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An examination of the blockchain technology as new public sector tool

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An examination of the blockchain technology as new public sector tool

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Abstract – Industry and governments worldwide have enthused over blockchain's revolutionary potential to decentralise interactions between all members of society and have lost no time in embracing their purported benefits, ranging from greater transparency, efficiency, security to scalability of transactions. Amidst the hype, blockchain technology still remains at a nascent stage of development and the race to develop novel applications obscures a deeper understanding of the technology's fundamentals and the larger role being played by blockchain across different applications and sectors. Against this backdrop, this study examines the emergence of blockchain technology in the public sector. As the basis of our analysis, we first review the underlying mechanisms of blockchain comprising of multiple technologies, including consensus protocols, linked timestamping, public key cryptography and digital cash. We then analyse the key functions of blockchain and discuss various use cases enabled by these functions. Next, we examine the hybridity of the blockchain technology and explore concepts of policy tool, meta-tool, support infrastructure, platform, force multiplier and investigate how blockchain technology relates to these concepts by examining its abilities and features and whether it acts as a specific tool or as a technological enabler that facilitates both substantive and procedural tools through a myriad of functions and capabilities it provides.

Keywords: blockchain, distributed database, smart contract, meta-tool, policy tool, ecosystem, support infrastructure, force multiplier, public sector, policymaking

1. Introduction

Blockchain technology has received a great deal of attention by corporations, governments, academia, and individuals around the world for its key innovation – a system for peer-to-peer transactions without requiring trust in a central authority (Nakamoto 2008, Swan 2015). First introduced by Satoshi Nakamoto in the form of a cryptocurrency Bitcoin, many cryptocurrency applications of blockchain such as Bitcoin Cash, Ethereum and Ripple have since emerged. The hype over cryptocurrencies initially surged from 2017 to 2018, with the total market capitalisation peaking at around $800 billion in January 2018, but has since diminished significantly as expectations about what the technology can deliver has declined, with the total market capitalisation of cryptocurrencies falling to $134 billion in the start of 2019 (Nam et al. 2019; Aste 2019). However, expectations about blockchain's potential remain positive as the technology has much more to offer beyond the realm of financial transactions. Greater transparency and integrity of data, greater user control and privacy, and

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cost savings from the automatic execution of transactions on smart contracts are among the many benefits that blockchain promises for various sectors ranging from the tracking of products along the supply chain, the storage of public and medical records and the enforcement of contracts for compliance (Drescher 2017; Gabison 2016; Swan 2015). With continued support from the private sector in the form of initial coin offerings (ICOs), venture capital and private investments and proliferating collaborations between companies, research institutions and industry consortia as well as startups to develop these applications (CB Insights 2018; Salviotti et al. 2018), the global blockchain market is expected to grow significantly in the near future.

Many governments around the world recognise blockchain's transformative benefits and have begun exploring blockchain's applications in the public sector, as the technology allows transactions to be automatically recorded on the ledger enabled by smart contracts[2], ensures the immutability of transactions and allows all participants to access a copy of all records (Martinovic et al. 2017; Batubara et al. 2018). Blockchain can significantly increase the efficiency, security and transparency of transactions performed in the public sector. For instance, governments can use blockchain to store and share sensitive personal data such as medical records (Swan 2015), transfer the ownership of assets such as land titles (Ølnes et al. 2017; Cheng et al. 2017) and for secure and anonymous electronic voting (Narayanan and Clark 2017). Despite these developments, blockchain technology still remains at a nascent stage of development and the race to develop novel applications obscures a deeper understanding of the technology's fundamentals and the potential larger role that could be played by the blockchain technology in the public sector across different applications and domains.

This article addresses the following questions: (a) Examine the key functions of blockchain technology and the new developments in the technology (b) Explore applications of the blockchain technology (c) and examination of the blockchain technology as a (i) policy tool, (ii) platform, (iii) meta-tool, and (iv) ecosystem and (vi) force multiplier, (d) and how new developments of blockchain can perform these roles.

In the next section, we briefly introduce the blockchain technology and in Section 3 we examine the key functionality of the technology. We then study the hybridity of the blockchain technology and explore concepts of policy tool, meta-tool, support infrastructure, platform, ecosystem, and force multiplier and explore how blockchain technology relates to these concepts by examining its abilities and features and whether blockchain acts as a specific tool or as a technological enabler that facilitates both substantive and procedural tools through a myriad of functions and capabilities it provides. We then examine the current developments of the technology before the concluding remarks.

2. Background to the blockchain technology

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[2] The concept of Smart contracts will be elaborated in section 3.3.

Blockchain is often referred to as a "data structure" or a database (Glaser et al. 2019) comprising of blocks listed in chronological order, where each block contains a list of transactions (Xu et al. 2017). As a decentralised network, all participants (nodes) in the blockchain can publicly access and validate all transactions that ever occurred (Narayanan & Clark 2017), which provides greater transparency and eliminates the need for third party intermediaries to process and distribute data (Salviotti et al. 2018). Blockchain is also characterised by *immutability* and *auditability* of records, *anonymity* of participants and *data integrity*.

As an example of the blockchain technology, the design of the Bitcoin system is as follows:
1. First, a participant (node) requests to perform a new transaction, which is "broadcast" to all nodes.
2. Each node stores the new transaction into a block, and validates the transaction through a process called "mining" (the process of adding new blocks to the chain), where nodes solve a cryptographic puzzle that requires sufficient computational effort (Nakamoto 2008).
3. When a node solves the puzzle, the new block is broadcast to the network and other nodes will verify it and update their local copy of the blockchain (Atzei et al. 2017). The block is now permanently added to the chain with a timestamp linked to the previous chain of blocks (Batubara et al 2018, Nakamoto 2008).

Consensus mechanisms and linked timestamping are the technical components underlying the mining process. A consensus mechanism, such as the Proof of Work (PoW) mechanism[3] utilised in Bitcoin, establishes rules and procedures that govern the addition of new blocks (Batubara et al. 2018) to prevent "double-spending" attacks – the attacker spends the digital coin, "receives goods and services" in exchange, and then removes the transaction and recover the coin (McReynolds et al. 2015). To prevent such attacks, users solve a computationally-intensive puzzle to validate each transaction (Salviotti et al 2018) and the ledger will be secure as long as "honest" nodes possess greater computational power than any group of attacker nodes (Nakamoto 2008), which is ensured by rewarding miners with cryptocurrency (e.g. Bitcoin) from the blockchain everyime they solve a puzzle (Narayanan & Clark 2017). Once the majority of the nodes agree on a transaction's validity, the latter is recorded in a new block and linked (by a hash pointer) to a timestamp and the previous block (Batubara et al. 2018, Xu et al. 2017). The chronological order of timestamps enables transactions to be easily tracked and verified (auditability) (Batubara et al 2018) and the irreversible property of the hash ensures that transactions cannot be easily modified, reordered or terminated (immutability) (Narayanan & Clark 2017, Salviotti et al. 2018).

Public key cryptography and digital signatures establish secure digital identities for all participants while ensuring their anonymity. Each participant possesses a public key (visible to the public) that is used to encrypt the transaction details and verify the sender's digital signature, whereas private keys (kept secret) are used only by owners to "decrypt" transaction

[3] Various blockchain technologies adopt different consensus mechanisms, such as Proof of Work (e.g. Bitcoin), Proof of Stake (e.g. Peercoin) and Proof of Authority (PoA) (Tasca et al. 2018, Salviotti et al. 2018).

details (Salviotti et al. 2018). As public keys are anonymous, everybody can view the transaction details but cannot identify the participants of that transaction (Nakamoto 2008). This means that users/nodes' identities are pseudonymous, which some have argued provides greater privacy than in existing electronic transactions (Batubara 2018, Nakamoto 2008), but the transaction details are not anonymous and visible to all nodes, raising concerns that data analytics can be applied to analyse and identify user activity (Risius & Spohrer 2017).

Most studies have categorised blockchain according to its degree of openness (public, private or consortium) and the permissions given to its participants (permissioned or unpermissioned) (Brennan & Lunn 2016; Ølnes et al. 2017). In public blockchains, anybody can access the network and participate in transactions. In private blockchains, only members of one organisation have access to data and transactions, whereas consortium blockchains allow multiple organisations to access and transact (Ølnes et al. 2017; Xu et al. 2016). Anybody can participate in the consensus mechanism in unpermissioned blockchains, whereas in permissioned blockchains, only a select group of participants can do so (Martinovic et al. 2017). Some studies have argued that public and unpermissioned blockchains enable greater transparency and auditability, but create risks to informational privacy and copyright (Xu et al. 2016; Gabison 2016).

2.1 Limitations of and scepticism regarding the blockchain technology

However, the hype over blockchain's potential has created unrealistic expectations about what the technology can achieve in terms of its capabilities, ease of implementation and scalability (Pisa 2018). Many of blockchain's key features and benefits are not new and derived from technologies invented in the past. For instance, the greater security and privacy that blockchain offers are derived from other technologies such as encryption and identity management that are not specific to blockchain (Ølnes et al. 2017). Furthermore, blockchain is less efficient than centralised systems as the former requires additional "layers of encryption" that increases complexity and delays in operations (Pisa 2018; Ølnes et al. 2017). Widespread blockchain adoption is also essential for positive network effects to be realised, but this can be hindered by the institutional and social "inertia" to transition to blockchain platforms, as well as the lack of integration of most existing blockchain architectures between different firms, such as their protocols and consensus mechanisms (Ølnes et al. 2017; Brennan & Lunn 2016).

In addition, blockchain can introduce new risks. Firstly, as mentioned earlier, there are emerging concerns regarding potential violations of privacy in public and permissionless blockchains. While the identities of participants are encrypted on the blockchain, transactional data are not encrypted in order for them to be successfully validated and added onto the chain, which exposes transaction data to adversaries who may attempt to deanonymise the identities of the transactions' users (Brennan & Lunn 2016; Goldfeder et al. 2017). Secondly, the end-point security risk (security of users and devices) of blockchain is much greater than that of centralised institutions as blockchain transactions are irreversible, instantaneous, and anonymous, and users can easily lose their assets once they lose their private keys (Narayanan & Clark 2017, Brennan & Lunn 2016). Thirdly, as all nodes have access to a copy of the aggregate data stored on the blockchain, blockchain systems are vulnerable to cyber attacks as hacking only one node is sufficient to gain access to all parties' data (Brennan & Lunn 2016). The cryptographic hash functions that secure transactions can also potentially be broken in future with the emergence of quantum computers (Kietzmann & Archer-Brown 2019).

3. Key functionalities of the blockchain technology

Below we highlight the key functionalities that the blockchain technology provides and highlight their applications.

3.1. Facilitates transactions (resource allocation)

A key function of blockchain technology is facilitating transactions directly between individuals and organisations without the need for a trusted intermediary. By reducing transaction costs (i.e. the cost of coordinating, monitoring and governing transactions), blockchain enables the exchange of all kinds of assets directly between anyone on a global scale and at any time horizon (Iansiti & Lakhani 2017).

3.1.1. Transactions involving currency and financial assets

Blockchain enables transactions involving fiat money, cryptocurrency, and other financial assets, which can potentially be carried out with more inclusivity, security and at a much larger scale with further technological advancements. Cryptocurrencies (or "coins") such as Bitcoin are digital currencies that serve as a "general purpose medium of exchange and store-of-value" (Howell et al. 2018, p1) and can be circulated independently from any central institution (Drescher 2017). One use case in the financial sector are initial coin offerings (ICOs) that are used by venture firms to raise capital for their digital platforms, where the firm sells digital assets called "tokens" in exchange for fiat money or cryptocurrency (Momtaz et al. 2019). The most common tokens being issued are "utility tokens" that can be used by the purchaser to acquire certain rights, such as to access or use the token issuer's goods and services on a "preferential basis" can be purchased by anybody without minimum levels of capital and are not subject to securities legislation (Yeung 2019; Swanson 2015).

Transacting with cryptocurrencies on blockchain can also increase equity and inclusivity by enabling micropayments in developing nations that would typically incur huge transaction costs through intermediary fees (Drescher 2017). For instance, a data services company, IHB (I Have Bitcoins), enables people in rural India to sell their paintings on a "global market platform" and receive micropayments through their mobile devices without having to pay commission fees to conventional exporters (Pilkington 2016). Similarly, blockchain can significantly reduce or eliminate high commission fees from the transferring of remittances, which make up a significant proportion of GDP in Central and Eastern European countries (Pilkington 2016). Apart from cryptocurrencies, digital fiat currencies can also be transferred and managed on the blockchain (Drescher 2017).

3.1.2 Transactions involving non-financial assets

A much wider range of transactions can be enabled by the blockchain technology, such as delivering goods and services, transferring rights and ownership of various types of assets and the exchange of other forms of information.

1) Goods and services

The use of the blockchain technology can facilitate transactions of goods and services, such as in the energy sector in generation, sharing and distribution, carbon markets, and the provision of aid. Blockchain enables peer-to-peer generation and distribution of energy (Yeung 2019) by facilitating the sale of excess solar-generated electricity in peer-to-peer markets without the need for intermediaries (e.g. through PowerLedger, TransactiveGrid). Blockchain can also be used to create a tradable market of carbon credits to offset the greenhouse gas emissions generated and the money exchanged from credits can be allocated into environmentally beneficial projects such as the construction of new wind farms and hydroelectric power stations or "planting new forests" (Smith 2018). Bitcoin can also be used to deliver aid funds efficiently to targeted groups with publicly traceable addresses during crises, unlike the traditional banking flows where aid cannot be delivered immediately during such situations (Swan 2015).

2) Rights and ownership of assets

The blockchain technology can be used for granting permissions and for proof or transfer of ownership of assets. As an example, Ølnes et al. (2017) point out that in the transfer of ownership of an asset such as a car or a land title, blockchain technology enables the examination of the asset's history of transactions, identification of the owner of the asset, and allows the owner to validate the payment for the transfer of the asset's ownership. Use of such a technology can reduce or prevent manipulation of property rights as well as loss of the data and thus, can facilitate dispute resolution and prevent unauthorized or fraudulent changes (Ølnes et al. 2017). However, blockchain technology creates its own challenges when it comes to guaranteeing the accuracy of the titles and should be relied on more for certifying the authenticity of the titles, as errors in inputting data through the blockchain due to its immutability can create complex challenges. As such, it should be used as an instrument for development of a digital registry and used for better administration of registry of assets and cannot be seen as a standalone replacement for current systems.

3) Other information

As blockchain technology increases interoperability, it can for instance, lower barriers to voting and enable more convenient ways of voting through smartphones, computers or through electronic public booths (Narayanan and Clark 2017; Gabison 2016). Every vote can be recorded and secured from tampering due to immutability and blockchain can increase transparency through the ability to access and check the votes and reduce ghost voting.[4] Consensus for the recorded data makes manipulation of the data harder and thus, increases

[4] "Ghost voting is the practice of voting for individuals who are not present or do not exist. A smart blockchain could contain a protocol automatically to check birth and death registries. A smart blockchain could also record the location of individuals when they vote through their phone's GPS, computer IP address, or voting booth". (Gabison 2016)

the legitimacy of the votes (Pilkington 2016; Gabison 2016; Osgood 2016). Real-world applications of using blockchain for e-voting include that by a Danish political party for internal elections (Pilkington 2016), Follow My Vote and VoteWatcher (Osgood 2016).

3.2 Record transactions

Apart from enabling new forms of economic transactions in society, blockchain provides an immutable and auditable record of the entire history of transactions. In public blockchains, records are accessible to anybody as every node records a copy of the same data.

One use case in the public sector enabled by this function of blockchain is public record keeping, such as recording land and property titles, vehicle registries, shipping registries, health and safety inspections, tax returns, and energy usage records (Zago 2018). Potential benefits include opening access to public records and reducing delays associated with existing laws that allow citizens to request information from government agencies that will improve transparency, as well as facilitating information exchange while safeguarding the privacy of individuals and organisations who can also retain control over their data by giving public agencies read or write permission to certain data with their consent (Gabison 2016; Cheng et al. 2017). Public agencies can adopt blockchains with public access for only reading but with private access for writing so that only those with permission can write on it, which prevents any unwanted information from entering the chain (Gabison 2016). Blockchain also enables the storage and management of electronic medical records, which are currently fragmented as they exist in different formats (Liu 2016) and are scattered across different healthcare providers' private data silos (Azaria et al. 2016).

A real-world application of this is MedRec, a blockchain-based record management system to manage electronic medical records that does not store health records but allows patients to access and manage their health records stored in multiple providers and thus, affording much greater control to the patient (Kshetri 2017). The system also provides an immutable and auditable log of the patient's medical records for patients, providers, insurance companies and regulators to access with their private keys (Azaria et al. 2016; Swan 2015). In addition, a blockchain-based data repository of electronic health records could act as a private health data research commons whereby researchers can access the data securely by private key and individuals could provide their own personal health data with customised degrees of privacy while enabling public access to researchers to read and analyse their data (Swan 2015).

3.3. Automate transactions (smart contracts)

Smart contracts encode the rules and obligations surrounding an agreement between two or more parties into programmable code and can be defined as a mechanism that governs the distribution of assets between the involved parties (Buterin, 2014, para. 2). Once the rules or conditions are validated by all the nodes on the blockchain, the consensus mechanism automatically executes the conditions of the smart contract, which enforces the transaction (Luu, Chu, et al., 2016; Ølnes et al. 2017). Thus, a smart contract is also considered a "self-enforcing governance mechanism" (Luu et al. 2016) or an escrow "which can hold funds until the obligations defined in the smart contract have been fulfilled" (Xu et al 2017).

Smart contracts enable greater efficiency through disintermediation (no need for bank, creditors or insurance companies) and automation of all aspects including record-keeping, enforcement, and self-execution of the contract when certain conditions are triggered. Smart contracts also reduce transaction and legal costs that are often incurred through intermediation, such as administration and legal fees (Giancaspro 2017; Allam 2018). Transparency and reduction of fraud are other benefits of using smart contacts. Once a contract is initiated, these details become explicitly visible to the different nodes in the network and thus, changes to the contract cannot be easily implemented (Giancaspro 2017; Allam 2018).

Smart contracts crease their own set of challenges as well, which include:

- Security and crime: There are strong financial incentives to attack smart contracts, given that they can handle virtual currencies (Luu et al. 2016). Criminals can use smart contracts for demanding ransoms, money laundering and undertaking illicit transactions such as the infamous case of the Silk Road online marketplace (Giancaspro 2017). Atzei et al's (2017) review shows that a common security vulnerability present in smart contracts is "the difficulty of detecting mismatches between their intended behaviour and the actual one" and they highlight the limitations of the verification that can be done.
- Legal adjudications and enforceability: Existing contract law and other laws governing financial transactions have not established the "legal enforceability" of smart contracts (Allam 2018)
- Immutability: The rigidity of smart contracts makes it challenging to amend the terms and conditions of long-term contracts (Allam 2018)[5]. Moreover, the existing legal frameworks need to be translated to software logic to ensure smart contracts can adhere to legal regulations (Meng et al. 2018).
- Privacy issues/Contractual secrecy: a protocol needs to be developed to facilitate verification of transactions without reading the contents of the transactions, as the ledger is currently maintained publicly (Allam 2018)
- Jobs: many tasks that are currently carried out by financial and legal professionals will automated. However, some highly complex tasks such as programming of the contracts will be required (Giancaspro 2017).

A myriad of use cases for smart contracts have already been established:

- Energy: Smart contracts enable the development of energy markets without the need for a trusted entity to provide oversight and allow Crowdsourced Energy Systems, where energy trading and generation can be crowdsourced from distributed energy resources (Hahn et al. 2017; Wang et al. 2018).

[5] Use of an escape hatch has been suggested as a means for modification of the contracts; however, implementing such solutions can compromise the security of the smart contracts to avoid unauthorised manipulation of the contracts and initiation of invalid transactions (Allam 2018).

- Regtech: Using technology to enhance regulation. It is suggested that smart contracts and their "technical code" of conditions could be used to ensure legal compliance at lower costs (Yeung 2019). An example of such an initiative is R3's Corda platform led by a group of regulated financial institutions, which aims to develop distributed ledgers for recording and managing legal agreements between parties (Yeung 2019).
- Digital rights management: Savelyev (2018) and Huckle et al. (2016) show that blockchain is beneficial for the distribution of copyrighted works and can provide a platform for ownership and use of digital assets, as it increases transparency and control over digital copies and facilitates automatic payment to copyright holders (e.g. artists and authors).

3.4. Identification, verification, and authorization (proving/clarifying ownership of assets)

The blockchain technology can facilitate identification, verification, and authorisation processes (Drescher 2017). In financial and medical services for instance, blockchain technology can help provide improved identity authentication and verification processes to reduce fraudulent activities (Shrier et al 2016). Furthermore, blockchain technology can facilitate greater data exchange without disclosing unnecessary personal data (Mattila et al. 2016) and can strengthen the control of the data owner over how their personal information is being used. For instance, the use of a blockchain-enabled medical record management system enables patients to initiate these data exchanges and can also be used for enabling features such as time-limited access to the records via smart contract provisions (Pilkington 2016; Azaria et al. 2016).

Use of blockchain technology in tandem with connected devices can help with tracking the origins, transfers and transformations of a product through a supply chain, strengthen the product's compliance with health and safety regulations, facilitate the verification of the authenticity of products and thus, reduce counterfeit products (Pilkington 2016). With the increased use of e-commerce facilitated through the use of online platforms for instance, US has seen a tripled growth in incoming packages and parcels over the past four years, which necessitates greater protection for consumers from counterfeit goods and stronger enforcement procedures against criminal activities (Stanley 2018). Using blockchain technology also increases transparency around the ways in which a product was manufactured (Stanley 2018). For example, the issue of agri-food supply chain safety and quality has been an important issue in China in recent years and can be addressed using blockchain technology along with RFID technology to establish an agri-food supply chain traceability system to enhance food safety and reduce logistics related losses (Tian 2016).

The use of the blockchain technology can provide a decentralised and trustless system that enables the creation of unique digital identities for individuals that cannot be controlled by a central entity (Pilkington 2016). Research shows that the lack means to prove one's identity can lead to exclusion from many economic opportunities, particularly in the digital realm (Taeihagh 2017a). The use of blockchain technology also makes digital identities "more ubiquitous in that they can be freely integrated to any service where the identity holder and the counterparty together wish to do so" (Mattila et al. 2016). This can potentially address a major issue with the use of online platforms which is the inability to transfer one's reputation from one platform to another (Taeihagh 2017b). This ability will increase the trust in one's online reputation and will make it more pervasive and meaningful, which can potentially result in increase of trust in strangers because of their long standing and documented reputation over time" (Mattila et al. 2016).

4. Discussion: the hybridity of the blockchain technology

Given the description of the blockchain technology and analysis of its key functions and applications, we now examine the role that the blockchain technology can play in the public sector.

4.1. Blockchain as a policy tool

In the NATO model (Hood 1986; Hood and Margetts 2007), governments can use four types of resources to address policy problems (see Table 1):

- Nodality: using informational advantage as a result of centrality of the government in various networks;
- Authority: using legal power to regulate/delegate and command;
- Treasure: using financial means, such as demanding tax and using funds; and
- Organisation: using resources, to form markets/organisations and providing goods and services

Table 1 Example of policy instruments by principal governing resources (Howlett, Ramesh and Perl 1995, based on Hood 1986)

Nodality/Information	Authority	Treasure	Organization
Information collection and release	Command and control regulation	Grants and loans	Direct provision of goods and services and public enterprises
Advice and exhortation	Self-regulation	User charges	Use of family, community, and voluntary organizations
Advertising	Standard setting and delegated regulation	Taxes and tax expenditures	Market creation
Commissions and inquiries	Advisory committees and consultations	Interest group creation and funding	Government reorganization

The NATO model categorisation of the instruments is not mutually exclusive, a strict and singular dependence of an instrument on solely one of the four resources is not required, and as such, the categorisation of the tools can be carried out according to the primary means they require for successful address of their goals (Taeihagh 2017b). Another relevant distinction is whether the instruments are substantive ("directly providing or altering aspects of provision, distribution or delivery of goods and services to the public or governments") or procedural ("rather than directly affecting the delivery of goods and services, the intent is to adjust or amend the policy process and indirectly alter the behaviour of actors involved in policymaking") (Howlett 2000; 2010).

Marsal-Llacuna (2018) argues blockchain can be used as a policy tool to deliver urban governance though a bottoms-up, decentralized and citizen-centric manner. However, given various functions and applications of the Blockchain as highlighted in the previous sections, the technology can play different roles as a policy tool in different contexts. As such, Dutil (2015) argues that Hood's model (1986) is no longer applicable to 21st century tools (e.g. crowdsourcing and blockchain technology). However, as Lehdonvirta and Bright (2015) point out, the main advantage of using these new tools is the enabling power of these digital technologies. The use of blockchain can potentially reduce transaction costs and barriers to entry and increase the speed and ease of participation in various initiatives, which in turn can result in orders of magnitude increased participations and reduced costs of participation (Taeihagh 2017b).

Using the taxonomies of Hood and Howlett, it is evident that the blockchain technology utilises information and information exchange, has embedded rules and smart contracts that govern how the technology functions, and in many instances use tokens that have monetary value and can only function with a critical mass of users. Therefore, it appears according to the NATO model all types of resources are used for the functioning of the blockchain. In the authors view, depending on the purpose of the blockchain, the primary means that is required and thus, the categorization of the blockchain differs according to NATO. While the blockchain technology affords new opportunities for improved decision reporting, transparency and accountability to stakeholders (Rahimzadeh, 2018) that suggests its more procedural nature, the technology can be used for direct provision of information and treasure for instance. It is therefore in authors view that IT-mediated technologies such as blockchain cannot be considered as "a policy tool".

4.2. Blockchain as a meta-tool

Some scholars have used the term "meta-tool" as a set of policy instruments that can be used to facilitate and coordinate different policy tools and policy packages to make them more effective. Scholars note that much of the literature on policy instruments focus on improving the effectiveness of policy instruments in meeting policy goals and objectives and aim to design new alternative policy instruments and "meta-instruments" to improve the effectiveness of traditional instruments, such as through "planning, organisational reconfiguration, framework agreements or networks" (Kassim & le Galès 2010; Lascoumes & le Galès 2007; Woo 2016). While meta-tools offer an interesting perspective, blockchain technology cannot be reduced to a meta-tool that helps with the coordination of other policy instruments, as it was demonstrated earlier that blockchain can have both procedural and substantive nature and have different primary uses of resources that go beyond coordination.

4.3. Blockchain as a platform

The concept of platforms has evolved over the years and currently still remains highly fragmented. Many scholars refer to blockchain in terms of platforms – "blockchain platform", "blockchain-based platforms", an "emerging type of digital platform" (Cong & He

2019; Glaser et al. 2019) while some see blockchain as an infrastructure on top of which additional services can be built (Mougayar 2015; Ølnes & Jansen 2018). Choudary (2015) has examined numerous platforms by focusing on their architecture and suggests that platforms often all have elements of community building, infrastructure and data and patterns of exchange of information (with primary focus on information, currency, and/or goods, and services). With this view in mind, the emphasis in blockchain technology is the provision of infrastructure as argued by Mougayar (2015) and Ølnes and Jansen (2018). This view of blockchain technology is in line with the definition of industry platforms that allow complementary products, services or technologies to be built on top of those already developed by firms, such as Apple and Google's smartphone application platforms and Microsoft's Windows operating system, whereby participants can directly interact with each other and greater participation increases the platform's value to others (Sørensen et al. 2015; Brown et al. 2017). Furthemore, studies have also categorised open platforms that allow "freely available" service, process and technology standards that facilitate participation by multiple users to consume these services based on these standards and consequently promote innovation around these goods and services (Brown et al. 2017).

A more recently introduced type of platforms are digital platforms that provide application programming interfaces (APIs) to third party service developers who can customise and adapt the platform's core functionalities to various needs, such integrating it with external and complementary functionalities, services or platforms (Glaser et al. 2019). Blockchain is purported to be a new type of digital platform as its two functions of 1) facilitating transactions through the exchange of digital currency and tokens, and 2) automating transactions through smart contracts, enable it to become an infrastructure for organisations to offer various services (Glaser et al. 2019; Mougayar 2015). However, blockchain differs from typical digital platforms in the provision of their core functions – Unlike digital platforms, blockchain does not provide an API for users to engage in its services, but it allows users to execute personalised smart contracts that can be accessed by all other users of the blockchain (Glaser et al. 2019).

4.5. Blockchain as ecosystem or support infrastructure

A strong argument against the view of blockchain technology as a platform is the fact in order for the system to function, a large number of entities and not just the platform/infrastructure providers need to be involved for the function of the technology. In fact, there needs to be an ecosystem in place for blockchain to function appropriately. Riasanow et al. (2018) examined the roles of 11 different actors in the blockchain ecosystem (after analysing 479 organisations). In fact, value can be created from the interaction and complementarity of participants, also known as value "co-creation", and synergy is created from the aggregated effects of these complementarities at the ecosystem level (Smedlund et al. 2018). In this view, blockchain technology provides the ability to use resources, skills, and knowledge more efficiently and in an integrated fashion. In a similar perspective, studies highlight that blockchain can be defined as "a *shared, open* and *unbounded, heterogeneous and* evolving *socio-technical system"* comprising of networks of distributed but inter-linked information systems (e.g. the Internet) and their *"user, operations, and design communities*" that "*shape, maintain, and extend it in modular increments, not all at once or globally*" (Ølnes & Jansen 2018).

Glaser et al. (2019) argued that blockchain may be considered as a decentralised institution as it allows the implementation of new types of governance mechanisms. Looking at the core functionality of the blockchain such as Ethereum and the applications that can run on top of the core, Glaser et al. (2019) argue that the core layer (fabric layer) of the blockchain technology constitutes a conscious design of informal institutions[6] where individual agents negotiate governing rules and interactions to reach their goals and the application layer is a conscious design of formal institutions, which can lead to improvements in society. The application layer enables the development of various new features through smart contracts based on formal enforcement of protocols imposed by the core layer. Maintenance of the fabric layer is carried out by spontaneous open source community crowds through informal mechanisms.

4.6 Blockchain as a technological enabler and force multiplier

An emerging literature has also framed some of the IT-mediated platforms as more of a technological enabler or force multiplier for other platforms rather than being just a platform itself, as it enables and increases the speed and ease of access to many other platforms and technologies or technological systems, such as AI, robotics and 3D printing (Taeihagh 2017b; Epstein 2017; Catalini & Gans 2016). In other words, if a technology such as blockchain enables doing a myriad of tasks, perhaps it facilitates the speed of participation through providing an enabling ecosystem with the previous subsection. Some suggest that blockchain is a general purpose technology (GPT), similar to the steam engine, electricity and the internet, as the data that is exchanged and recorded on blockchain can be flexibly represented across many applications, depending on the nature of the transaction (e.g. type of asset transacted), allowing for increases in productivity across multiple sectors (Catalini & Gans 2016). Similar to how the Internet is open, globally accessible, "neutral" to the information exchanged on the network and has "minimum functionality" in the network with application functionalities located at the communicating end-points, blockchain is open to everybody and also has minimum functionality on its own, on top of which additional functionalities can be built to support and share applications across multiple communities (Ølnes & Jansen 2018).

5. New developments in the blockchain technology

Airdrops are one of the recent innovations in this domain. Blockchain's key function of enabling transactions has been widely applied by firms to raise capital by offering purchasers digital assets of the firm in exchange for fiat money or cryptocurrency. Emerging shortly after Bitcoin's introduction in 2010, airdrops are tokens that are distributed directly to individuals for free to incentivise users to increase their usage of the network, which essentially increases network effects to promote the growth of the blockchain-based platform

[6] The enforcement of rules in the core layer is informal because the blockchain cannot enforce the protocol on itself and would require network effects and implicit adoption of the proposed protocol and use of social mechanism.

(Blockchain 2018). Airdrops can be credited to participants that hold another token in the network, potentially reaching "millions of users" within a short time and thus, increasing awareness for that particular token (Arnold et al. 2019). Airdrops generate network effects as when the number of network participants increases, the utility of each individual node increases, which incentivises other individuals to join the network and consequently increases the value of the overall network (Blockchain 2018). Unlike ICOs where individuals need to have significant financial resources to purchase cryptocurrencies and that require expensive equipment to mine these cryptocurrencies, airdrops allow anyone to acquire cryptocurrencies at no cost. By allowing more users to acquire ownership of the cryptocurrency, airdrops enables greater decentralisation of the network, whereas tokens that are distributed through ICOs may be held by a small number of individuals that reduces the overall value of the network (Blockchain 2018). Benefits of airdrops have been highlighted, such as facilitating the "implementation of governance procedures", enabling "network testing prior to full launch", and using the information on participants' network activity to address issues and thus, increasing the project's credibility (Concannon et al. 2018). In the context of the NATO model (Hood 1986), the use of airdrops can facilitate the function of the blockchain as an organisational tool through network effects, and perhaps increase the value of the network in case of its success thus increasing treasure. Furthermore, airdrops increase awareness about the initiative (nodality).

However, there are several limitations in the extent of network effects that can be accrued and new privacy risks can arise from using airdrops. As airdrop recipients must use their private keys to "create a transaction on the blockchain belonging to the airdrop" (Harrigan et al. 2018, p1), the recipient's unique address will be broadcasted, resused and shared across other blockchains, potentially revealing information regarding the participants to other third parties. Airdrops may also not be effective in stimulating network effects if participants store the free tokens without spending them. The accumulation of tokens can also have the effect of "re-centralising" the network, which defeats its original purpose of decentralisation, and without spending these tokens, token-issuers will lack sufficient information to improve issues in the network (Cagechain 2018; Blockchain 2018).

Against this backdrop, Smartdrops are a new form of airdrops that allow transfer of tokens to a target group based on a set of predetermined criteria to tackle the shortcomings of airdrops, which is primarily the user accumulation of tokens without their use (Cagechain 2018). Smartdrops intelligently target and transfer tokens to entities that are more likely to use them, promote the development of the community and make the task of verification automatic and the process cheaper and easier (Milano 2018; Cagechain 2018).

6 Conclusions

In this article, we examined the literature on blockchain technology and examined and explored the functions and application of the blockchain technology. We first reviewed the key mechanisms of blockchain technology and then explored the functions it provides using these mechanisms and highlighted its potential different applications in various sectors. As blockchain technology is still in its early days, we aimed to provide a deeper understanding of the technology's fundamentals and how it relates to the public policy literature. We examine the hybridity of the blockchain technology as it relates to concepts such as policy tool, meta-tool, support infrastructure, platform, ecosystem and force multiplier by examining its abilities and features, as well as whether it has a specific function or acts more as an technological enabler that facilitates both substantive and procedural tools through a myriad of functions and capabilities it provides.

We questioned considering blockchain technology as a policy tool, a metal-tool or a platform and suggest that the blockchain technology is more akin to an ecosystem or a technological enabler and force multiplier that simply can increase the speed and ease of participation. We then focused on the new developments in the blockchain technology, namely the development of airdrops and smartdrops that can potentially increase the rate of network effects beyond ICOs. With the growth in the demand for digital services, technologies such as blockchain can help create an environment in which innovation can be better fostered due to the lower transaction costs and barriers to entry. Institutional complexities, sunk costs, and lack of capacity can hinder the adoption of the blockchain technology.

We hope this article illustrates the nuances of the characteristics and functionalities of the blockchain technology to the scholars and policy practitioners, and helps bring a clearer understanding and appreciation of the potential of the blockchain technology in the public sector.

References

Allam, Z. (2018). On Smart Contracts and Organisational Performance: A Review of Smart Contracts through the Blockchain Technology. *Review of Economic and Business Studies, 11*(2), 137-156.

Arnold, L., Brennecke, M., Camus, P., Fridgen, G., Guggenberger, T., Radszuwill, S., ... & Urbach, N. (2019). Blockchain and Initial Coin Offerings: Blockchain's Implications for Crowdfunding. In Business Transformation through Blockchain (pp. 233-272). Palgrave Macmillan, Cham.

Aste, T. (2019). Cryptocurrency market structure: connecting emotions and economics. *arXiv preprint arXiv:1903.00472*.

Atzei, N., Bartoletti, M., & Cimoli, T. (2017). A survey of attacks on ethereum smart contracts (sok). In Principles of Security and Trust (pp. 164-186). Springer, Berlin, Heidelberg.

Azaria, A., Ekblaw, A., Vieira, T., & Lippman, A. (2016, August). Medrec: Using blockchain for medical data access and permission management. In 2016 2nd International Conference on Open and Big Data (OBD) (pp. 25-30). IEEE.

Batubara, F. R., Ubacht, J., & Janssen, M. (2018, May). Challenges of blockchain technology adoption for e-government: a systematic literature review. In Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age (p. 76). ACM.

Blockchain. (2018). Blockchain The Airdrop Program. Luxembourg S.A. https://www.blockchain.com/airdrop

Brennan, C., & Lunn, W. (2016). Blockchain: the trust disrupter. Credit Suisse Securities (Europe) Ltd.: London, UK.

Brown, A., Fishenden, J., Thompson, M., & Venters, W. (2017). Appraising the impact and role of platform models and Government as a Platform (GaaP) in UK Government public service reform: Towards a Platform Assessment Framework (PAF). Government Information Quarterly, 34(2), 167-182.

Cagechain. (2018). SMARTDROPS: NEW WAY TO AIRDROP CRYPTO. Cagechain. http://cagechain.com/2018/10/02/smartdrops-new-way-to-airdrop-crypto/

Buterin, V. (2014). Ethereum: A Next-Generation Smart Contract and Decentralized Application Platform. URL: https://github.com/ethereum/wiki/wiki/ %5BEnglish%5D-White-Paper.

Catalini, C., & Gans, J. S. (2016). *Some simple economics of the blockchain* (No. w22952). National Bureau of Economic Research.

CB Insights. (2018). 8 Trends Shaping The Future Of Blockchain Technology. *CB Insights*. https://www.cbinsights.com/research/blockchain-future-trends/

Cheng, S., Daub, M., Domeyer, A., & Lundqvist, M. (2017). Using blockchain to improve data management in the public sector. McKinsey & Company. https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/using-blockchain-to-improve-data-management-in-the-public-sector

Choudary, S.P. (2015). Platform Scale: How an Emerging Business Model Helps Startups Build Large Empires with Minimum Investment. Platform Thinking Labs

Concannon, D. L., Valdez, Y. D., & Wink, S. P. (2018). The yellow brick road for consumer tokens: The path to SEC and CFTC compliance. *Blockchain & Cryptocurrency Regulation*.

Cong, L. W., & He, Z. (2019). Blockchain disruption and smart contracts. The Review of Financial Studies, 32(5), 1754-1797.

Drescher, D. (2017). Blockchain basics. Berkeley, CA: Apress.

Dutil, P. (2015). Crowdsourcing as a new instrument in the government's arsenal: Explorations and considerations. *Canadian Public Administration*, 58(3), 363–383.

Epstein, J. (2017). How Blockchains Are an Economic 'Force Multiplier'. *Medium*. https://medium.com/@jer979/how-blockchains-are-an-economic-force-multiplier-342dcc955e8f

Gabison, G. (2016). Policy Considerations for the Blockchain Technology Public and Private Applications. SMU Sci. & Tech. L. Rev., 19, 327.

Giancaspro, M. (2017). Is a 'smart contract'really a smart idea? Insights from a legal perspective. Computer Law & Security Review, 33(6), 825-835.

Glaser, F., Hawlitschek, F., & Notheisen, B. (2019). Blockchain as a Platform. In Business Transformation through Blockchain (pp. 121-143). Palgrave Macmillan, Cham.

Goldfeder, S., Kalodner, H., Reisman, D., & Narayanan, A. (2018). When the cookie meets the blockchain: Privacy risks of web payments via cryptocurrencies. *Proceedings on Privacy Enhancing Technologies*, *2018*(4), 179-199.

Hahn, A., Singh, R., Liu, C. C., & Chen, S. (2017, April). Smart contract-based campus demonstration of decentralized transactive energy auctions. In Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), 2017 IEEE (pp. 1-5). IEEE.

Harrigan, M., Shi, L., & Illum, J. (2018, November). Airdrops and Privacy: A Case Study in Cross-Blockchain Analysis. In *2018 IEEE International Conference on Data Mining Workshops (ICDMW)* (pp. 63-70). IEEE.

Howell, S. T., Niessner, M., & Yermack, D. (2018). Initial coin offerings: Financing growth with cryptocurrency token sales (No. w24774). National Bureau of Economic Research.

Hood, C. (1986) *The Tools of Government*. Chatham House Publishers. Chatham.

Hood, C. and Margetts, H. (2007) *The Tools of Government in the Digital Age*. London, Palgrave Macmillan.

Howlett, M. (2010) *Designing Public Policies: Principles and Instruments*. Taylor and Francis.

Howlett, M. (2000) Managing the hollow state: Procedural Policy Instruments and Modern Governance. *Canadian Public Administration,* 43(4), 412–31.

Howlett, M., Ramesh, M. and Perl, A. (1995) *Studying public policy: Policy cycles and policy subsystems.* Toronto: Oxford University Press.

Huckle, S., Bhattacharya, R., White, M., & Beloff, N. (2016). Internet of things, blockchain and shared economy applications. Procedia Computer Science, 98, 461-466.

Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. Harvard Business Review, 95(1), 118-127.

Kassim, H., & Le Galès, P. (2010). Exploring governance in a multi-level polity: A policy instruments approach. West European Politics, 33(1), 1-21.

Kietzmann, Jan and Archer-Brown, Chris (2019) *From hype to reality: Blockchain grows up.* Business Horizons, Online. ISSN 0007-6813

Kshetri, N. (2017). Blockchain's roles in strengthening cybersecurity and protecting privacy. Telecommunications Policy, 41(10), 1027-1038.

Lascoumes, P., & Le Galès, P. (2007). Introduction: understanding public policy through its instruments—from the nature of instruments to the sociology of public policy instrumentation. Governance, 20(1), 1-21

Lehdonvirta, V., and Bright, J. (2015) Crowdsourcing for public policy and government. Policy and Internet, 7(3), 263–267.

Liu, P. T. S. (2016, November). Medical record system using blockchain, big data and tokenization. In International conference on information and communications security (pp. 254-261). Springer, Cham.

Luu, L., Chu, D. H., Olickel, H., Saxena, P., & Hobor, A. (2016, October). Making smart contracts smarter. In Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security (pp. 254-269). ACM.

Marsal-Llacuna, M. L. (2018). Future living framework: Is blockchain the next enabling network?. Technological Forecasting and Social Change, 128, 226-234.

Martinovic, I., Kello, L., & Sluganovic, I. (2017). Blockchains for Governmental Services: Mattila, J. (2016). The blockchain phenomenon.):'Book The Blockchain Phenomenon'(Berkeley Roundtable of the International Economy, 2016, edn.).

Mattila, Juri – Seppälä, Timo – Holmström, Jan (2016): Product-centric Information Management – A Case Study of a Shared Platform with Blockchain Technology; Conference Paper; Industry Studies Association Conference 2016.

McReynolds, E., Lerner, A., Scott, W., Roesner, F., & Kohno, T. (2015, January). Cryptographic currencies from a tech-policy perspective: Policy issues and technical directions. In International Conference on Financial Cryptography and Data Security (pp. 94-111). Springer, Berlin, Heidelberg.

Meng, W., Wolfgang, E., T., Wang, Q., Wang, Y., & Han, A. J. (2018). When Intrusion Detection Meets Blockchain Technology: A Review. IEEE Access, 6(1), 10178-10188

Milano, A. (2018). Say Hello to SmartDrops: The New Way to Give Away Free Crypto. Coindesk. https://www.coindesk.com/say-hello-to-smartdrops-the-new-way-to-give-away-crypto-money

Mims, C. "M-Pesa: 31% of Kenya's GDP Is Spent Through Mobile Phones." Quartz, February 27, 2013. *http://qz.com/57504/31-of-kenyas-gdp-is-spent-through-mobile- phones/.*

Momtaz, P. P., Rennertseder, K., & Schröder, H. (2019). Token Offerings: A Revolution in Corporate Finance?. Available at SSRN 3346964.

Mougayar, W. (2015). Understanding the blockchain. *O'Reilly*. https://www.oreilly.com/ideas/understanding-the-blockchain

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

Nam, K., Dutt, C. S., Chathoth, P., & Khan, M. S. (2019). Blockchain technology for smart city and smart tourism: latest trends and challenges. *Asia Pacific Journal of Tourism Research*, 1-15.

Narayanan, A., & Clark, J. (2017). Bitcoin's academic pedigree. Communications of the ACM, 60(12), 36-45.

Ølnes, S., & Jansen, A. (2018, May). Blockchain technology as infrastructure in public sector: an analytical framework. In Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age (p. 77). ACM.

Ølnes, S., Ubacht, J., & Janssen, M. (2017). Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. Government Information Quarterly, 34(3), 355-364.

Osgood, R. (2016). The future of democracy: Blockchain voting. *COMP116: Information Security*.

Pilkington, M. (2016). 11 Blockchain technology: principles and applications. Research handbook on digital transformations, 225.

Pisa, M. (2018). Reassessing expectations for blockchain and development. Innovations: Technology, Governance, Globalization, 12(1-2), 80-88.

Rahimzadeh, V. (2018). Ethics Governance Outside the Box: Reimagining Blockchain as a Policy Tool to Facilitate Single Ethics Review and Data Sharing for the'omics' Sciences. Blockchain in Healthcare Today.

Rajan, D., & Visser, M. (2019). Quantum Blockchain Using Entanglement in Time. Quantum Reports, 1(1), 3-11.

Riasanow, T., Burckhardt, F., Soto Setzke, D., Böhm, M., & Krcmar, H. (2018). The Generic Blockchain Ecosystem and its Strategic Implications.

Risius, M., & Spohrer, K. (2017). A Blockchain Research Framework. Business & Information Systems Engineering, 59(6), 385-409.

Salviotti, G., De Rossi, L. M., & Abbatemarco, N. (2018, January). A structured framework to assess the business application landscape of blockchain technologies. In Proceedings of the 51st Hawaii International Conference on System Sciences.

Savelyev, A. (2018). Copyright in the blockchain era: Promises and challenges. Computer Law & Security Review, 34(3), 550-561.

Shrier, D., Wu, W., & Pentland, A. (2016). Blockchain & infrastructure (identity, data security). MIT Connection Science, 1-18.

Smedlund, A., Faghankhani, H., Ikävalko, H., & Turkama, P. (2018). Platform Ecosystem Orchestration for Efficiency, Development, and Innovation. In Collaborative Value Co-creation in the Platform Economy (pp. 29-40). Springer, Singapore.

Smith, O. (2018). Ben & Jerry's Bets On Blockchain To Cancel Out The Carbon In Every Scoop. *Forbes*. https://www.forbes.com/sites/oliversmith/2018/05/29/ben-jerrys-bets-on-blockchain-to-cancel-out-the-carbon-in-every-scoop/#688dfa1b688c

Sørensen, C., de Reuver, M., & Basole, R. C. (2015). Mobile platforms and ecosystems. Journal of Information Technology, 30(3), 195-197. doi:10.1057/jit.2015.22

Stanley, A. (2018). Supply Chain Titans, U.S. Chamber Eye Blockchain For Global Commerce. *Forbes*. https://www.forbes.com/sites/astanley/2018/05/22/facilitate-trade-protect-consumers-supply-chain-titans-eye-blockchain-for-global-commerce/2/#52cdf0eb7905

Swan, M. (2015). Blockchain: Blueprint for a new economy. O'Reilly Media, Inc.

Taeihagh, A. (2017a). Crowdsourcing, sharing economies and development. *Journal of Developing Societies*, *33*(2), 191-222.

Taeihagh, A. (2017b). Crowdsourcing: a new tool for policy-making?. *Policy Sciences*, *50*(4), 629-647.

Tasca, P. Thanabalasingham, T., & Tessone, C. J. (2018) Taxonomy of Blockchain Technologies. Principles of Identification and Classification. Forthcoming Ledger Journal.

Tian, F. (2016, June). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In Service Systems and Service Management (ICSSSM), 2016 13th International Conference on (pp. 1-6). IEEE.

Wang, S., Taha, A., & Wang, J. (2018). Blockchain-Assisted Crowdsourced Energy Systems. arXiv preprint arXiv:1802.03099.

Woo, J. J. (2016). Taking a Public Policy Theoretical Approach. In Business and Politics in Asia's Key Financial Centres (pp. 31-52). Springer, Singapore.

Xu, X., Pautasso, C., Zhu, L., Gramoli, V., Ponomarev, A., Tran, A. B., & Chen, S. (2016, April). The blockchain as a software connector. In Software Architecture (WICSA), 2016 13th Working IEEE/IFIP Conference on (pp. 182-191). IEEE.

Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., ... & Rimba, P. (2017, April). A taxonomy of blockchain-based systems for architecture design. In Software Architecture (ICSA), 2017 IEEE International Conference on (pp. 243-252). IEEE.

Yeung, K. (2019). Regulation by Blockchain: the Emerging Battle for Supremacy between the Code of Law and Code as Law. The Modern Law Review, 82(2), 207-239.

Zago, M. G. (2018). 50+ Examples of How Blockchains are Taking Over the World. *Medium*. https://medium.com/@matteozago/50-examples-of-how-blockchains-are-taking-over-the-world-4276bf488a4b