individuals) as a result of large increases in spending (Leeson and Sobel, 2008). Disasters can also wreak havoc on records. For example, hurricanes routinely displace individuals who then may lose access to their identification records. Here, unlike with procurement, where there has been more experimentation with public service delivery, applications for public service delivery have yet to be implemented.

Blockchain can increase the prospects for transferring and securing information, providing a framework for "smart" government management of information such as automatic sharing of information among parties subject to agreed-upon protocols. Together, that is often referred to as networked public services. Coordination failures among government, nonprofit, and business organizations have been especially implicated as a reason for inability of governments to respond quickly to crises, such as hurricanes (Moynihan, 2009).

Networked public services are a significant advantage for the government. Responding to crises is illustrative. Government responses to crises involve coproduction, which recognizes that public goods and services are jointly supplied by government, nonprofit, and private businesses (Parks et al., 1981). Successful response to crisis involves matching supply of needed services to demand. That involves supply chains. Blockchain applications can coordinate government with suppliers, with information shared on a need-to-know basis. Such hybrid blockchains recognize that there is a need to protect privacy of individuals, as well as to share information with a community of responders.

To date, applications of blockchains for crisis response remain in proof-of-concept stages. The IBM "Bonds of Trust" project offers solutions to coordinate government action.[8] However, it is not clear how much these technologies have been deployed by government. IBM lists examples of deployment to oil and gas supply chains and to cross-border trade, but of widespread deployment by governments. Thus, blockchains for crisis remain aspirational. Since technology exists and private businesses offer the service, an open question is why governments have been slow to deploy it.

Blockchains have also been proposed to reduce fraud and corruption during crisis response. Citing the need to distribute resources to vulnerable people during the pandemic as well as a need to reduce potential fraud, a group of legislators in the US Congress proposed using blockchain to administer unemployment funds from the CARES Act. Eleven members of Congress urged Secretary of Treasury Mnuchin to "...utilize private-sector innovations such as blockchain and DLT [Distributed Ledger Technology] to support the necessary functions of government to distribute and track relief programs and direct that all guidance support the use of technology to facilitate delivery of CARES Act benefits" (Brett, 2020).[9] Administering unemployment payments in the United States had become challenging with the spike in unemployment, and blockchain (which has yet to be implemented) promised to improve the efficiency of these distributions.[10]

Beyond improving efficiency of crisis response, improvements in public service delivery through blockchain promise to improve trust in government. American Indian nations provide another example. There are currently over three hundred federally recognized American Indian nations, each with sovereign governments. American Indian reservations are, on average, the poorest regions in the United States, and so there is a substantial need for federal assistance. American Indian nations are often mired in paperwork due to complicated rules and regulations governing the relationship between tribal citizens living on reservations and the government (Crepelle, 2021). Distrust of the federal government remains an ongoing issue. Though blockchains have barely scratched the surface of American Indian reservations, the use of technologies for the provision of government services is an important consideration as transparency is a part of sovereign control over records of American Indian citizens dealing with the federal government.

Such promise has yet to be realized fully, in part because of ongoing challenges. One is that such programs to an extent presuppose very high levels of digitalization, including placing identities on a blockchain to link them to grants. In addition, the issues mentioned earlier—access of individuals to technology, trust in those technologies, and government capacity to implement blockchain-based delivery of public services—remain an issue. For example, American Indian reservations are among the least connected regions in the United States. Reducing paperwork through digitalization would likely be as much of an improvement, without the implementation challenges that affect blockchain systems. Thus, blockchains offer promise, but much remains hypothetical.

[8]https://www.ibm.com/blockchain/resources/disaster-recovery/

[9]Indeed, over two dozen members of the US Congress have established the "Congressional Blockchain Caucus" to promote application of blockchains to government services. See https://congressionalblockchaincaucus-schweikert.house.gov/members.

[10]Rather than focus on applications to improve public service provision, the Department of Treasury under President Trump and Mnuchin rushed through a Financial Crimes Enforcement Network (FinCEN) to combat financial crimes.

Public Health

Blockchain's improvement in record-keeping, in a decentralized and distributive setting compared to traditional recording, make it an attractive option in public health because not all parties are using the same information platform. The coronavirus pandemic served as a reminder of the importance of public trust in public health responses, as misinformation was an issue, as was the need to coordinate data on vaccines. Data on clinical trials, validation of data on trial, etc., all could be improved with blockchain to record and share information. To the extent such information is transparently recorded, it could improve trust in vaccines. Another potential use of blockchain is recording information on testing, with results that are easily accessible. This is significant as widespread testing is considered an important public health measure to control the pandemic and ultimately to unfreeze economies. Companies began to explore how to use blockchain as a platform to record information about antibody testing soon after the start of the pandemic (Abd-Alrazaq et al., 2021). To the extent that blockchain promises to reduce human error in evaluating health status and perhaps to ensure privacy to a greater extent, blockchain can have important advantages over traditional record-keeping in managing public health. In addition, essentially anything that constitutes public health information could be placed on a blockchain, increasing both the speed and accuracy at which information could be used by scientists, medical professionals, and public health officials globally.

The social challenges of compliance in pandemic management remain, although they may be mitigated by better privacy and transparency affordances through blockchain. Privacy concerns about widespread surveillance testing and contact tracing, actions critical to curtailing cases, may be alleviated through blockchain privacy. Questions about data accuracy and recording have also hampered the management of the COVID-19 pandemic. Accurate data dashboards that rely on smart contracts could provide for even greater trust in these data. Trust is significant here as there is also misinformation on COVID-19 cases, in the most extreme cases with conspiracy theories about the extent of the virus. While blockchain cannot itself provide an antidote to conspiracy theories, the presence of an immutable record would be a useful response to such ideas.

Applications have moved beyond the proof-of-concept stage. In Estonia, the government provides, among other things, a secure database of health records that has been extended to businesses. Still, such applications are limited to date. As such, reforms to public health involving blockchain remain an opportunity. In response to the coronavirus pandemic, IBM established MiPasa, a project that supports an open data hub to detect COVID-19 carriers and infection hotspots.[11] It can of course be done without blockchain, though blockchains offer superior integration of data and confidence in data. In addition, MiPasa can reconcile disparities in government data, ensure new data matches original data, and include the public to validate data. Again, it could be accomplished without blockchain, but blockchain ensures all parties with access to the data would be able to verify and approve any changes.

Public Finance

Taxation is an area where governments have made some progress in implementing blockchain-based solutions. Efficiency in taxation relies on the identification of citizens and their taxable activities and assets. Inefficiencies due to fraud and corruption are also challenges in taxation. Small scale applications have shown some promise in the tax realm. Taxation is complicated, as there are taxes on income, transactions, business, and assets. There are exemptions for nonprofits. Blockchain has not been implemented across all types of taxation, though for certain classes of transactions, it has been implemented successfully, as the following example from Denmark illustrates.

The Government of Denmark is exploring blockchain technology to effectively collect taxes on used car sales. They partnered with the private company Nets to develop a system, Vehicle Wallet, that maintains all the available data on a vehicle in a decentralized public ledger (Notheisen et al., 2017). The implementation is part of an effort to streamline the Danish taxation apparatus. Not only does this blockchain-based system allow tracking and sharing consistent information, but it also helps identifying fraud and validity. Vehicle Wallet is just a first step in a larger effort by the Danish Tax Administration to implement blockchain in most of their processes to minimize operational costs and eliminate repetitive manual tasks.

Government spending can also be put on a blockchain. Governments disperse large sums for various causes, in a process that is frequently convoluted and inefficient, causing money to be lost to banking fees, brokers, and potentially corrupt financial diversions. Blockchains could be used to build public trust in such systems—disintermediating and reducing the number of actors in grant awards could reduce costs and streamline initiatives. Examples include a pilot program in Buenos Aires focused on the city's arts and cultural grants and some similar plans for NSF grants in the US. Though blockchains promise efficiency, it is not clear that programs such as the NSF require such improvements, as the grant process is largely effective in distributing funds to researchers. A more significant application is public procurement, as discussed above, though our review suggests that e-procurement may be a cheaper, nearly as effective, alternative.

Democracy

Another application of blockchains is voting. One of the challenges in democratic political systems is corruption in voting. Blockchain promises to improve democracy by providing an immutable record of votes and greater veracity and security in the identification of voters, thus offering election security, integrity of voter registration, and reductions in election tampering—as well as improvements in trust in government (Allen et al., 2019a). Though surveys have

[11]https://www.ibm.com/blogs/blockchain/2020/03/mipasa-project-and-ibm-blockchain-team-on-open-data-platform-to-support-covid-19-response/

identified limitations with e-voting and novel affordances offered by blockchains for voting (Hjálmarsson et al., 2018), the potential of blockchains is likely to encourage experimentation with democracy outside of government elections. Thus, the use of blockchains to secure elections, while useful, only scratches the surface of blockchain applications to democracy, as self-governance is an aspect of democracy beyond elections that is strengthened by blockchains.

The governments of Denmark and Australia have geared efforts towards developing blockchain-based voting platforms. For instance, the Australian postal service, Australia Post, is starting an initiative to research blockchain technology for voting purposes (Sinclair, 2020). They plan to start with community and private sector elections until they can eventually move to nationwide voting. Thus, one expects that this could further improve the quality of government, help people learn the value of blockchain, and increase its adoption. The fiasco in the Democratic caucus in Iowa in February 2020 presidential primary in the US—when the votes were not counted until the following day because of a bug in an app—shows that any technology has risks, as well as benefits.

There are risks with any system. Social trust in the technology is an issue. Another is that digital voting, even on a blockchain, may be subject to manipulation or cyberattacks, but with no paper trail. This runs the risk that blockchains will be used along with paper as a redundancy, thus reducing some of the benefits from such technologies. There are also privacy risks with blockchains that must be addressed, as any such voting system would require some features of a private blockchain to preserve anonymity of votes for many voting applications.

To date, surveys of blockchains and democracy have focused on security of elections. This is a narrow notion of democracy that excludes broader logics of self-governance and collective action, including freedom to associate with others, that are also central aspects of democracy. Here, blockchains offer much promise. The Internet provides for communication in collective action, while blockchain opens up new possibilities for governance.[12] Blockchains offer a new technology for collective action. DAOs, or Decentralized Autonomous Organizations on the blockchain, are another potential improvement in collective action. Blockchains provide new opportunities to experiment with constitutions for such organizations. Painted Rock and Zur could also be thought of as collective action with blockchain, where the result is a new form of government in response to perceived challenges with traditional governance institutions. People would be free to create their own rules, as blockchains are mini-exercises in constitution-building (Alston, 2020), including experimenting with voting rules that could not be implemented at scale in "normal" political institutions (Allen et al., 2021a).

[12]https://medium.com/blockchannel/blockchain-is-governance-e0d827b97b3f.

BLOCKCHAINS FOR ECONOMIC EXCHANGE

Property Registration and Real Estate Markets

Reviews of blockchain applications to public sector governance emphasize personal data (such as birth certificates and social security cards) and voting. Such a view risks underestimating the role of blockchains in the public sector since governments can also deploy blockchains to the governance framework for economic exchange.

One potentially promising application of blockchains is for governments to initiate processes of placing real property on blockchains. Currently, most economies have legal rights to real property that are backed by governments. Blockchains promise greater transparency in transactions and improved speed, though the necessity of blockchain is far from clear, as real estate markets in most contexts where blockchains have been implemented were largely functional.

As Alston et al. (2018) explain, organizations articulate rules, and so rules can be divided into government rules, or public rules (including laws, constitutions, and regulations), and private rules (such as company policies, contractual commitments, codes of a criminal organization). Blockchains promise new solutions in several of these areas, especially property relations, contracts, licensing, and the realm of cryptocurrencies.

Regarding real (physical) property relations, blockchains have been considered as a way to increase the efficiency of land registration. Blockchains can save participants in real estate markets billions in transaction fees, as well as provide opportunities to transfer partial property rights. Ultimately, the entire property system could be placed on blockchains, with transactions initiated on smartphones (Graglia and Mellon, 2018). By integrating blockchain land recording systems, countries could technically enable property transactions on a global scale. In some contexts where trust in government is an issue, governments hope to use blockchains to reduce vulnerability to corruption and even expropriation of land by government. In this way, blockchains could expand transparency in land registration and, ultimately, improve security by providing a decentralized, publicly verifiable, and difficult-to-tamper-with record-keeping system.

The Republic of Georgia has put millions of deeds on the blockchain. In 2016, the Georgian Ministry of Justice, Bitcoin mining company BitFury, the Republic of Georgia's National Agency of Public Registry, and economist Hernando de Soto announced plans to implement a blockchain-based land registration to add security to land transactions data. It enables auditors to make real-time audits (thereby auditing the registration not once a year but nearly continually). Blockchain reduced friction in registration by decreasing the cost of property registration. It allows people to register land using their smartphones and provides a notary service (Shin, 2016). By 2017, the Georgian project was expanded, with nearly 1.5 million parcels entered on the blockchain (Shin, 2017). The project resulted in great cost savings (Qiuyn and Price, 2018).

The Government of Ghana is using blockchain-based technology to solve two structural problems: determining the legal status of land ownership and solving longstanding miscommunication problems between the Ghanaian Land Commission, property owners, and financial institutions. A central problem of miscommunication is inefficiency. For instance, providing collateral data for a property, a simple administrative process, was taking up to a year. Another example, the government hired BenBen, a company using blockchain systems for land management. BenBen records geospatial, property transactions, and land information in Ghana to provide a complete picture of the status of a property. Additionally, all parties involved have access to the same ledger. Due to this shift to blockchain for land recording and other procedures, administrative processes like registering collateral now take only 3 months. And the time needed to obtain property data decreased from 1 month to 3 days (Kshetri and Voas, 2018).

From these examples and the ones above, it appears that governments that place property registration on a blockchain can reduce fees and thus encourage transactions, leading to more productive use of properties and more potential tax revenue. However, the promise of blockchains must be tempered as follows. First, in the examples above, governments remain the central entities for recording property ownership–including recording ownership and securing agreements over who owns what—before putting it on a blockchain. Blockchains themselves cannot formalize property rights. In countries without a reliable registry of land, it is necessary to first digitalize ownership. This is significant because the quality of property rights depends on registries, or repositories of information that are easily accessible (Arruñada, 2012). Thus, blockchains are not a solution in the absence of sufficient investment by governing in addressing issues with informal or incomplete property rights.

Second, there are transaction costs of unbundling property rights. Property is traditionally thought of as land and improvements such as buildings on it, but it can also include mineral rights below ground, water rights, etc. Put another way, property rights are bundles of rights. If they can be unbundled, a society benefits from the greater possibilities of exchange, provided the government can enforce the rights (Ellickson 1993). Unbundling rights creates complexities that result in higher transaction costs. Blockchain may facilitate this process by keeping track of complex rights such as fractional rights—subdividing individual parcels—or the full unbundling of rights. There is also the potential for fully peer-to-peer contracting, as well as integration of blockchains—enabling smartphone-initiated trades over the smallest units of property. Each of these potential applications of blockchain in property rights depends on recording land ownership in the first place, as well as digitalization of identification, which, as we've seen, depends on the government or a trusted party. In addition, blockchain has features of a knowledge commons, which applies the logic of the resource commons to other domains, including intellectual property (Madison et al., 2010) and technology (Bustamante et al., 2020). One way to think of blockchain is that it creates a framework for essential knowledge about the property to be shared, thus increasing the value of property rights (Allen et al., 2021b). Still, the transaction costs of unbundling still exist, and blockchain can only reduce them once some are addressed.

Third, usability gap is an issue with blockchains. For example, property transactions can occur on a blockchain, but very few people know enough about their property to digitalize all the information. There is also a need for most property transactions to have people physically present to verify the features of a property.

Fourth, digital governance of land may be efficient compared to blockchains. Digitalization is costly to implement, and further introduction of blockchain may not offer many advantages over such digitalization. In lower-trust environments, simple community-based recording of information is often all that is needed in a community to provide greater certainty with land registration (Murtazashvili and Murtazashvili, 2016). In Afghanistan, for example, land recording at the community level with very simple technology, without a role for government, is often most effective in improving certainty about property ownership (Murtazashvili and Murtazashvili, 2021), though the ability to implement anything on a blockchain—given concerns about usability, and access to technology—are questionable at best.

Blockchains thus remain an area with promise, though their ability to redefine property governance is questionable (Arruñada, 2018). To date, blockchain is implemented for more routine transactions, and interoperability remains a faraway dream. Nor is it clear they are needed in higher-trust environments.

Business Licensing and Banking

Governments have also been exploring applications of blockchain to improve the efficiency of business licensing and banking. Besides property registration, an important aspect of the legal framework of business is providing easy opportunities for businesses to secure a license (de Soto, 2000). Blockchain is used to bring together private and public sectors in an expedited and secure manner. Dubai's Smart City initiative seeks to use technology, including blockchain and AI, to increase government efficiency and reduce costs of doing business. Some of its accomplishments include using blockchain to issue business licenses more quickly and to make all business and government transactions entirely paperless, thereby increasing the efficiency of transactions in both the public and private sectors (Donovan-Stevens, 2020).

Governments can create a legal environment to encourage businesses to adopt blockchain. It can benefit the government because it creates incentives for businesses to locate within its jurisdiction if it is less costly to run a business. An important example is the US state of Delaware, which is home to most Fortune 500 companies, has the most initial public offerings in the US, and is the corporate host of many venture capital-backed businesses from around the world—making it one of the world's most concentrated corporate centers. Already friendly to business, the state's government was also receptive to blockchain technology. In 2017, Delaware's governor announced the Delaware Blockchain Initiative, including

amendments to the Delaware General Corporation Law. Its purpose was to create legal institutions that take advantage of blockchain technology, including recognizing smart contracts (Klayman et al., 2017). Several other states had already given smart contracts the same legal weight as traditional pen and paper contracts. Blockchain-friendly regulatory and legal institutions can provide states with a competitive advantage.

The Delaware Blockchain Initiative simultaneously hoped to improve commerce and the quality of public sector governance. In 2017, the Delaware Public Archives worked with Symbiont, a distributed ledger and smart contracts startup, to archive state records on a blockchain to secure government records, reducing opportunities for fraud. Although the deal collapsed, they signed another agreement with IBM to develop blockchain-based digitalization of records in 2018. Also, in 2018, Colorado lawmakers passed a bill requiring governments to consider the use of blockchain for record-keeping. Governor Jay Polis also formed a 12-person blockchain council, as well as appointed a "blockchain solution architect" in 2019. Polis' hope is to "establish Colorado as a national hub for blockchain innovation in business and government" (Freed, 2019). Since then, the governor has hosted a meeting called Consensus to further consider blockchain governance applications, including in 2021 considering using blockchain to collect taxes—thus directly speaking to the ways in which blockchain can be used to benefit the government, as taxation is arguably the defining function of a government.[13]

Singapore's government has been active in applying blockchain to banking. In 2016 they launched a 6-week project to explore the potential of distributed ledger technology for financial transactions within the central government and other financial institutions around the world. In conjunction with private companies, the central bank of Singapore was facing significant challenges in government securities transactions. On average, they were able to conduct transactions for only 2 h a day due to the complexity of balancing accounts and informing all parties involved. Moreover, they wanted to implement a system that would run 24/7 with minimal human intervention. To solve the problem, Singapore used blockchain as a decentralized system that would run 24 h a day while maintaining a uniform copy of all transactions for all parties involved. After developing the systems, they made the code open source to encourage research and further development by academic and private institutions (Berryhill et al., 2018).

Blockchain applications have also been employed to regulate illicit and illegal activities and international trade. In Dubai, blockchain is being explored as an alternative for the diamond trade because of the high rate of illicit trading. Specifically, the government is interested in digitizing the process of managing diamond certificates to avoid conflict diamonds from entering the market. In Afghanistan, blockchain businesses are working with Afghan gem traders, along with the UN, to place gem information on a blockchain (Langhorne 2020). Blockchain has an important potential role in addressing illegal trades in artifacts. For example, there has been some discussion of its application to the theft of cultural artifacts from Native Americans (Moskowitz, 2019). The idea is that blockchain could better regulate authentication in art markets, thereby reducing incentives to engage in the theft of cultural artifacts.

In some areas, blockchain is a source of self-regulation when regulations are complex and uncertain. For instance, web services enabling sex workers to connect with clients have been shut down because of child welfare concerns and sex trafficking regulations, or more generally because the activity is morally repugnant (Roth, 2007), even though they also facilitate legal activities. A blockchain-based app, SpankChain, allows sex workers to work on a robust platform that cannot be taken down in a single node (Cowen 2019). Such apps can be a tool to enforce contracts when using the courts is difficult (Cunningham and Kendall, 2017). A matching platform, Craigslist, has been shown to improve the safety of sex workers (Cunningham et al., forthcoming). Thus, apps like SpankChain, which also provide greater anonymity for patrons, could provide added protections to vulnerable sex workers.

Cryptocurrencies and Macroeconomic Policy

Much of the discourse on cryptocurrencies focuses on whether these currencies compete with government. Central banking is considered a core function of public sector governance. Blockchain promises what has been called polycentric banking, which has as one of its manifestations allowing the choice of currency besides those controlled by central banks (Salter and Tarko, 2017). Despite the concern of losing control, central banks are issuing their own digital currencies. These central bank digital currencies (CBDCs) would serve as a bank for anyone and provide services to people, much like a regular bank. Under any agreement, central banks would have to ensure the interface between people and their currencies is transparent and open. Relatedly, central banks in several countries are exploring open banking, where the central bank shares information with other banks provided the customer allows such sharing of information (Prates, 2020).

In June 2021, the government of El Salvador decided that cryptocurrency must be accepted as a payment for services.[14] Specifically, every economic agent must accept bitcoin, and all obligations in money expressed in USD may be paid in Bitcoin. In April 2022, lawmakers in Central African Republic, one of the world's poorest countries, voted to adopt Bitcoin as legal tender.[15] Debates are ongoing regarding what this means.[16] For our

[13]https://www.9news.com/article/money/colorado-cryptocurrency-taxes/73-873ba24a-fceb-42a0-a349-4632ed6e38a5.

[14]https://www.reuters.com/world/americas/el-salvador-approves-first-law-bitcoin-legal-tender-2021-06-09/

[15]https://www.bbc.com/news/world-africa-61248809.

[16]George Selgin considers some of the cons of forcing businesses to accept Bitcoin. See https://www.alt-m.org/2021/06/17/the-bitcoin-law-nayib-bukeles-counterfeit-free-choice-in-currency/

purposes, the message is clear: Bitcoins do not strictly compete with governments, as some governments require them to be accepted alongside traditional currencies.[17]

Political considerations are an issue with blockchains. Returning to Ukraine, in 2019, the government considered introducing a semi-cryptocurrency on a public or state blockchain, called e-hryvnia. However, regulators opposed its introduction for fear of losing control over monetary policy. At the time, the regulators believed that they would be second movers after developed countries. Because of a lack of trust in the government, there is some justification for the use of blockchains. However, the government worried about losing what little control it has left. Thus, banning cryptocurrencies is a defensive move (Hendrickson and Luther, 2017).

CONCLUSION

Blockchain is a first successful ledger that can provide a decentralized and distributed system that supports transactions of goods and services among individuals and businesses. The most significant conclusion of our review, which would not be apparent from any individual survey of blockchain applications to government in a specific realm (such as voting), is that blockchains offer opportunities for nearly all aspects of public administration. Our review also highlights that governments can use blockchains to provide a more robust economic framework. This does not mean government necessarily has the lead. In many instances, governments can facilitate the emergence of blockchain by enabling decentralized innovation and integrating blockchain solutions into legal frameworks. Still, our review also suggests that such applications have barely scratched the surface. For this reason, an emergent area is to consider more explicitly where blockchains have been adopted and to assess their performance, especially compared to "conventional" digital technologies. The above comparison of e-procurement with blockchain-based procurement in Ukraine is one example where successful blockchains adoption critically depends on its implementation. Adopting the technology itself is not the only consideration.

Another theme of our review is that there are both implementations by government and implementations that involve government providing autonomy for blockchain development. Implementations by government include changes such as putting social security numbers and birth certificates on blockchains and deployment of blockchains for public procurement. The World Economic Forum suggests several general hurdles to the adoption of public sector blockchains, including the small number of large-scale public blockchains that have been tested to date, the need to establish systems for error correction, the necessity of administrative buy-in, and the potential for regulatory mistakes arising from a misunderstanding of blockchain technology.[18] Still, politicians and governments require incentives to deploy such technology, and their motivations may not align with improving social outcomes.

Beyond these obstacles, there is a question of the political digital divide. For governments adopting blockchains to improve the efficiency of transactions, the challenge is less loss of political control and more the fact that countries or locales that already have high levels of trust in government and administrative capacity are more likely to improve the quality of public sector governance. These places are more ready to adopt new technologies such as blockchain, but the gain is likely to be small. On the other hand, countries with lower levels of trust in government, lower administrative capacity, and less developed infrastructure may have more to gain by adopting blockchain technology. However, they face many obstacles. One of them is startup costs: deploying and maintaining the technology is costly, and not all governments have the resources to do it (as many confront challenges with the digitalization of records or record-keeping). Another issue is building trust in the technology. People can read their social security cards and hold on to them. With blockchain, everything becomes digital, and that creates some rational fears of where the information is ultimately located and whether it is secure. Synergy between public sector governance and blockchain applications will depend, as with any technology, on the design, implementation, and populations it serves.

One reason the political digital divide is significant is that blockchains may be most advantageous when trust is low in government. These are the same governments where the ability to implement blockchains is also low, such as lack of technological savvy. What appears to be most likely is continued marginal improvements in the quality of public administration in countries that already have governance advantages—countries such as Denmark and China, which are conventionally understood as enjoying higher-quality public-sector governance (Fukuyama, 2013).

There remains another important opportunity for government to enable blockchains. Pilot proposals for smart cities that use blockchain extensively are occurring in rich countries, such as the Painted Rock example in the United States, because there is the technological infrastructure to support such initiatives. Blockchain contracts are developed without government but depend to an extent on a legal framework that recognizes those contracts. Here, the role of government is to offer autonomy for development and to recognize the outcomes of decentralized coordination. For example, if citizens decide to implement blockchain solutions for local elections, governments can recognize the outcomes of those elections.

Another political consideration is that the implementation of blockchains may benefit from learning from experimentation. This suggests that relatively decentralized political systems may have an advantage. In the United States, the federal system

[17]The libertarian criticism is that mandating acceptance of bitcoins undermines choice, though resolving that is not necessary for our stock-taking exercise in this paper.

[18]https://www.weforum.org/reports/exploring-blockchain-technology-for-government-transparency-to-reduce-corruption.

provides significant opportunities for states to experiment with blockchain regulation. States such as Wyoming are challenging Delaware as the leader of the crypto hub (Castillo, 2020; Chon, 2021). Other governments can then learn from the experience of states and municipalities that adopt smart government technologies. To the extent states face constraints in implementing these technologies, national governments still play a significant role in encouraging adoption.

Our review suggests several areas for future research. While there are indexes of blockchain use and regulations favorable to blockchain, there are currently no indexes of the extent of blockchain deployment by governments. Developing such an index would be useful to measure progress and challenges with government deployment of blockchains. Another area for future research is to better understand the challenges of scaling up blockchains. Many pilot programs have been attempted, but few have become national policy. Real property registration is an example where proof of concept has been shown but scaling up appears to be an issue. Blockchain is an innovative technology and holds many promises, but carefully evaluating whether it is the right technology for each application is critical. Ultimately, this review demonstrates that blockchain's contribution to public sector governance is not yet fully realized and, even as it is embraced in more governance contexts, it promises more augmentation than revolution.

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REFERENCES

Abd-Alrazaq, A. A., Alajlani, M., Alhuwail, D., Erbad, A., Giannicchi, A., Shah, Z., et al. (2021). Blockchain Technologies to Mitigate COVID-19 Challenges: A Scoping Review. *Comput. Methods Programs Biomed. Update* 1, 100001. doi:10.1016/j.cmpbup.2020.100001

Allen, D. W. E., Berg, C., Davidson, S., MacDonald, T., and Potts, J. (2021a). Building a Grammar of Blockchain Governance. *Cryptoeconomics Aust*. Available at: https://medium.com/cryptoeconomics-australia/building-a-grammar-of-blockchain-governance-c2cb4b70f915 (Accessed August 10, 2021).

Allen, D. W. E., Berg, C., Davidson, S., and Potts, J. (2021b). "Property Rights, Knowledge Commons, and Blockchain Governance," in *Governing Markets as Knowledge Commons*. Editors E. Dekker and P. Kuchar, 159–175. doi:10.1017/9781108692915.008

Allen, D. W. E., Berg, C., and Lane, A. M. (2019a). *Cryptodemocracy: How Blockchain Can Radically Expand Democratic Choice*. London: Rowman & Littlefield.

Allen, D. W. E., Berg, C., Lane, A. M., and Potts, J. (2018). Cryptodemocracy and its Institutional Possibilities. *Rev. Austrian Econ.* 33, 363–374. doi:10.1007/s11138-018-0423-6

Allen, D. W. E., Lane, A. M., and Poblet, M. (2019b). The Governance of Blockchain Dispute Resolution. *Harv. Negot. Law Rev.* 24, 75–101.

Alston, E., Alston, L. J., Mueller, B., and Nonnenmacher, T. (2018). *Institutional and Organizational Analysis: Concepts and Applications*. Cambridge University Press.

Alston, E. (2021). "Blockchain and the Law: Legality, Law-Like Characteristics, and Legal Applications," in *Handbook on Blockchain and Cryptocurrencies*. Editor J. Caton and E. Elgar. doi:10.2139/ssrn.3641997

Alston, E., Law, W., Murtazashvili, I., and Weiss, M. B. (2021). Can Permissionless Blockchains Avoid Governance and the Law? *Notre Dame J. Emerg. Technol.* 2, 1–32.

Alston, E., Law, W., Murtazashvili, I., and Weiss, M. (2022). Blockchain Networks as Constitutional and Competitive Polycentric Orders. *J. Institutional Econ.* 1–17. doi:10.1017/S174413742100093X

Alston, M., and Bowles, W. (2020). Systematic Reviews. *Case West. J. Law Technol. Internet* 11, 133–159. doi:10.4324/9781003117094-8

Arruñada, B. (2018). Blockchain's Struggle to Deliver Impersonal Exchange. *Minn. J. Law Sci. Technol.* 19, 55–106.

Arruñada, B. (2012). *Institutional Foundations of Impersonal Exchange: Theory and Policy of Contractual Registries*. Chicago: University of Chicago Press.

Atzori, M. (2015). *Blockchain Technology and Decentralized Governance: Is the State Still Necessary? Available SSRN 2709713*.

Benkler, Y. (2004). Sharing Nicely: On Shareable Goods and the Emergence of Sharing as a Modality of Economic Production. *Yale Law J.* 114, 273. doi:10.2307/4135731

Berg, A., and Berg, C. (2020). Exit, Voice, and Forking. *Cosm. Taxis* 8, 76–89.

Berg, C., Davidson, S., and Potts, J. (2019). *Understanding the Blockchain Economy: An Introduction to Institutional Cryptoeconomics*. Cheltenham, United Kingdom: Edward Elgar Publishing.

Berryhill, J., Bourgery, T., and Hanson, A. (2018). Blockchains Unchained: Blockchain Technology and its Use in the Public Sector. *OECD Work* 1–53. Pap. Public Gov.

Boettke, P. J., Salter, A. W., and Smith, D. J. (2021). *Money and the Rule of Law: Generality and Predictability in Monetary Institutions*. New York: Cambridge University Press.

Brett, J. (2020). *11 Members of Congress Urge Treasury Secretary Mnuchin to Use Blockchain for COVID-19 Stimulus Payments*. Forbes. Available at: https://www.forbes.com/sites/jasonbrett/2020/05/02/congress-urges-treasury-secretary-mnuchin-to-use-blockchain-for-covid-19-stimulus-payments/?sh=6dfa0077471d.

Bustamante, P., Gomez, M., Murtazashvili, I., and Weiss, M. (2020). Spectrum Anarchy: Why Self-Governance of the Radio Spectrum Works Better Than We Think. *J. Institutional Econ.* 16, 863–882. doi:10.1017/s1744137420000259

Castillo, M. del. (2020). A Bitcoin Bastion in the Wild West. *Forbes*. Available at: https://www.forbes.com/sites/michaeldelcastillo/2020/04/01/a-bitcoin-bastion-for-the-wild-west/.

Chon, G. (2021). Cryptocurrency's Wild West Is in Wyoming. *Reuters*. Available at: https://www.reuters.com/breakingviews/cryptocurrencys-wild-west-is-wyoming-2021-07-07/ (Accessed August 16, 2021).

Cohney, S., Hoffman, D., Sklaroff, J., and Wishnick, D. (2019). Coin-Operated Capitalism. *Columbia Law Rev.* 119, 591–676.

Cowen, N. (2019). Markets for Rules: The Promise and Peril of Blockchain Distributed Governance. *Jepp* 9, 213–226. doi:10.1108/jepp-03-2019-0013

Crepelle, A. (2021). White Tape and Indian Wards: Removing the Federal Bureaucracy to Empower Tribal Economies and Self-Government. *Mjlr* 54, 563–610. doi:10.36646/mjlr.54.3.white

Cunningham, S., DeAngelo, G., and Tripp, J. (Forthcoming). Craigslist Reduced Violence Against Women. *J. Hum. Resour.*

Cunningham, S., and Kendall, T. D. (2017). Prostitution, Hours, Job Amenities and Education. *Rev. Econ. Househ.* 15, 1055–1080. doi:10.1007/s11150-017-9360-6

Davidson, S., De Filippi, P., and Potts, J. (2018). Blockchains and the Economic Institutions of Capitalism. *J. Institutional Econ.* 14, 639–658. doi:10.1017/s1744137417000200

De Filippi, P., and Loveluck, B. (2016). The Invisible Politics of Bitcoin: Governance Crisis of a Decentralized Infrastructure. *Internet Policy Rev.* 5, 1–28. doi:10.14763/2016.3.427

De Filippi, P., Mannan, M., and Reijers, W. (2020). Blockchain as a Confidence Machine: The Problem of Trust & Challenges of Governance. *Technol. Soc.* 62, 101284. doi:10.1016/j.techsoc.2020.101284

De Filippi, P., Wray, C., and Sileno, G. (2021). Smart Contracts. *Internet Policy Rev.* 10 (2). doi:10.14763/2021.2.1549

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

de Soto, H. (2000). *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else*. New York: Basic Books.

Donovan-Stevens, A. (2020). *How Dubai Is Embracing Fintech to Become a Smart City*. FinTech. Available at: https://fintechmagazine.com/venture-capital/how-dubai-embracing-fintech-become-smart-city.

Freed, B. (2019). *Colorado Hires "Blockchain Solution Architect"*. StateScoop. Available at: https://statescoop.com/colorado-hires-blockchain-solution-architect/.

Frolov, D. (2021). Blockchain and Institutional Complexity: an Extended Institutional Approach. *J. Institutional Econ.* 17, 21–36. doi:10.1017/s1744137420000272

Fukuyama, F. (2013). What Is Governance? *Governance* 26, 347–368. doi:10.1111/gove.12035

Graglia, J. M., and Mellon, C. (2018). Blockchain and Property in 2018: At the End of the Beginning. *Innov. Technol. Gov. Glob.* 12, 90–116. doi:10.1162/inov_a_00270

Hendrickson, J. R., and Luther, W. J. (2017). Banning Bitcoin. *J. Econ. Behav. Organ.* 141, 188–195. doi:10.1016/j.jebo.2017.07.001

Hjálmarsson, F. Þ., Hreiðarsson, G. K., Hamdaqa, M., and Hjálmtýsson, G. (2018). "Blockchain-Based E-Voting System," in 2018 IEEE 11th International Conference on Cloud Computing (CLOUD) (IEEE), 983–986.

Howell, B. E., and Potgieter, P. H. (2021). Uncertainty and Dispute Resolution for Blockchain and Smart Contract Institutions. *J. Institutional Econ.* 17, 545–559. doi:10.1017/s1744137421000138

Juskalian, R. (2018). Inside the Jordan Refugee Camp that Runs on Blockchain. *MIT Technol. Rev.*

Klayman, J. A., Peck, G. R., and Wojchiechowski, M. S. (2017). *Why the Delaware Blockchain Initiative Matters to All Dealmakers*. Forbes. Available at: https://www.forbes.com/sites/groupthink/2017/09/20/why-the-delaware-blockchain-initiative-matters-to-all-dealmakers/?sh=3b6b8bc07550.

Kshetri, N., and Voas, J. (2018). Blockchain in Developing Countries. *IT Prof.* 20, 11–14. doi:10.1109/mitp.2018.021921645

Leeson, P. T., and Sobel, R. S. (2008). Weathering Corruption. *J. Law Econ.* 51, 667–681. doi:10.1086/590129

Lemieux, V. L. (2017). "A Typology of Blockchain Recordkeeping Solutions and Some Reflections on Their Implications for the Future of Archival Preservation," in 2017 IEEE International Conference on Big Data (Big Data) (IEEE), 2271–2278. doi:10.1109/bigdata.2017.8258180

Lemieux, V. L. (2019). Blockchain and Public Record Keeping: Of Temples, Prisons, and the (Re)Configuration of Power. *Front. Blockchain* 2. doi:10.3389/fbloc.2019.00005

Madison, M. J., Frischmann, B. M., and Strandburg, K. J. (2010). Constructing Commons in the Cultural Environment. *Cornell Law Rev.* 95, 657–710.

Kyiv School of Economics Marin, J. M. (2016). Co-Creation of ProZorro: An Account of the Process and Actors. Report. Berlin: Transparency International. Available at: https://images.transparencycdn.org/images/2017_ProzorroCaseStudy_EN.pdf.

Moskowitz, T. (2019). The Illicit Antiquities Trade as a Funding Source for Terrorism: Is Blockchain the Solution Notes. *Cardozo Arts Entertain. Law J.* 37, 193–228.

Moynihan, D. P. (2009). The Network Governance of Crisis Response: Case Studies of Incident Command Systems. *J. Public Adm. Res. Theory* 19, 895–915. doi:10.1093/jopart/mun033

Murtazashvili, I., and Murtazashvili, J. (2016). Can Community-Based Land Adjudication and Registration Improve Household Land Tenure Security? Evidence from Afghanistan. *Land Use Policy* 55, 230–239. doi:10.1016/j.landusepol.2016.04.010

Murtazashvili, J. B., and Murtazashvili, I. (2021). *Land, the State, and War: Property Rights and Political Order in Afghanistan*. New York: Cambridge University Press.

Mylovanov, T., Shapoval, N., Zapechelnyuk, A., Huffman, D., Vohra, R., and Sobolev, O. (2017). *Selling Toxic Assets in Ukraine: Overview of the Current Situation and Suggestions for Improvement of the Auction Design*. Kyiv: Kyiv School of Economics. Available at: https://kse.ua/kse-research/selling-toxic-assets-in-ukraine-overview-of-the-current-situation-and-suggestions-for-improvement-of-the-auction-design/.

Notheisen, B., Cholewa, J. B., and Shanmugam, A. P. (2017). Trading Real-World Assets on Blockchain. *Bus. Inf. Syst. Eng.* 59, 425–440. doi:10.1007/s12599-017-0499-8

Parks, R. B., Baker, P. C., Kiser, L., Oakerson, R., Ostrom, E., Ostrom, V., et al. (1981). Consumers as Coproducers of Public Services: Some Economic and Institutional Considerations. *Policy Stud. J.* 9, 1001–1011. doi:10.1111/j.1541-0072.1981.tb01208.x

Poblet, M., Allen, D. W. E., Konashevych, O., Lane, A. M., and Diaz Valdivia, C. A. (2020). From Athens to the Blockchain: Oracles for Digital Democracy. *Front. Blockchain* 3. doi:10.3389/fbloc.2020.575662

Prates, M. M. (2020). The Big Choices When Designing Central Bank Digital Currencies. *coindesk*. Available at: https://www.coindesk.com/big-choices-designing-central-bank-digital-currencies.

Qiuyn, S., and Price, A. (2018). A Blockchain-Based Land Titling Project in the Republic of Georgia. *Innov. Technol. Gov. Glob.* 12, 72–78.

Reijers, W., Wuisman, I., Mannan, M., De Filippi, P., Wray, C., Rae-Looi, V., et al. (2018). Now the Code Runs Itself: On-Chain and Off-Chain Governance of Blockchain Technologies. *Topoi* 40, 821–831. doi:10.1007/s11245-018-9626-5

Reinsberg, B. (2019). Blockchain Technology and the Governance of Foreign Aid. *J. Institutional Econ.* 5 (3), 1–17. doi:10.1017/s1744137418000462

Roth, A. E. (2007). Repugnance as a Constraint on Markets. *J. Econ. Perspect.* 21, 37–58. doi:10.1257/jep.21.3.37

Rozas, D., Tenorio-Fornés, A., Díaz-Molina, S., and Hassan, S. (2021a). When Ostrom Meets Blockchain: Exploring the Potentials of Blockchain for Commons Governance. *SAGE Open* 11, 21582440211002530. doi:10.1177/21582440211002526

Rozas, D., Tenorio-Fornés, A., and Hassan, S. (2021b). Analysis of the Potentials of Blockchain for the Governance of Global Digital Commons. *Front. Blockchain* 4, 577680. doi:10.3389/fbloc.2021.577680

Salter, A. W., and Tarko, V. (2017). Polycentric Banking and Macroeconomic Stability. *Bus. Polit.* 19, 365–395. doi:10.1017/bap.2016.10

Schuster, E. (2020). Cloud Crypto Land. *Mod. Law Rev.* 84 (5). doi:10.1111/1468-2230.12603

Shapoval, N., Memtova, I., and Palamarchuk, D. (2017). *ProZorro Anniversary: Overview of Public Procurement Reform Changes*. VoxUkraine. Available at: https://voxukraine.org/en/prozorro-anniversary-en/.

Shin, L. (2016). *Republic of Georgia to Pilot Land Titling on Blockchain with Economist Hernando De Soto*. BitFury: Forbes.

Shin, L. (2017). *The First Government to Secure Land Titles on the Bitcoin Blockchain Expands Project*. Forbes. Available at: https://www.forbes.com/sites/laurashin/2016/04/21/republic-of-georgia-to-pilot-land-titling-on-blockchain-with-economist-hernando-de-soto-bitfury/?sh=378cd03544da.

Sinclair, S. (2020). Australia Post Now Lets Customers Pay for Bitcoin at Over 3,500 Outlets. *Coin Desk*.

Sullivan, C., and Burger, E. (2017). E-Residency and Blockchain. *Comput. Law Secur. Rev.* 33, 470–481. doi:10.1016/j.clsr.2017.03.016

Werbach, K., and Cornell, N. (2017). Contracts Ex Machina. *Duke Law J.* 67, 313–382.

Werbach, K. (2004). Supercommons: Toward a Unified Theory of Wireless Communications. *Tex. Law Rev.* 27, 863–973.

Werbach, K. (2018). *The Blockchain and the New Architecture of Trust*. MIT Press.

Whitford, A. B., and Anderson, D. (2021). Governance Landscapes for Emerging Technologies: The Case of Cryptocurrencies. *Regul. Gov.* 15 (4), 1053–1070. doi:10.1111/rego.12366

Zambrano, R. (2020). Taming the Beast: Harnessing Blockchains in Developing Country Governments. *Front. Blockchain* 2, 27. doi:10.3389/fbloc.2019.00027

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