BLOCKCHAIN LAND REGISTRY BEST PRACTICES: THE POLITICAL AND TECHNICAL FEASIBILITY OF HARNESSING BLOCKCHAIN TECHNOLOGY TO IMPROVE LAND ADMINISTRATION

by

Lee Bratcher

APPROVED BY SUPERVISORY COMMITTEE:

____

Banks P. Miller, Chair

____

Clint W. Peinhardt

____

Eric Zheng

____

Vijay S. Mookerjee

This research is dedicated to the millions of people around the world whose property rights have been infringed by corruption, mismanagement, and improper titling in land administration. My wife Becca and my daughters Kenzie, Ivy and Kayli have been a great inspiration throughout this process.

BLOCKCHAIN LAND REGISTRY BEST BRACTICES: THE POLITICAL AND TECHNICAL FEASIBILITY OF HARNESSING BLOCKCHAIN TECHNOLOGY TO IMPROVE LAND ADMINISTRATION

by

LEE BRATCHER, BA, MA

DISSERTATION

Presented to the Faculty of

The University of Texas at Dallas

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY IN

POLITICAL SCIENCE

THE UNIVERSITY OF TEXAS AT DALLAS

August 2024

ACKNOWLEDGMENTS

The tremendous assistance and efforts of my dissertation committee made this research possible. Dr. Miller, Dr. Peinhardt, Dr. Zheng, and Dr. Mookerjee have all been instrumental in this process. My wife has been incredibly patient over the past decade as I have worked towards this goal.

July 2024

BLOCKCHAIN LAND REGISTRY BEST BRACTICES: THE POLITICAL AND TECHNICAL FEASIBILITY OF HARNESSING BLOCKCHAIN TECHNOLOGY TO IMPROVE LAND ADMINISTRATION

Lee Bratcher
The University of Texas at Dallas, 2024

Supervising Professor: Banks Miller

Property rights and, by extension, trusted land administration, are essential elements to the progress of any nation that is attempting to rise from poverty to wealth. Hernando DeSoto estimates that there exists in the world $20 trillion dollars' worth of real estate owned by the world’s poor that is illiquid, underproducing, and ineligible to be used as collateral for loans because it is either improperly titled or not titled at all. Furthermore, the World Bank estimates that 70% of the world’s population lacks legal title to their land. Blockchain, also known as distributed ledger technology, has the potential to radically change record keeping and the process of transferring title within the real estate industry. Blockchain land registries promise to increase land tenure security and transparency thereby leading to increased access to credit using land as collateral. This study catalogs political and technical obstacles to be overcome for the successful implementation of a blockchain land registry pilot in a given jurisdiction and seeks to understand the conditions in which a blockchain registry would succeed. There is a dearth of studies examining the political and governance issues surrounding blockchain based land registries which is problematics as the political obstacles are far more daunting than the technical.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

AN INTRODUCTION TO BLOCKCHAIN LAND REGISTRIES

Blockchain technology, alternatively referred to as distributed ledger technology, is the technological framework that underpins cryptocurrencies like Bitcoin and Ethereum. The philosophical and technical mechanisms that enable a blockchain to function were unleashed on the world by way of an anonymously published white paper in 2008. The pseudonymous author, Satoshi Nakamoto, did not use the term blockchain in the paper on peer-to-peer electronic cash systems, but the clever code that enabled distributed ledger technology traces its roots to these humble beginnings (Bratcher & Sullivan, 2021). While the technology was initially utilized in the finance services industry by investors, currencies traders, and libertarian cypherpunks, a growing group of technologists and social scientists are realizing the potential applications for distributed ledger technology in solving a variety of problems stemming from deficits in social capital. Blockchain technology has the potential to be as disruptive in the future as the internet has been over the past several decades (Casey and Vigna, 2018). As is common with disruptive technologies, most analysts and observers overestimate the technology's impact in the short-term and underestimate it in the long-term. The applications for blockchain in the public sector are myriad as it provides are more transparent and secure way of maintaining public registries (Kaczorowska, 2019).

Blockchain technology is essentially a digital, distributed ledger that lacks a central administrator. It is a further iteration of double entry accounting developed by Luca Pacioli in the late 15^{th} century. The technology might also be compared to the law merchants of the middle ages who acted as intermediaries in abrogating the need for trust between merchants. The opening question of Milgrom, Douglass, and Weingast's seminal paper on the role of institutions asks, "How can people promote the trust necessary for efficient exchange when individuals have short run temptations to cheat?" (Milgrom et al., 1990, p. 1). Modern blockchain technology has the capability to transform the way we think about trust institutions.

Technically speaking, a blockchain is a network of computers called nodes. These nodes use public key cryptography to secure assets and use various consensus mechanisms to ascertain the ordering and validity of transactions. Transaction information is stored on blocks with the information from the first block (the genesis block) and the information from each subsequent block all hashed together on the current block. By referencing the data from each previous block, the information chain is known by all parties to be true and unaltered. It is an append only data structure so once it is in the chain, it cannot be removed by anyone. Before blocks of transaction information are added to the blockchain, they are subject to a verification and block templating process by miners called proof of work for bitcoin. Ethereum and other public blockchains use proof of stake but there are many other less often used consensus mechanisms. Proof of stake differs from proof of work in that the former distributes consensus to stakers who have staked their ETH tokens as validators and the later relies on distributed nodes running the SHA-256 algorithm. Private blockchains have a permissioned structure that does not require a decentralized consensus mechanism. Given the complexity of consensus mechanisms, it appropriate to explain bitcoin mining, the process for the proof of work consensus mechanism, in more detail here.

Bitcoin miners are machines, or computers, that incorporate the SHA-256 algorithm as they provide "decentralized transaction recording and validation" (VanValkenburgh, 2020). Here is how it works. First bitcoin miners collect new transaction information that has not yet been confirmed. For example, recent transactions from the present to ten minutes in the past as a new block of transactions are formed approximately every ten minutes (Pritzker, 2019). The next step is the formation of a block header which contains information about previous transactions, a nonce (number used once), a timestamp, and the network difficulty level at that time. At this point, the SHA-256 hash function is applied to the block header with the goal of having the resulting string of sixty-four alphanumeric characters be below a target number. As more mining machines and therefore more hash power come on the network, the difficulty is adjusted upward and the target number becomes correspondingly more difficult for a machine find. To find a valid hash, miners must adjust the nonce (number used once) in the block header and hash it repeatedly, generating millions or even billions of attempts. This process requires significant computational power and electricity to power the machines (Pritzker, 2019). The first miner to find a hash under the target number is awarded with the right to form the next block and add it to the bitcoin blockchain. The miner broadcasts this block to the other miners in the network. The other miners and nodes on the network validate that the miner in question has in fact obtained a hash under the target number and validates that all of the transactions in the block are correct.

This process can be conceptualized by thinking of someone rolling a multi-sided die. Imagine that this die had one hundred sides and the numbers one through one hundred each written on one of the sides. And then imagine that someone asked you to roll a number under the number three. So you are rolling a one hundred sided die attempting to roll a one or a two. It is likely to take quite a while to roll a one or a two but once you have, everyone in the room can see that you have rolled it. The target number concept is similar but on an exponentially and mathematically more complex level (Frumkin, 2022).

Even just one change to a number in one of the thousands of transactions in that block will completely invalidate the block and it will be discarded. As a reward for participating in the network and finding the block, the successful miner receives a block reward, which consists of newly minted bitcoins and the transaction fees from the transactions included in the block. The block reward provides a financial incentive for miners to continue to secure the network and validate transactions. At the time of writing the block reward is 6.25 bitcoin but is about to be halved to 3.125 bitcoin in April of 2024.

When two parties transact on a blockchain, they use a combination of their private and public keys to submit the transaction to the nodes which then, using the process described above, verify the validity of the transaction and add it to the chain. This is the process for a public blockchain network like one would find with Bitcoin. Private blockchain networks use other consensus mechanisms that are described later. Public blockchains are permissionless while private blockchains are permissioned. Permissionless means that anyone can join and participate in the network. Permissioned means that there are rules written into the code which allows only those entities that are known to view and transact on the network. Permissioned blockchains are compliant with Know Your Customer and Anti-Money Laundering regulations. It is not that public, permissionless chains an uncompliant with those regulations, but that it is difficult for corporations and large enterprises to justify the risk of operating on public networks due to the risk of running afoul of regulators.

There are also hybrid blockchains that satisfy Know Your Customer and Anti-Money Laundering regulations but also use public blockchains to verify “proof of existence” (Kaczorowska, 2019). Hybrid or private blockchains remain the most likely to be used in the land registry space as most government entities do not trust public blockchains.

The security of blockchains is another area of strength. Because the complete ledger resides on each node (computer) in the network, there is no central point of exploitation for hackers. If a hacker gained access to a node and changed transaction information, then that change would be rejected by the hundreds of other nodes in the network that know the true state of the ledger. In other words, hackers would have to hack into a large number of computers all over the world simultaneously in order to attempt to change anything.

If a malicious actor attempts to insert a false transaction, he or she would need to gain control over 51% of the hashing power, or nodes, of the network in a proof of work blockchain. This is nearly impossible because most chains have hundreds or thousands of nodes, each with the economic incentive to ensure that the integrity of the chain is maintained. Decentralization in public blockchains so that one actor cannot control the network is mission critical. Ethereum founder Vitalik Buterin describes three separate axes of decentralization below (Buterin, 2017): *Architectural (de)centralization — how many physical computers is a system made up of? How many of those computers can it tolerate breaking down at any single time?*

Political (de)centralization — how many individuals or organizations ultimately control the computers that the system is made up of?

Logical (de)centralization— does the interface and data structures that the system presents and maintains look more like a single monolithic object, or an amorphous swarm? One *simple heuristic is: if you cut the system in half, including both providers and users, will both halves continue to fully operate as independent units?*

Further explanation of this can be found, among other places, in Casey and Vigna's (2018) seminal book, *The Truth Machine*.

Blockchain economics is an emerging field of interdisciplinary study that delves into the incentives, rules and governance structures of blockchains. Public Choice Theory can elucidate the ways in which blockchain economics may affect the economy (Davidson, De Filippi, and Potts 2016). While not the focus of this paper, a basic outline of blockchain economics is presented here.

As Davidson and Potts point out, the gains realized by decentralized systems in economics were first enumerated by Adam Smith when he coined the phrase dynamic efficiency. Hayek, a champion of the Austrian School, further elaborated on the benefits of open, unencumbered markets in *Law, Legislation and Liberty. Volume 1: Rules and Order* (Hayek, 1973). The Austrian school's focus on individual action and libertarian political theory meshes nicely with the economics of decentralized ledgers. The economic incentives of nodes in a blockchain network form a strong defense against malicious actors. Additionally, the decentralization of blockchain coalesces well with the Austrian's emphasis on laissez-faire treatment of markets. There are two different overarching types of blockchains; public blockchains and private blockchains. Public blockchains utilize proof of work consensus mechanism while private chains use other consensus mechanisms like proof of elapsed time or proof of stake, or proof of authority. The libertarian minds prefer public chains because they are nearly anonymous and are free from any centralized authority; even governments. Enterprises prefer private chains because of their hybrid approach that allows for many of the transparency and immutability benefits of a public chain coupled with the ability to selectively grant access to the network. This is important because of the regulations requiring companies to know their customer (KYC) and anti-money laundering (AML) regulations.

Public blockchain enthusiasts, while many may not know it, are most closely aligned in their thinking with the Ludwig von Mises camp of Austrian Economics. Von Mises advocated a libertarian political theory that eschewed most government regulation of the economy. This fits well with public blockchains because they are free of any centralize control and provide a good deal of anonymity to users. The enterprise blockchain advocates like IBM, Corda, and Quorum fall more in line with the thinking of Hayek. Hayek, the most famous Austrian Economist, was a bit less radical in his libertarianism and relied more on empirical models than did pure Austrians. One of the reasons for his popularity, in addition to his stellar reasoning and writing, was his ability to be flexible about the need for regulation of the economy in some circumstances. Just as enterprise blockchain companies understand the need for KYC and AML, Hayek knew the business and regulatory environment in which he was operating. Most enterprises will be weary of public blockchains and will opt for hybrid or private chains. Governments will be tempted to opt for private/permissioned blockchains as well because it provides more controls for bureaucrats. Private/permissioned blockchains, though, jettison many of the architectural benefits that make blockchains appealing in the first place. Private/permissioned chains lack the “decentralized” effect that public chains exhibit which leads to greater transparency and accountability allowing for trust to increase and transaction costs to fall (mostly as a result of fewer intermediaries) (Konashevych, 2020). Countries that lack trusted institutions or whose leaders are overly risk averse will be more likely to opt for private/permissioned blockchains. The irony here is that a pilot or implementation is more likely to be approved by the political veto players using a private/permissioned blockchain, but the chances that this technology fails short of the expected benefits greatly increase.

Several governments have commissioned studies on blockchain for the public sector including several states within the United State (Texas, Vermont, Wyoming, Delaware, Illinois, Arizona, California and Arkansas) the United Kingdom, Australia, Cyprus, India, Georgia, Estonia, Sweden, the European Union and many more. Most of these studies included examinations of digital assets, digital securities, and the study of blockchain for real estate. In fact, the author is this dissertation is the President of the Texas Blockchain Council, an industry association that had its hand in much of the Texas legislation and research on blockchain for the public sector.

The purpose of this research is to understand the political and technical obstacles to blockchain adoption for land administration and to theorize as to why the political obstacles are now far more significant than the technical obstacles whereas scholarship from the late 2010s and early 2020s contemplated the reverse.

Blockchain in the Marketplace

The true value add in blockchain is a more efficient and transparent transfer of value in a trustless environment. In other words, it does not require third party verification due to the checks and balances of the distributed network of nodes, clever code and public-private key cryptography (Bratcher & Sullivan, 2021). According to IBM, blockchain technology adds irrefutable proof that a transaction occurred because of these four qualities: consensus (agreement that a transaction has occurred), provenance (history of transactions), immutability (an append-only data structure), and finality (an agreed source of truth). In the context of land administration, one could see how these four qualities would provide gains in efficiency and effectiveness. The real estate industry is “plagued by inefficient processes and unnecessary transaction costs defended by self-interested professionals and institutions” (Baum, 2017, p. 1). What is more, Transparency International estimates that 20% of the world’s population have paid a bribe to register their land or view ownership rights (Avramov, 2017). While there is much to be gained in the United States with respect to efficient land markets, there is even more to be gained in developing countries. Analysts at De Soto Inc. estimate that there exists in the world $20 trillion dollars' worth of real estate owned by the world’s poor that is illiquid, under producing, and ineligible to be used as collateral for loans because it is either improperly titled or not titled at all (DeSoto, 2000). The introduction of blockchain based land registries could greatly increase not only liquidity in land markets in OECD countries, but also unleash millions of acres/hectors of land to be used as collateral for loans in developing countries. Blockchain land registry pilot programs are underway in South Burlington Vermont, Chicago Illinois (Cook County), Wyoming, Australia, Bermuda, Bolivia, Brazil, Colombia, Georgia, Ghana, Honduras, several states in India, Japan, Kenya, Liberia, Mexico, The Netherlands, Nigeria, Paraguay, Peru, Russia, Rwanda, Saudi Arabia, South Africa, St. Kitts and Nevis, Sweden, Ukraine, UAE, United Kingdom, and Zambia. In total, there are 28 blockchain land registry pilots that are either in-progress, announced, abandoned, or have moved into full scale production (Currier, 2020).

There are many blockchain technology companies working in the real estate, and specifically the land administration, industry vertical. The most influential include, ChromaWay, Medici Land Governance, and Propy. While there are several other blockchain real estate companies with large valuations and revenues, these three are unique in that at least part of their business model involves working with governments to streamline land administration and recording of titles. ChromaWay is a blockchain technology company that operates in multiple arenas with land administration just one of four main areas of service offerings (Bratcher & Sullivan, 2021). Medici is the leader in blockchain land governance solutions for the developing world and does some work in OECD countries as well. Propy is a more traditional real estate firm that is working to disrupt the real estate marketplace in the developed world. Their blockchain services include land administration services for the recorder's office and various other market-making services.

Here are a few market indicators that demonstrate the rise in blockchain adoption across a variety of industries. Approximately 34% of executives surveyed by Deloitte say that their company has initiated a blockchain deployment and 80% of businesses see blockchain as a strategic priority (ConsenSys, 2019). The Market Cap of all cryptocurrencies increased from $18 billion in 2017 to over $600 billion today. IBM alone has 1,500 industry and technical experts working on over 500 blockchain projects, several of which pertain to land administration (IBM Blockchain, n.d.).

A Blockchain Solution for Land Administration

Prior to the description of the processes inherent in most blockchain land registries, a definition of terms is required. The most pivotal and novel phrase in this process is a smart contract (Bratcher & Sullivan, 2021). Smart contracts are “self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. The code and the agreements contained therein exist across a distributed, decentralized blockchain network. The code controls the execution, and transactions are trackable and irreversible” (Frankenfield, 2019). The other phrase with which the reader will want to be familiar is public-key cryptography. This describes a form of cryptography that utilizes pairs of keys, one of which is public and one of which is private. The owner of the private key is the only person with knowledge of that key but the public key can be known by anyone that would care to look. Encrypted code or text can be decrypted with a private key so that only the owner of the private key could view it. Lastly, a hash, is an algorithm that takes an input and transforms it into a smaller output. In many blockchain applications, the SHA256 hash algorithm is employed witch converts inputs into outputs of 256 bits. This translates to a string of numbers and letters that is exactly 64 characters in length.

Each company involved in the development of a blockchain land registry constructs the process differently, but they generally follow a similar pattern, and most utilize private or hybrid blockchains. First, a distributed registry is established with pre-written rules coded into the smart contract. The registry has a user interface that is accessible to buys, sellers, lenders, attorneys, appraisers, the land office, and the public. In each transaction, the smart contract rules grant permissions to various actors based on their role in the transaction. The public will have the fewest permissions but enough to view transaction histories and ownership. The land office and other parties with a need to see deeply into the transaction will have the broadest permissions.

Buyers and sellers use a combination of public and private keys to validate their role in the transaction.

A transaction flow might follow a pattern such that the buyer and seller agree to the terms of the sale and the terms of the smart contract. Following this, appraisers and lenders conduct their due diligence and upload their findings on the blockchain registry in accordance to the procedures laid out in the smart contract. The purchaser would then submit the down payment to the smart contract escrow account. Following this, the lender would submit the remaining payment to the same smart contract escrow account. The smart contract would then execute by sending the funds in escrow to the seller while simultaneously sending the token representing title and ownership to the buyer and changing ownership status in the registry. This process is self-actuating but is visible to and auditable by the land administration office. All of these aspects to the transactions are stored on the blockchain in hashes in order to minimize the amount of data that is stored on chain. Full copies of all information can be stored off chain with hashes and metadata that are on chain pointing back to the source documents. We can be sure that no one has changed even a comma in these documents because if something even as small as a comma or a single digit were changed, the hash would change dramatically. Figure 1 depicts the output of a title record when it is hashed with a SHA-256 algorithm. Figure 2 depicts this same title record with the addition of a single comma. As you can see, any attempt to add or change any letter or number or even spacing, on the document will generate a completely different hash.

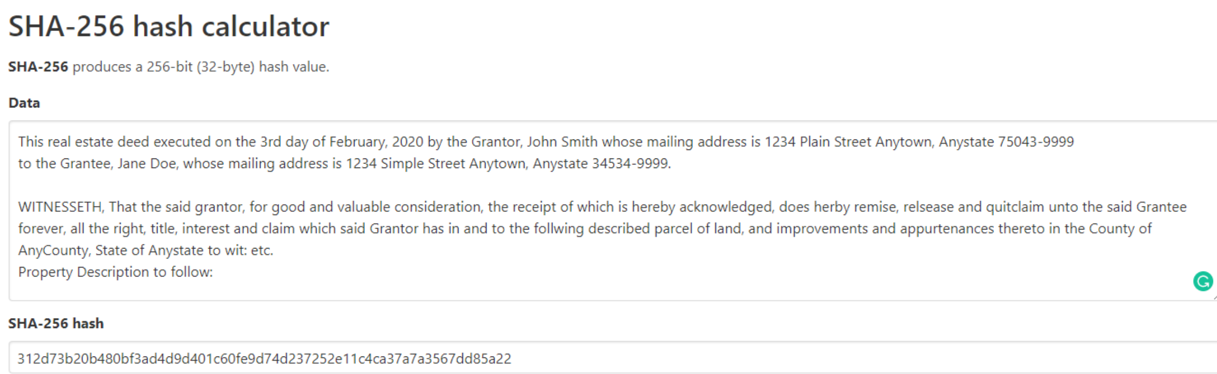

Figure 1. Hash Calculator Example (a)

Figure 2. Hash Calculator Example (b)

The image below is a visual representation of how a blockchain mortgage would be registered with the recording authority and how the transaction might develop.

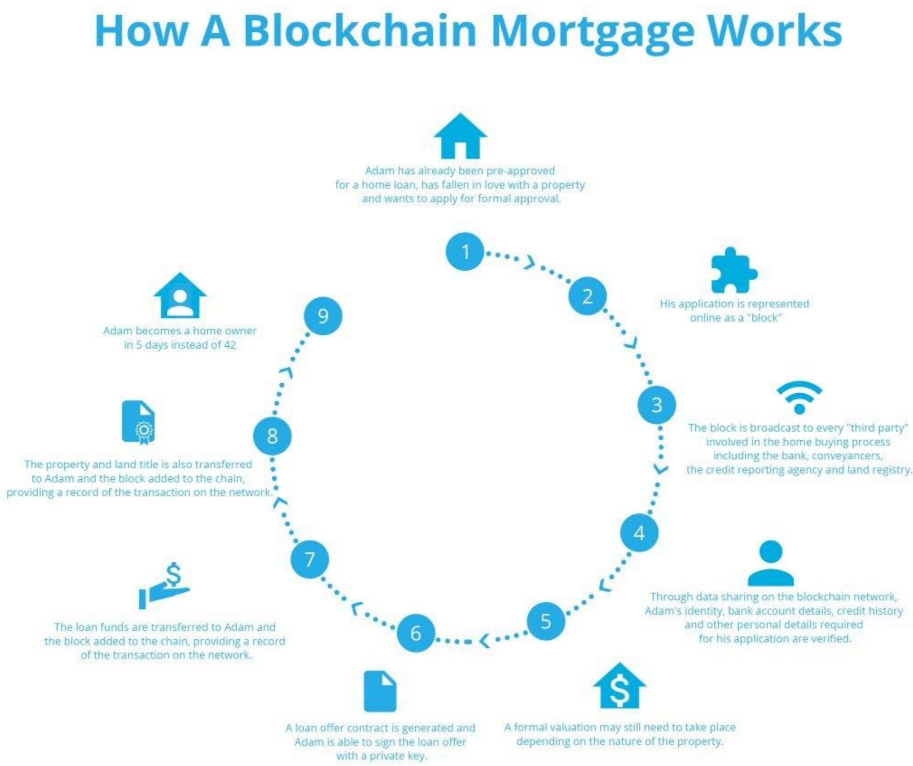

Figure 3. Blockchain Mortgage Process

Source: Home Loan Experts, https://www.homeloanexperts.com.au/home-loan-articles/blockchain-mortgage/

Pre-Requisites for Blockchain Adoption in Land Administration

Graglia and Mellon (2018) note several pre-requisites for successful adoption of a blockchain land registry. Obviously there is a spectrum of attainment when it comes to these criteria so generally it is assumed that some level of attainment of these pre-requisites are necessary but it is unclear as to what level of attainment is necessary. The pre-requisites are:

- An Identity Solution – it is important for actors within the transaction ecosystem to be known through valid and authentic state issued identity.

- A Digitized Land Registry – this technology cannot be used with land administrations that do not have at least some of their land records digitized or a plan to move in that direction.
- Multi-signature digital wallets (for private key recovery) – if someone loses a private key that demonstrates their ownership of an asset, there must be a key recovering mechanism which is only possible through multi-signature wallets.
- The use of a private or hybrid blockchain – when Graglia and Mellon wrote their article it was assumed that private or hybrid blockchains were the only types of blockchains feasible for deployment of blockchain based land administration systems. However, public blockchains like Bitcoin and Ethereum are capable of storing hashes of land and deed records. It is a matter of control and how much decentralization a land office is willing to stomach.
- Accurate Data – perfect data is not needed but blockchains obviously cannot improve bad data, they would just perpetuate it.
- Connectivity and a Tech Aware Population – about two thirds of the world has access to the internet and it would be necessary to have internet access for this technology. Intermittent internet access is sufficient.
- A trained and professional land administrator that interacts with the registry – there must be some level of buy-in from land administrators and civil servants.

It is unclear if these pre-requisites have a hierarchy or what level of impact each would have relative to the rest (Shuaib et. Al, 2022). To varying extents, these pre-requisites were present in each of the pilot programs in the developed and developing countries that will be examined in Chapters 3 and 4.

The implementation of blockchain to the real estate transaction process could create tremendous opportunities for businesses. Title companies that elect to adopt blockchain or at least understand how blockchain can advantage them relative to their peers, could grow their market share significantly. Efficiencies in real estate transactions would allow banks to increase the volume of transactions in ways not too dissimilar from how Rocket Mortgage has streamlined the mortgage application process.

Adjacent to the land administration process is the private equity and real estate investment world. A world that has not adopted much new technology and which still relies on syndicators and manual processes to aggregate investors and purchase or sell property. Real estate investment trusts (REITs) were an attempt to streamline this process, but any efficiencies gained were offset by the fees charged by the REIT administrators. The Invesco QQQ ETF and similar indices drove fees down quite low for the equity investors but there is not an efficient way for an individual investor to gain access to a bundle of real estate assets, much less fractionalized ownership in a single property, without paying considerable fees.

As assets become more liquid and available to a greater number of investors, all else being equal, that asset will increase in value due to the increased demand. The business case for tokenized real estate is quite clear and the use of blockchain in land administration is a parallel track in the process of innovating how we transfer value in the form of the world’s oldest asset class.

Research Question

This research seeks to answer the following question: What political and technical obstacles are most likely to derail efforts to transition to a blockchain based land registry. In answering that question, the research serves as a manual and map through the minefield for those working to implement a blockchain based land registry systems

The remaining chapters will unfold as follows. Chapter 2 will delve into the history of land reform and overview the literature of land reforms that enhanced property rights. Within Chapter 2, there will also be a review of the surprisingly ample literature surrounding blockchain land registries. Chapter 3 covers the political obstacles to implementing a blockchain land registry. As the reader will discover, it is the political obstacles that are most likely to derail a blockchain land registry project. Observations, firsthand experience demonstrating the political challenges and case studies of failed pilot programs are included within this chapter. Chapter 4 covers technical obstacles to the implementation of a blockchain land registry. Many of the technical obstacles are intertwined with the political obstacles. For example, the decision whether to utilize a public blockchain or a private chain quickly becomes a political question with various parties preferring one or the other. As with the chapter on political obstacles, Chapter 4 includes survey data from professionals, firsthand experience, as well as first hand interviews with professionals in the field. Chapter 5 concludes with a discussion on the path forward for blockchain land registries.

CHAPTER 2

A BRIEF HISTORY OF REFORM IN LAND ADMINISTRATION

The literature review outlines previous studies on the connection between property rights and investment specifically around the land titling space where ownership security is increased by trusted land administration institutions. There is a diverse and expansive literature on property rights and land reforms in the realm of land administration. This paper will limit its scope to property rights involving real property and technologically focused land reforms in the area of titling and land registries. The first half of the literature review will also cover the history of land reform in India and the enclosure movement in Sweden as these two countries figure prominently in today's blockchain land registry movement. The second half of the literature tackles the literature on blockchain land registries specifically.

Property Rights are defined as control over the land itself and, if they exist, to enjoy the fruits of the land such as "the assets that are produced and improved" (Rodrik 2000, p. 4). Secure land rights are more broadly defined as a continuum of tenure security where the owner perceives that he or she will enjoy the benefits of ownership and there are limited chances of expropriation (Henley, 2013). In this context, expropriation is defined as confiscation of the real property or fruits of production by the state or other powerful entities. This leaves some room for more traditional and informal structures but not to the point at which the real property could be described as communal. The literature is divided into two main positions, authors who support the premise that increased property rights leads to increased investment and therefore greater societal well-being, and authors who are unconvinced of this connection. Empirical studies do not predominantly support either camp, but rather, fall between these two groups with the preponderance of the evidence falling towards a positive effect on economic growth. The majority of those that are unconvinced of the connection are not claiming that an increase in property rights has a detrimental effect, but rather, that the evidence is mixed and is obscured by a litany of confounding variables that differ from place to place and culture to culture.

In the seminal work produced by the UK Government's Overseas Development Institute (ODI), Henley (2016) identifies three frameworks for examining the causal effects of increased property rights specifically on agricultural investment. While this work finds mixed effects on the benefits of private property rights, the authors cite several prominent proponents of property rights from the development literature. The first framework, the security effect, was originally posited by Besley and Ghatak (2009) and states that land owners invest more in their property and reap greater rewards when they have confidence that their land will not be expropriated and that they can keep the fruits of the land. The same authors provide the second framework, the gains from trade effect, investment will increase when efficient land markets allow for land owners to maximize their comparative advantage based on whatever factor of production they have in the most abundance. This second framework is of particular relevance in this paper since the title and property registry functions normally are studied alongside efficient land markets. The third framework, and most important for this research, is the collateralization effect put forward by Hernando De Soto. De Soto argues that land owners, who previously may have been unable to access the productive capacity of their largest asset, can use the title of their land as collateral for loans (De Soto, 2000).

In the camp of authors that are more skeptical about the positive effects of property rights, the argument goes that existing property rights systems are a product of the culture and institutions in which they are found and provide sufficient incentives for investment without the need for land reform or formalized property rights (Braselle et al., 2002 and Fenske, 2011). There is a logic to this argument, but the authors still provide evidence that land administration is significant in investment outcomes for a variety of investment types. Fenske (2011) admits that tenure is significantly linked to investment outcomes in regards to fallow plots and tree planting and only finds it insignificant as it pertains to investments in labor and fertilizer. Might it be that the labor practices are culturally engrained and may take many years to change? In this case, the land owner with capital to spare would likely choose to invest in other areas of productivity. And might limited access to fertilizer be a reason why a land owner with capital to expend would find a different avenue through which to increase his or her land's productive capacity? Brasella et al. (2002) provide a clear and convincing criticism of the aforementioned relationship between land tenure security and investment by noting that there is an endogeneity problem with the majority of studies on the topic. It is possible that greater investment leads to a greater sense of security for a variety of reasons such as establishing facts on the ground or such that the community observes the investment and is more likely to support the land owners rights thereafter. This presents the most logical argument regarding the ambiguity of the causal arrow between these variables. Brasella and her colleagues might be right, but the vast majority of academics (Avramov et al., 2017; Barnes et al, 1999; Baum, 2017; Besley, 1995; Besley et al., 2000; Bethell, 1999; DeSoto, 2000; Gonzalez, 2005; Haydaroglu, 2015; Hayek, 1973; and Milgrom et al. 1990) conducting studies on this topic find a positive correlation and evidence for causation between secure land tenure and investment and make convincing arguments that the causality of this relationship begins with stronger property rights especially land tenure security.

Additionally, Brasella and her colleagues only looked at one country in their study which can hardly be considered representative.

In another single country study that questions the causal arrow of property rights and development, Galiani and Schargrodsky (2010) found that property rights did lead to greater economic development, but not in the way that most authors within the literature find. They found that it was the increase in human capital that led to poverty reduction in the particular portion of the slums that enjoyed robust property rights. The authors did not do a good job parsing out the human capital variable to show that it is exogenous to other factors described previously. It does seem logical that investment in human capital would increase as the wealth of a neighborhood increases, and this would be a driver of poverty reduction. However, the authors overstep by claiming that the formalization of land and access to credit are not factors in this process. The natural experiment was not set up to effectively test access to credit or the utilization of land as collateral, and it seems likely that increased investment in human capital and increased access to credit are not mutually exclusive.

There is a group of academics that do not see private property rights as an important variable in economic growth. They range from those that think that private property rights are overrated (Trebilcock, 2008), to those that think they are harmful in some situations (Glaeser et al 2004; Fogel 2004; Schmid 2006; Leeson and Harris, 2018). Schmid (2006) argues that uncertainty around property rights can actually be a driver of growth by unshackling entrepreneurs so that they are not too constrained by reimbursing property owners if their quest for innovation becomes a bit destructive. Schmid’s analysis looks at westward expansion in 19th century and finds that the lack of defined property rights created an environment for innovation.

There certainly was dynamic economic growth during this period and if the lack of property rights had anything to do with it, this finding does not travel as the opening up of millions of acres of nearly undisturbed land is a one off.

The most convincing sub-strain in the literature that argues against the connection between property rights and growth is that made by Daron Acemoglu his 2005 article about institutions. He cautions that property rights can entrench the well-off at the expense of the poor by creating a rent-seeking class of property owners and a subservient class of impoverished renters (Acemoglu, 2005). While Acemoglu and his co-author Robinson are champions of property rights as can be seen in their most recent book, Why Nations Fail, they is most concerned about inclusive institutions. They would say that it is better to have private property rights than not, but we must ensure that institutions are inclusive and not merely the mechanism through which the educated and elites can concentrate more power. Advocates for private property rights should take pause here and realize that, just as free markets do not always "work," private property rights are amoral and can lead to harmful externalities in some situations.

Acemoglu and Robinson's concerns about rent-seeking elites was taken to extremes in one of the more recently published articles on property rights. Leeson and Harris (2018) do not mince words in the title of their article; Wealth Destroying Private Property Rights. They argue that the decision to privatize the commons is made by elites, and when the elites have a stake in the social wealth generated by the commons, they make good decisions about when to privatize. However, when elites do not have a stake, they may choose to privatize the commons even if that decision leads to a destruction of social wealth. The authors in this instance look mostly at

African communal property and do not adequately account for issues of corruption and patronage that have coincided with many privatization schemes in Africa (Boone, 2007). With that said, they are correct that it is not entirely clear that all communal property should be privatized. There are valuable uses for the commons and institutions can be developed to administer them effectively (Ostrom, 2003).

The majority camp posits that increased access to capital, security in the asset and formalization of the asset is the mechanism that boosts the economic productivity of the asset's owner (DeSoto, 2000; Pejovich, 1990; Bethel, 1999; Hayek, 1973; Coase, 1998; North, 1973 & 1991; Rodrick, 2004; Demarest, 2009; Clague et al., 1994; Leblang, 1996; Olsen, 1993; and Rand Corporation, 2009). Others ascribe the benefits of property rights to human capital investment, government investment in social services, or other tangential benefits.

Leblang (1996) is laser focused on property rights as a driver of economic growth, but most others in this camp are equally concerned with other variables such as social norms, societal capital, geography, and history. One of the most thoughtful and oft cited scholars to engender this viewpoint is Jean-Philippe Platteau. In his book Institutions, Social Norms and Economic Development, he unpacks the variables that either support or degrade the effect of property rights on economic growth by their presence or lack thereof (Platteau, 2000). In a similar vein, Douglass North (1991) places a good deal of emphasis on institutions and the way they shape commerce and specifically, property markets. In addition to incomplete information, "transaction costs in political and economic markets make for inefficient property rights." Further highlighting the role institutions play, Ronald Coase demonstrates in "The Problem of Social Cost" that institutions play an outsized role when transaction costs are high (Coase, 1960). While

North and Coase are referring to institutions more broadly, their observations include the institution of property rights. The importance of understanding transaction costs in politics and economics has proved enduring and will be revisited throughout this paper.

One of the most well-known academics to champion property rights, and specifically land titling programs, is Hernando DeSoto who was mentioned in the abstract. In the opening pages of his seminal work, *the Mystery of Capital*, he describes the poor in developing countries by saying that "they have houses but not titles; crops but not deeds; businesses but not statutes of incorporation. It is the unavailability of these essential representations that explains why people who have adapted every other Western invention, from the paper clip to the nuclear reactor, have not been able to produce sufficient capital to make their domestic capitalism work" (DeSoto, 2000, p. 49). One would be hard pressed to find a more concise statement about the need for property rights in the developing world. DeSoto's influence and charisma has been behind most of the recent land reform in Peru and in many other countries as well. His team of researchers estimates that there is twenty trillion dollars of capital locked up in the land holdings of the poor in developing countries because there are significant issues with the titling of their land (DeSoto, 2000). If they were able to gain access to a reliable titling system for their land, they could use this asset in the formal economy to generate wealth.

In developed countries, the idea of property rights is so engrained in our social and legal fabric, that people are not quite sure what a world without those rights would look like. In fact, they likely have not thought to imagine such a world (DeSoto, 2000; World Bank, 2010). At this point, the institution of property rights, especially as those rights relate to land, has taken on a heuristic quality in that there is no need to think critically about something so logical. This is not to say that there are not those in the West who argue for more communal property and less private property, but rather, that the knowledge about how the current institution of private property developed has been lost to our collective memory. Private property and sound land governance is one factor that has enabled Western countries to develop economically at such a blistering pace (DeSoto, 2000; Pejovich, 1990; Bethel, 1999; Hayek, 1973; Coase, 1998; North, 1973; Leblang, 1996). China's meteoric rise presents a challenge to this theory at first glance. However, there are a few reasons why, after further inspection, the case China is less problematic to the theory. China abolished private property early on and in the cities in 1982, but then quickly changed tack and in 1994, allowed for 70-year leases of residential property and slightly shorter leases on commercial property (Clark, 2017). It remains to be seen what will happen as some of the leases begin to expire, but it is almost as if this is a face-saving measure as the Communist Party admits that private ownership and cultivation of property is essential to growth. It was in the 1990s and 2000s that China's growth really took off with GDP growth averaging around ten percent per year for several years.

The institutional quality of land governance and the surrounding rights is of paramount importance. The empirical studies described above show that cadaster, a word of French origin that describes land registries, and land administration systems cannot be copied and pasted from the developed world onto the developing world because of the unique social and historical traditions in each country and the lack of institutional memory for such a system. The legal institution of property rights that supports an efficient land market does not fit into the "more formal and indigenous rights to land found especially in developing countries where tenures are predominantly social rather than legal" (World Bank, 2010).

Another difference between developed land administration systems and developing ones stems from transaction costs. Elucidated by the great and aforementioned Ronald Coase (1960), transaction costs can include market research, enforcement of property rights, and bargaining costs. An enlightening study conducted by Harvard academics in an impoverished area of Peru elucidated one of the nuanced aspects of land tenure reform. The study found that government titling drives did not necessarily increase access to credit when the funds are sought from a private lender but it did for public lenders (Field and Torero, 2006). However, they did find that homeowners with titles are 10% more likely to "have undertaken housing improvements in the last two years prior to the survey" and that "titled households are 15% more likely to finance improvements through formal loans" (Field and Torero, 2006). The land title availability did increase access to credit from public lending institutions, but for access to capital to make a demonstrable effect on a community, private lending must also be part of the equation. The main reason the authors gave for this lack of private lending was that of transaction costs. The cost of collateral processing, confirmation of title, foreclosure, and resale are immense relative to the small size of the loans requested by many of the urban poor. This issue of transaction costs is not one that should be quickly overlooked as it can be a major driver in "credit rationing" in developing countries (Coase, 1960; Field and Torero, 2006). The authors tackle another interesting challenge by teasing out the effects on demand for credit from the effects on supply of credit. We agree that it is an interesting academic inquiry to understand the nuance between the effects of property titling on supply and demand of credit, but it is even more interesting and relevant to get at how the process of increasing access to credit can be improved through technological advances in land titling.

The World Bank Report on Land Administration and Governance provides several examples, mostly from the developing world, in which corruption in land administration and governance have derailed development. For example, they note that in places like Kenya, India, Tanzania, Ethiopia and Bangladesh, to name but a few, corruption within land administration and governance is a major obstacle to economic growth (World Bank, 2010). In Honduras, around 80% of land held by private individuals is either untitled or incorrectly titled (Collindres et al., 2016). To make matters worse, a 2015 audit of the Honduran land titling entity uncovered more than 700 irregularities, most of which were related to "criminal acts of corruption" (Collindres et al., 2016). The system is highly politicized in that elected officials change titles for key supporters or refuse to enforce the titles of political opponents. In India, it is estimated that 66% of all civil cases in the court systems involve disputes over land (Thomason Reuters Foundation, 2016). Millions of these cases are currently awaiting adjudication in the backlogged Indian court system. It is estimated that the lack of land rights in India is a greater cause of poverty than illiteracy and the caste system (Kanojia, 2015). Because India and Sweden play an outsized role in the brief history of blockchain land administration reform efforts, the following section is a deep dive into the history of land reform in India. This section will be followed by a deep dive into the history of land reform in Sweden.

The History of Land Reform in India

India is an interesting case because the British did not establish a uniform land administration system throughout the regions under their control. Rather, the land administration system was based on when that particular region was brought under British control and the impression that the British administrators had of the previous Mughal era land administration systems (Banerjee & Iyer, 2005). The systems that developed are classified as landlord-based land administration, individual cultivator land administration, and village land administration. The landlords were given quotas on property taxes that were to be paid to the British and they were at liberty to tax their tenants accordingly (Banerjee & Iyer, 2005). In the individual cultivator model, individual landowners paid the British directly. As a result of this arrangement, the regions in which the individual cultivator model was utilized saw the establishment of robust property rights and the completion of thorough land surveys for a cadaster. Similar efforts were not need in the village or landlord model because the property tax responsibility was aggregated to the top for the entire area and therefore it mattered little where one plot began and another ended.

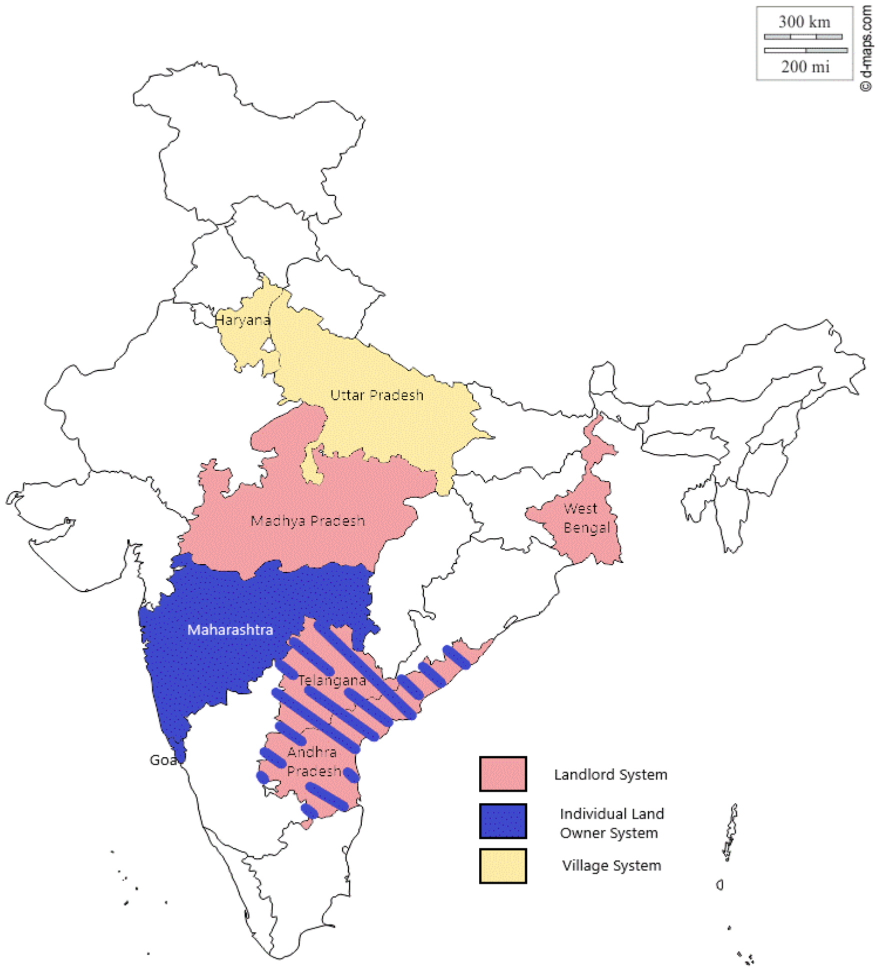

Figure 4. Indian Land Registry Map

After independence, India states were granted constitutional authority to enact land reforms independently (Besley and Burgess, 2000). As a result, there is variation in policy from state to state. This variation provides for public policy experimentation and creates an excellent environment for empirical analysis. Beasley and Burgess divided state-level land reforms into four categories; (class 1) regulating tenancy contracts, (class 2) abolishing intermediaries, (class 3) land redistribution and ceilings on landholdings, and (class 4) reforms that attempted to consolidate "disparate landholdings" (Besley and Burgess, 2000). While the goal of these reforms was poverty alleviation, there is not much consensus in the academic literature as to whether or not they were successful. There is some consensus that reforms that abolished intermediaries had positive effects on the poor and increased tenure security (Wadley & Derr, 1990).

The states with active blockchain based land registry programs are Andhra Pradesh, Telangana, Maharashtra, West Bengal, Uttar Pradesh, Goa, Madhya Pradesh and Haryana so rather than list land reforms in all Indian states, the following paragraphs focus exclusively on these eight. Telangana will be included with Andhra Pradesh as Telangana was part of Andhra Pradesh state until 2014.

The area that is now Andhra Pradesh was administered under both the landlord-based land administration system and the individual cultivator land administration (Banerjee & Iyer, 2005). Land reforms there began as early as a few months after the Indian Constitution was ratified in November of 1949. In 1950, the Andhra Pradesh Legislative Assembly passed the Tenancy and Agricultural Lands Act that protected tenants and provided them with a minimum tenancy term (Besley and Burgess, 2000). The most interesting and effective reforms came in the mid-1950s when five class 2 (abolishing intermediaries) land reforms were passed. In 1952, the Jagirs system, akin to feudalism in medieval Europe, was abolished. The other four acts followed in quick succession abolishing all kinds of feudal style land grants that were given to Jagirs and Inams which freed up 11,137 estates and eliminated nearly 1000 Jagirs and many more Inams (Besley and Burgess, 2000). Andhra Pradesh is now continuing in this line of effort by implementing blockchain property technology (prop tech) for the purpose of eliminating intermediaries and middle-men. Previously these middle-men performed tasks that could be easily digitized and automated thereby saving time, money, and layers of bureaucracy in which graft and fraud could proliferate.

The British administered land in Haryana and Uttar Pradesh, near New Delhi, through the Village System and therefore the need for abolishing a landlord-based system was not as prevalent. Instead, Haryana's land reform centered around tenancy reform. In 1953 and 1955, the Haryana Legislative Assembly passed the Punjab Security of Land Tenures Act and the Pepsu Tenancy and Agricultural Land Act respectively (Besley and Burgess, 2000). This legislation provided for tenure security for landowners who cultivated plots of less than fifteen acres. Uttar Pradesh passed land reforms of all four varieties (classes 1, 2, 3, and 4). The literature gives the impression that land tenure struggles were not as acute in Haryana and Uttar Pradesh as they were in Andhra Pradesh.

Madhya Pradesh, and West Bengal, both regions previously administered under the landlord system, passed reforms mainly of class 1 and 2, regulating tenancy and abolishing intermediaries. West Bengal passed class 3 and 4 reforms as well, (class 3) land redistribution and ceilings on landholdings, and (class 4) reforms that attempted to consolidate "disparate landholdings" (Besley and Burgess, 2000).

Maharashtra, having been administered by the British under the individual land owner system, had less of a need to dispatch the middle-men and landlords, so its reforms were of class 1 and 3; tenancy reform and land redistribution. These occurred in the 1950s along with the reforms from many of the other states listed.

Goa was ruled by the Portuguese until 1961 and therefore their history of land reforms is of a different track. They were under a mixed system in which the Portuguese assigned land to landlords similar to parts of India. Upon independence, the Goa Legislative Assembly passed land reforms of the class 1 variety, tenancy reforms (Colvalkar, 2017). The point in describing land reforms state by state is to underscore the nuance present in the process of Indian land reform. Despite this nuance, there are generalizations to be made.

In a recent paper published by the India Institute, Chandra and Rangarajun (2017) describe a labyrinth of legacy systems that hinder efficient land markets in India. India has two different systems of land administration, land records and land registrations, administered by the Department of Revenue and the Department of Stamps and Registration respectively. The authors note high levels of uncertainty and the practice of paying bribes to patwari (village accountant) in order to get transactions process (Chandra and Rangarajun, 2017). These challenges prevent small landowners from accessing credit and drives up the interest rates on mortgages. Another challenge is that most land records are not digitized. In Andhra Pradesh for example, only around half of the hard copy land records are in legible condition (Behra, 2009). The lack of digitization of land records is a large impediment to a blockchain based solution, but India has rapidly expanded the percentage of digitized land records at the time of publishing.

The actual process of buying and selling land is different depending on the state, but Chandra and Rangarajun have distilled the process into a more generalizable form. They outline a seventeen-step process that can take three to four months to complete. Because the transaction costs of land markets are an area of focus for this paper, it is worth summarizing the seventeen steps:

1. A property owner desires to sell her property 2. The seller finds an agent and agrees to terms 3. The agent check the land records 4. The property is put on the market 5. The buyer goes to the bank and receives a loan commitment. 6. The buyer that is the highest bidder reconfirms credit with their bank. 7. The bank conducts due diligence similar to that done by the agent initially. 8 The bank approves the loan. 9. The agent confirms with the bank that the buyer has the loan. 10. The agent arranges for the signing of four identical copies of the contract. 11. The contract is sent to the buyer's bank. 12. The bank sends credit documents to the buyer. 13. The buyer sends the signed loan agreement back to the bank. 14. The bank receives the loan documents. 15. The bank initiates payment to the seller. 16. The sale deed is signed and the transfer of property is registered with the land department. 17. Commissions are paid to the agents (Chandra and Rangarajun, 2017).

The process is differs mostly in structure rather than substance from property transaction in OECD countries, but the lack of digitization of title, contract, and deed documents creates a lethargic process. The authors observe some specific problems, though, that are unique to India. The Land department does not get involved with active measures until step sixteen. There is an opacity to the system that requires everyone to constantly check and confirm what other parties have already spent time looking into. A property market in which transactions can take up to four months can hardly be described as fluid. In the Indian Government's Blockchain Report of 2019, they list land registries as one of the foremost areas of innovation in which blockchain can bring efficiency gains (Nasscom, 2019).

The Enclosure Movement in Sweden

There is a limited literature written in English on Swedish land reform, but it is clear that most academics place great emphasis on the three major land reforms on the past few centuries: storskifte (Great Partition) in 1757, enskiftet in 1803, and lagaskifte in 1827 (Skalos et al., 2012). The storskifte, or Great Partition, was the brainchild of Jacob Faggot, the director of the Swedish Land Survey Board (Helmfrid, 1961). His inspiration was likely the agrarian revolution in England but the needs in Sweden were unique due to the idea of the "village community." The village community system allotted an equal amount of land to each farmer in the village but, in order to ensure equity, the farmer received several different plots in various locations, and of various quality, around the village (Helmfrid, 1961). The Storskifte reform aimed to eliminate the inefficiency in the village community system by giving farmers single continuous plots to cultivate. Opposition to the reform meant that very few villages enacted it with vigor, and many not at all.

By 1783, farmers were able to request that their land be removed from the village community and enclosed. This process, known as "enskifte" was successful and formalized through legislation by 1807. In a continuation of this process, the "lagaskifte" Act of 1827 "permitted more than one piece of land per farm, so that each farm got its part of the old common forest and pasture land, a piece of meadowland and one piece of arable land" (Helmfrid, 1961). The "lagaskifte" Act rolled back some of the more radical and forceful aspects of the enskifte and provided for greater acceptance of the reforms among community-oriented farmers. In the decades after these reforms were implemented, it is estimated that Sweden's cultivated land area tripled in size "from 0.8 million hectares in 1800 to 2.5 million hectares in 1860" (Helmfrid, 1961).

It is clear that Swedish academics have found evidence that agricultural production was higher for land that was owned by the farmer himself, a "freeholder," than it was for land owned by nobles or the clergy (Olssen and Svensson, 2010). The 19th Century saw an increase in the proportion of arable land, mostly in southern Sweden, that was owned by freeholders. Olssen and Svensson conclude that property rights provided the foundation for increased investment and the industrialization process.

The modern Land Code was established in 1970 and updated in a reform in 1973 when Sweden became the first country to adopt a computerized land registry (Jensen, n.d.). This reform came just a few years after extraordinary growth in Sweden's GPD per capita that was matched only by Japan in the century from 1850 – 1950 (Schön, 2008). Sweden's current climate in regards to property rights is a mixture between strong institutions that enforce property rights and recent legislation designed to protect tenants at the expense of landowners. There is a tradition of legal positivism in Sweden that is quite different from common law systems that many anglophile nations are accustomed to (Jensen, n.d.).

The main body responsible for land administration is the Lantmäteriet, in English the Swedish National Land Survey. This organization has three divisions; the Cadastral Services Division, the Land Registration Division, and the Geodata Division (Lantmäteriet Annual Report, 2016). It was the Lantmäterie, in partnership with Chromaway (a blockchain company), that conducted the initial pilots for a Swedish blockchain based land registry. One of the many reasons the Lantmäterie enthusiastically adopted the idea of blockchain based land registries is because the organization itself is modern and digitized, but the processes in place for the sale and transfer of land are outdated and the Lantmäterie is not brought into the process until "long after the contracts are signed" (Lantmäterie, 2017). Despite the outdated processes, Sweden is leagues ahead of developing countries and even many OECD countries in regards to an efficient and trusted marketplace for land transactions.

Blockchain Land Registry Literature

As one might expect with such a novel concept, there are but a few strains in the blockchain based land registry literature. The first group to write on the subject were technologists and academics with some level of tech enthusiasm who foresee myriad applications for blockchain technology in the social sciences (Casey & Vigna 2018; Collindres et al. 2016; Kaczorowska, 2019; Scott, 2016; and Snall 2017). There is another strain in the literature that can be described as the "not yet" group (Vos 2017; and Lemieux 2016). These authors recognize the potential of blockchain in land administration but feel that the technology is not mature enough to replace legacy systems of land registration. The last strain in the literature are those that feel blockchain technology is not the right fit for land administration (Barbieri and Gassen, 2017). The following arguments posited by the various subgroups in the literature were on display at the 2017 and 2019 World Bank Conference on Land and Poverty in Washington, D.C.

The enthusiasts argue that blockchain technology in land registries has the potential to open up the credit market for those who would normally not have access (Scott, 2016), curb corruption (Collindres et al., 2016), and minimize transaction costs (Casey and Vigna, 2018). These are all theoretically feasible but are not without obstacles. To dwell on the obstacle, though, is to miss the potential upsides of a successful implementation of a blockchain based land registry. The economic vitality and productivity of the world's poor are severely hampered by informal property arrangements and their inability to access credit markets (DeSoto, 2000). While the benefits are not as drastic, land management in OECD countries could also see a substantial lessening of transaction friction and efficiency. A blockchain based land registry that made records transparent to all citizens could reduce transaction costs and establish a function market for immovable property. USAID did a study in Uganda in which they found that the land of those who were secure in the property rights was 63% more productive than those who had a fear of eviction (USAID, 2016). No doubt there is room to critique how they measured the increase in productivity, but it is telling that organizations like USAID and the World Bank have been some of the first to champion innovation in the property registry space. Kaczorowska put it well in her 2019 paper when she said, “it is expected that the future stage of development of land registers will be the application of blockchain technology which shall revolutionize the land registration process” (Kaczorowska, 2019).

As described previously, the second strain in the literature represents a group that is more cautious than optimistic about the prospect of using blockchain as a tool in land administration. They observe that there are many avenues through which to implement a blockchain based system, and many questions that must be answered prior to an implementation. In the technical realm, these academics and practitioners debate whether or not the land registry should be placed on a public platform like Bitcoin or a private platform like the one that the Austin-based startup Factom attempted in Honduras. A public blockchain platform would provide “proof of work” checks that enhance immutability of the blockchain, but the transaction costs are high. Public blockchain transactions require 5,000 times more energy than a Visa credit card transaction (Barbieri and Gassen, 2017). This would appear not to be a problem since there might only be a few thousand real estate transaction per day in a given country, but with electricity and energy costs high in developing countries, this is a dissuasive factor. Put another way, a blockchain network that process 300,000 transactions per day would require a similar amount of energy that is consumed in a small country in that same twenty-four-hour period (Vos, 2017). The process that is so time and energy intensive is the “proof of work” process. While proof of work enhances the security and immutability of the system, it requires complicated mathematical computations along with majority consensus algorithms that require a good bit of computing power.

In 2017, when Vos presented his paper at the World Bank Conference on Land and Poverty, the only alternative was a tradeoff between system security and massive amounts of computing power. If one wanted to design a system that required less computing power and therefore less energy, one could utilize a private blockchain or use a different type of consensus mechanism, but this arrangement would provide less system security. Several blockchain protocols now provide transaction speeds in the hundreds of thousands per second. For example Hedera, a Texas based blockchain company, provides a solution to the energy consumption issue described above by allowing secure transactions at over 500,000 transactions per second (Baird et al., 2018). The author met with Mance Harmon, CEO of Hedera, this fall and he (Mance) demonstrated how the Hedera Hashgraph platform increases speed through a process called Gossip and Sharding These concepts are explained further in the Hedera Whitepaper (Baird et al., 2018). Several other platforms like The Linux Foundation’s Hyperledger Fabric, EOS, Ripple, and the Bitcoin Lighting Network have overcome the speed issues present by Vos and Barbieri & Gassen.

The third strain in the literature consists of academics and practitioners who feel that blockchain applied to land administration is not the right fit. Barbieri and Gassen (2017) are the most critical of the arrangement proposed by blockchain enthusiasts. While they recognize the economic hindrance caused by the fact that “of the 7.3 billion people in the world, only two billion have title that is legal and effective," they are fairly skeptical that blockchain will be the avenue through which these property owners formalize their property holdings (Barbieri and Gassen, 2017). Their primary concern is that a public blockchain network is not secure enough from cyber-attacks, and a private blockchain network, while more secure, forgoes many of the benefits inherent with a distributed ledger that make blockchain attractive in the first place. Other issues raised by the authors include; seismic shifts in political power, the risk of lost cryptographic keys, re-encryption challenges, energy consumption, and data accumulation issues. These are all valid concerns, but the concerns are no more or less, just different, than the concerns with the current systems in place in many developing countries. First of all, their concern about seismic political shifts is irrelevant because no cadastre or land management system, blockchain included, can protect against a totalitarian takeover or the predations of a roving bandit to use Mancur Olson’s terminology. If the state is captured by a despot, he can just as easily confiscate the real property of his people whether the property records are listed in a centralized database, on paper, or on a blockchain based ledger.

I question the logic of their concerns about lost cryptographic keys as well. Might it not be equally possible that the government entity responsible for land administration could misplace, damage, or corrupt a file that holds land registry information? At least in the blockchain scenario, the person who has the most interest in the property, the owner, is the one responsible for keeping their cryptographic key in a safe place rather than a bureaucrat with no dog in the fight. Furthermore, it is not as if someone who misplaces their cryptographic key will immediately be evicted from their land. On the contrary, no one else will have the key either and hence there is no way for a false claimant to enter the picture. In a situation where there is no proof of ownership under the current centralized storage system, a false claimant could hire an unscrupulous lawyer to draft a forged document and a legal battle over ownership would ensure (under the best of conditions, under the worst, there would be bloodshed). In the same situation under a blockchain based land registry, a false claimant would have no way to claim ownership since they would not be able to produce the cryptographic key. What is more, there are ways to store cryptographic keys in digital wallets that can be accessed with a variety of authentication methods. Perhaps the Aadhaar unique identification number in India would be a way for people without internet access to prove their identity, and therefore ownership of their digital wallet, biometrically at the land administration office.

The scenario described above heightens the need for strong network security to ensure that keys are not stolen in a hacking attack. This concern has the most merit out of all of their concerns. If 51% of a public blockchain network's miners and nodes reach consensus about some data point, then that data is secured into the blockchain as truth (Nakamoto, 2009). Therefore in a public blockchain, if one group can amass 51% of the miners and nodes to initiate some nefarious transaction, then the system has been compromised. While it is extremely unlikely that one group could do this since it is in the interest of the other blockchain miners and nodes to maintain a truthful ledger, it is possible. Most blockchain pilots have been conducted on hybrid or private blockchain networks rather than the public sort. The Hedera platform retains the benefits of a public blockchain but has the security of a private blockchain since it is overseen by a distributed council of respected intermediaries. The best analogy I can think of for this is that it is like the difference between direct democracy and the representative sort. Direct democracy is like a normal public blockchain in that it is prone to populism and demagoguery, while representative democracy retains many of the benefits of direct democracy but with more stability.

The last issue that will be addressed from the literature in the “never blockchain” camp is the argument that data accumulation makes blockchain too cumbersome to be used in land registries. It is true that blockchains steadily accumulate data since all of the data must remain as a whole rather than transmission of the limited, pertinent data in a transaction (Barbieri and Gassen, 2017). However, the Bitcoin network is continuing to operate with a quarter of a million transactions per day at time of writing. Most countries experience property transaction numbers in the thousands or hundreds of thousands at most and blockchain technology has quickly overcome the transaction speed limitations present in early blockchain platforms. Another way to ease this problem is to maintain a blockchain based land registry alongside a centralized database. The blockchain network might contain digital signatures and proof of ownership and hashes of files that are normally found in cadasters like land use plans, deeds, GIS overlays, regulations issued by the courts and any other overlays needed to complete the picture. This is known as storing things off-chain. In other words, the entire GIS overlay does not need to be placed on the blockchain network as that would be an unsustainable amount of data accumulation. The hash of the GIS overlay, though, could be easily placed on the blockchain. That way anyone looking at the overlay could quickly determine if it had been tampered with. If you recall in Chapter 1 of this paper, hashing was discussed in detail. To briefly recap, full copies of all information can be stored off chain with hashes and metadata that are on chain pointing back to the source documents. We can be sure that no one has changed even a comma, or GIS data, in these documents because if something even as small as a comma or a single digit were changed, the hash would change dramatically (see Figures 1 and 2).

In the following chapter, the technical challenges to blockchain for land administration will be examined in more detail along with some variables and indicators that may be helpful for practitioners in the field.

CHAPTER 3

OVERCOMING THE TECHNICAL OBSTACLES TO A BLOCKCHAIN REGISTRY

Methodology

This research is interdisciplinary in nature as it pulls from political science, technology, and business. For this reason, various research methods are employed to tackle the research question including; a survey, qualitative interviews, analysis of public policy guidelines, factor modeling, and elementary design science research.

The research is intended to help both practitioners and public policy experts better craft pilots and products for implementation as these efforts are almost always partnerships between the public and private sector. There are distinct limits to the applicability of this research as each jurisdiction is unique and there are numerous political and technical variables to consider. By focusing on political and technical obstacles to implementation, this research can serve as a jumping off point for future quantitative research that attempts to control for specific variables. The data for a purely quantitative study is not publicly available and, even if it were available, it would be deficient in sample size.

A variety of technical reason have been posited as to why blockchains will never be suitable for the public sector and specifically for blockchain land registries including: “hardforks, the immutability of the ledger, pseudonymity of transactions, exposure of personal data, the scalability of the technology and price volatility” (Konashevych, 2020). Another obstacle that straddles the technical and political space is that only a third of countries have fully digitized land registries (Currier, 2020). As mentioned previously in the literature review, academics such as Barbieri and Gassen (2017), Androulaki et al. (2013) and, to a lesser extent, Vos (2017) and Lemieux (2016) have concerns about blockchain's technical capacity for land registries. Vos and Lemieux, as suggested in the literature review, are more in the "not yet" camp, but they wrote on the topic several years ago which is quite a long time in the world of technological innovation. This chapter will cover the objects of the authors listed above, and will argue that, relative to the political obstacles, the technical obstacles to implementation can be easily overcome with proper design and the right technology partners. Furthermore, this chapter will discuss the survey that the author conducted of land professionals. Granted, technical obstacles such as hardforks and data pseudonymity are overcome by using technology stacks that require tradeoffs. In other words, the Bitcoin blockchain, the original public, permissionless chain, is hampered by all of the limitations listed above, but achieves the greatest level of decentralization, accountability, and transparency. As the technology stack is changed to avoid the limitations of a purely public/permissionless chain, the benefits of a blockchain system begin to diminish in a more or less linear fashion. Creative combinations of public blockchains, digital identity solutions, and some tradeoffs provide policy makers with an array of options for their technology solutions. These combinations will be discussed more later, but first we must define the technical limitations listed above.

Public, permissionless blockchains like Bitcoin and Ethereum use proof of work consensus mechanism that require a great deal of energy and necessitate limited numbers of transactions per second.[1] At the time of writing, the Bitcoin blockchain sees about seven

[1] Ethereum 2.0 will use proof of stake which will solve some of the scaling problems.

transactions per second (TPS), most of which are pure crypto transfer transactions. Bitcoin can be thought of as digital gold in that it is a store of value with intentionally limited possibilities for applications to be built on it. Despite the existence of layer two solutions to the slow TPS issues such as the Lightning Network that use "bidirectional payment channels without delegating custody of funds" (Popper, 2017), the vast majority of governments have steered clear of utilizing the Bitcoin blockchain for their land registry pilots. The transaction speed is one issue but, more importantly, governments do not trust the Bitcoin blockchain given the bitcoin community's ethos of avoiding government censorship and oversight. What appears to be a technical barrier, slow transaction speeds, is more of a political barrier meaning that governments have preconceived distrust of bitcoin due to media narratives and other biases.

Hard forks create another technical barrier to public, permissionless chains. Public blockchains like Bitcoin and Ethereum have "forked" in the past. In short, a fork occurs when some developers and users disagree about the best way to handle a controversial event. Because these chains are distributed without a central authority, there is no way to compel all of the developers and users to say install an updated version of the protocol or roll back transactions due to a hack. This is problematic for land registries because it could mean that, in the very unlikely event of a hard fork, there could exists two separate version of the registry. One would be on the original chain and the other on the forked chain. While this is uncommon and can be mitigated, it creates yet another barrier for public permissionless chains to be used in land administration.

While IT infrastructure and tech stack redevelopment budgets may seem technical in nature, these will be discussed in the political obstacles as it is the political will to stomach these costs that generates the barrier.

There are three primary ways, none of which are mutually exclusive, that technologists and land registry professionals have sought to overcome the aforementioned technical challenges. The first is utilizing private blockchains, the second is what many call the hybrid approach, and the third is utilizing hashing, a component of blockchain, to increase registry integrity.

Many pilot programs, observing the technical challenges with public blockchains, opted to utilize private, permissioned blockchains instead. Permissioned blockchains are distributed but have a central administrator that acts as the gatekeeper for the users of various applications on the chain. While this arrangement abrogates the need for a proof of work consensus mechanism, it is not as transparent or secure. There are distinct advantages for governments though. On private blockchains governments, accustomed to setting the rules, are able to fashion the network in a way that is suitable for them. They can set parameters around who can utilize the system and they retain the ability to edit transactions albeit in full view of the other nodes. Private blockchains are popular for pilot programs but rarely does one see a pilot move to full scale implementation. Conversations with practitioners at firms like ChromaWay and Medici Land Governance confirmed that despite the technical advantages, private blockchains are unable to deliver on the ethos and hype surrounding blockchain transparency, security, and immutability. In short, the very reason that private blockchains are more attractive to governments makes them unable to live up to the promise of the technology. Ironically, the private blockchain land administration systems offer few advantages over traditional land administration software making the costs difficult to justify. The functionality of private blockchains can be bolstered by interoperability with public chains but this is not yet common.

The hybrid approach took off in 2020 when it was clear that the majority of pilot programs were not moving towards full scale implementation. Rohan Bennet, Todd Miller, Mark Pickering and Al-Karim Kara coined the phrase "hybrid approach" in relation to blockchain for land administration in their article *Hybrid Approaches for Smart Contracts in Land Administration: Lessons from Three Blockchain Proofs-of-Concept* published in Land in 2021. It is the opinion of this author that their paper, or at least their lessons learned, will become a seminal work in this burgeoning subfield of land administration research. Their chief insight is that "a hybrid solution that mixes smart contract use with existing technology infrastructure – enabling preservation of the role of a land registry agency" is the best solution for overcoming objections from various stakeholders (Bennett, 2021, p. 1). This approach allows for blockchain and smart contracts to be inserted in the portion of the land transfer process in which it can generate the most value for stakeholders and eschews systemwide transformations.

One of the more salient technical concerns is related to the digitization of land administration records. Just over a third of countries have fully digitized land records (Shang and Price, 2018). However, in the survey discussed below 87% of respondents stated that more than half of their land records are digitized. While close to one third of all countries have a fully digitized land administration system, the majority have made significant progress towards digitizing their land records and the percentage is sure to grow each year.

The Survey

The survey, which collected responses from land registry professional across the world, was conducted in 2020 in partnership with the International Association for Trusted Blockchain Applications (INATBA). Respondents were concentrated in Europe were INATBA has a strong base of member organizations but they included respondents from Central Asia, South Asia, and Latin America. There was not a discernable pattern between those who responded to the survey and those who did not. Respondents came from a geographically diverse subset of the total and the respondents came from countries of varying wealth and economic development. Respondents hailed from regions ranging from central Europe to Latin America and countries ranging from Australia to India. Despite efforts to expand the number of respondents, only fifteen land registry professionals responded to the survey out of an initial group of sixty. While the number of respondents was low, the information gleaned still assists in the elucidation of the state of blockchain based land registry efforts. The respondents were fairly well geographically distributed and about a third came from low-income countries, a third from middle income countries and a third from high income countries. A snapshot of the results can be seen on Table 1. Respondents were asked about the various obstacles to the adoption of a blockchain based land registry with the option to select neither, technical, political, or both. There were fifteen total respondents to the survey but not all of them answered the technical and political obstacles questions.

Table 1. Technical vs. Political Obstacles

	Foresaw Technical Obstacles	Foresaw Political Obstacles
Low Income N=3	66%	100%

Middle Income N=3	66%	33%
High Income N=2	0%	100%

While the number of respondents is insufficient to draw conclusions in isolation, this information combined with the case studies of the various pilot programs across the developed and developing world provides valuable insight. 77% of respondents stated that they were familiar with blockchain technology. When asked about the obstacles to adopting blockchain in their land administration office, the technical obstacles were selected by 44% of respondents while the political obstacles were cited by 78% of respondents. The number is greater than 100% since respondents were permitted to select more than one and some selected both. It is interesting that the respondents from high income countries felt that there would be no technical obstacles to establishing a blockchain land registry but that the legal and political obstacles would be formidable. It is possible that, given the larger budgets in high income countries, the technical obstacles would present less of a challenge since a land office could secure services from outside technology firms that may be unavailable to land offices in low-income countries. When asked, who would most likely oppose a blockchain land registry, one of the respondents from India thought it would be “Politicians and bureaucrats [since] this is one area where corruption exists and blockchains will remove middlemen. Middlemen are created by politicians in the system to bring back money to their table. Blockchains will eradicate and can remove redundancy and duplication of data. land records are forged sometimes for political gains. So, advocating [for] this will be a challenge.”

Another interesting factor is that the survey respondents are all civil servants or politically appointed land administration officials. Bureaucratic officials are not know for innovation. In fact, research has found that "public managers working in politicized administrations and those whose education includes a law degree exhibit lower pro-innovation attitudes" (Lapuente and Suzuki, 2020). Interestingly, land administration offices are often filled with people with law degrees. These survey respondents are not prone to innovation so a blockchain based land registry is likely to be more feasible than is estimated by civil servants who are unlikely to have incentives to innovate. Public sector innovation tends to lag private sector innovation. Blackrock and JP Morgan Chase are already tokenizing money market funds using blockchain and several commercial buildings have been tokenized using blockchain. Of course, the ownership is tokenized through an LLC where the token holders all hold a percentage of the LLC equity. For example, if there are one thousand tokens that make up the cap table of the LLC that owns a building, someone who owns ten tokens would own 1% of the building. In fact, Larry Fink, the CEO of Blackrock, the largest asset manager in the world is on the record saying, "I really do believe this is where we're going to be going. We have the technology to tokenize today." The private sector does not need the public sector to move forward with blockchain technology. The profit incentive drives the private sector to innovate more quickly than the public sector. This is further evidence that the technical obstacles are not the main issue preventing land administration offices from adopting blockchain technology.

This research was also informed by firsthand interviews with professionals working in blockchain for land administration. The interviewees were selected based on their involvement in pilot projects. Examples of interviewees include people in positions such as Director of Business

Development at Medici Land Governance and Vice President of Operations at Chromaway. The qualitative type for these interviews was unstructured due to the fact that these interviews were conducted both virtually, and in an ad hoc manner at conferences. The method was a combination of observation and focus groups. The focus group contained mid-level managers at many of the technology implementation partners for the pilot programs.

The technical obstacles to establishing a blockchain land registry are insignificant when compared to the political and entrenched interest obstacles. In Chapter 4, brief summaries of various pilot programs from both the developing and developed world will be presented. These studies further confirm the theory that incumbent firms and elected officials would rather publicly site technical obstacles to the adoption of a blockchain based land system rather than reveal their true motivations.

An Index of Suitability for Blockchain in Land Administration

In an effort to apply data analysis to the question of which countries possess an environment conducive to the implementation of a blockchain land registry, the following index was developed. The index measures variables from one hundred and ninety countries using multiple data sources for the most recent year available across all sources. The data comes from the World Bank's Doing Business Survey and a variety of other World Bank development indicators. The following factors were included in the analysis: the percentage of the population that has access to the internet, per capita GDP, rule of law, quality of land administration, and the registration of property transparency rankings. Access to the internet was included as digital literacy and internet access are prerequisites for a successful implementation of a blockchain based land registry. The component was defined by the World Bank as “Internet users are individuals who have used the Internet (from any location) in the last 3 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.” Per capita GDP provides an indicator as to the public sector budgets that may be available for digital transformation. One would expect that countries with low per capita GDP are less likely to have sufficient resources to innovate in this way, but there are more pilots in the developing world than in the developed. The rule of law index was included for multiple reasons. Countries with high degrees of trust are more likely to successfully implement a digital transformation project, especially one that deals with ledgers of asset ownership and strong rule of law is a good indicator of high trust societies. Furthermore, rule of law as an indicator provides a decent sense of stability within a nation. Multi-ethnic societies that struggle with conflict tend to score low on rule of law analyses. One does observe that smaller, homogenous nations are overrepresented at the top of the index, but the countries represented in the pilots from across the world are not necessarily skewed towards small homogenous nations.

The two most direct indicators are quality of land administration and registration of property transparency rankings. These indicators get right at the heart of the question of conduciveness for blockchain land administration, so they were both given a double weight in the formula that determined the final ranking. The quality of land administration index is itself “composed of five other indices: the reliability of infrastructure, transparency of information, geographic coverage, land dispute resolution, and equal access to property rights. Data are collected for each economy’s largest business city (World Bank, N.D.).” The property transparency rankings are gauging the time and cost associated with purchasing land and the ability for people in a given jurisdiction to find the information about property ownership that would be required for such activities.

Each indicator was transformed into a score out of one hundred. For internet usage that figure was already a percentage out of one hundred. GDP per capita was transformed into a percentile thereby slightly diminishing the outliers at the top and bottom of the bell curve and diluting GDP per capita slightly in general since it is one of the broader and weaker indicators. Ther other indicators were accordingly transformed into a score out of one hundred. The five indicators were then summed with the land administration and transparency numbers multiplied by two to provide the proper weighting. The corresponding figure was divided by seven, since the weighting of the two more important indicators necessitated division by seven rather than five. The resulting numbers were then between zero and one hundred with the countries scoring closer to one hundred possessing an environment more conducive to a blockchain land registry.

As can be seen in Table 2, the countries at the top of the list shared certain unique characteristics. The most obvious similarity is that these are all wealthy, developed countries. All five indicators are to some extent improved by high levels of development. The less obvious similarities include countries that are geographically small, relatively homogeneous (possibly with the exception of the UK), generally free from intrastate ethnic conflict. Russia at 25th was the first large country to appear in the ranking with France, 31st, and Canada, 32nd, the next two large countries in the ranking.

From a theoretical perspective, it is logical that smaller, more homogenous countries have higher transparency and land administration scores and generally would be conducive to a digital transformation project such as a blockchain land registry.

Table 2. Top Ten Index

Rank	Country Name	Score
1	Singapore	92.67166216
2	Netherlands	90.6432682
3	Hong Kong SAR	90.44361533
4	Luxembourg	82.85396826
5	United Kingdom	82.85067488
6	Ireland	79.92313709
7	Sweden	79.68477727
8	Iceland	78.44900562
9	New Zealand	75.10366063
10	Korea, Rep.	73.46468777

There are some interesting outliers where development did not overcome the land administration and transparency figures. The United States ranked 45th and Germany 40th. On the other end of the spectrum, there were a few countries that are less developed, with lower per-capita GDPs that managed to score higher than might be expected. For example, Malaysia landed at 25th, the Ivory Coast at 54th, and Peru at 62nd.

The bottom ten countries in the index are not surprising with Niger, Liberia, Guinea Bissau, Haiti, Sudan, Somalia, Eritrea, South Sudan, Burundi, and Central African Republic ranking at the bottom. The data analysis can be found on this spreadsheet (Merged Data For Index - Bratcher Dissertation.xlsx).

Table 3. Bottom Ten Index

Rank	Country Name	Score

10	Niger	18.390
9	Liberia	14.849
8	Guinea-Bissau	14.638
7	Haiti	14.658
6	Sudan	14.106
5	Somalia	10.9
4	Eritrea	8.715
3	South Sudan	6.023
2	Burundi	5.492
1	Central African Republic	4.863

* rank 1 is the lowest ranking country

Building on the index, a factor analysis of the variables was conducted in order to understand which variables most impacted a country's predisposition for adopting a blockchain land registry. This factor analysis was necessary due to the potential correlation between the variables in the index. It also provided some additional insights that was not readily apparent in the strict index. This analysis (see Table 4) demonstrated that the percentage of internet penetration was the most impactful variable while the transparency of land administration variable was the least impactful. It is logical that internet penetration is the most impactful variable because a digitally connected society is more likely to have the tools and education to utilize digitally based services like a blockchain based land administration system. The transparency in land administration variable was the least impactful. On one hand, this could be expected since transparency of a country's current land administration system is not necessarily indicative of how successful a blockchain application would be in that context. On the other hand, one might expect the transparency of land administration component to have an outsized impact given how correlated it is with the topic at hand. It does provide a glimpse into the need for a system that provides greater transparency for those countries that currently lack it but the variable's ability to predict the ease with which a registry would be adopted is surprisingly not particularly strong. Another potential reason for the weakness of the impact of the transparency of land administration component is the qualitative nature of the data. Internet penetration percentages and GDP per capita figures lend themselves to more precise measurements.

Table 4. Principal Components

Principal Components (eigenvectors)		
Variable	Compl	Unexplained
Internet Penetration	0.504	0.18
Rule of Law Score	0.481	0.254
GDP Per Capita Percentile	0.393	0.502
Quality of Land Admin Index	0.482	0.25
Transparency of Info Index	0.357	0.589

The eigenvector Component 1 score explains 65% of the correlation with the Ease of Blockchain Factor Analysis. The Ease of Blockchain variable describes a country's predisposition or structural disadvantages or advantages when it comes to the adoption of a blockchain based land administration system. The phrase Ease of Blockchain will be used to describe this variable moving forward.

Table 5. Correlation Analysis

Correlation Analysis		
Principal components/correlation	Number of observations	190
	Number of components	1
Rotation: (unrotated = principal)	Trace	5

		Rho	0.645	
Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	3.225	2.237	0.645	0.645
Component 2	0.988	0.62	0.298	0.843
Component 3	0.368	0.124	0.074	0.916
Component 4	0.245	0.07	0.049	0.965
Component 5	0.174	.	0.035	1

After establishing the Ease of Blockchain Factor Analysis variable regression scoring was used to generate scores in which -3.829572 was the lowest score and 3.522742 was the highest score with the mean being zero (see Table 6).

Table 6. Variable Regression Scoring

Scores for Component 1				
	Percentiles	Smallest		
1%	-3.821	-3.83		
5%	-2.753	-3.821	Observations	190
10%	-2.396	-3.784	Sum of Weight	190
25%	-1.45	-3.538		
			Mean	-4.85E-10
50%	0.051		Std. Deviation	1.796
		Largest		
75%	1.365	3.298	Variance	3.225
90%	2.450	3.445	Skewness	-0.063
95%	2.753	3.492	Kurtosis	2.078
99%	3.492	3.523		

The following tables demonstrate the ranking of the top ten and bottom ten nations based on their Ease of Blockchain Factor Analysis Score.

Table 7. The Bottom 10 Countries in the Ease of Blockchain Factor Analysis

Country Name	Score
Central African Republic	-3.83

Burundi	-3.821
South Sudan	-3.783
Eritrea	-3.538
Somalia	-3.321
Guinea-Bissau	-3.027
Liberia	-2.986
Sudan	-2.909
Mozambique	-2.824
Chad	-2.753

Table 8. The Top 10 Countries in the Ease of Blockchain Factor Analysis

Country Name	Score
Ireland	2.753
Denmark	2.753
Korea, Rep.	2.756
Sweden	2.795
Luxembourg	2.995
Iceland	3.04
United Kingdom	3.3
Hong Kong SAR, China	3.445
Netherlands	3.492
Singapore	3.523

It is interesting to note the divergences, albeit modest, between the Factor Analysis rankings and the index rankings. Haiti shows up on the index as the 7^{th} worst location whereas it did not make the top ten worst scoring on the Ease of Blockchain Factor Analysis. Conversely, Mozambique appears on the bottom ten for the Ease of Blockchain Factor Analysis but is replaced by Niger on the index. The internet penetration rate for Niger is slightly higher than in Mozambique so that could explain the change given that the internet penetration rate explains a majority of the correlation for the Ease of Blockchain Factor Analysis. Haiti has an internet penetration rate double that of Mozambique which may explain why it would be one of the worst on the Index but not make the bottom 10 on the Ease of Blockchain Factor Analysis.

For the countries at the top of both the index and Ease of Blockchain Factor Analysis, it is interesting to note that the island nations and micro-states score slightly higher on index. Geography and the increased likelihood of homogeneity amongst the populations of micro-state like Singapore and Luxembourg seem to play a role here. High GDP per capita is also a shared trait amongst the top countries in both the index and factor analysis with the United Kingdom and South Korea being the only examples of countries that are not in the top 25 countries for GDP per capita but still made the top 10 in the index.

In summary, the index and factor analysis brings several interesting learnings about the factors influencing the ease of blockchain based land administration to the surface. Examples include the importance of internet penetration, the interesting role of country size and homogeneity, and finally, the likelihood of countries using the Torrens system to appear higher on the index and factor analysis. The Torrens system was developed by Sir Robert Torrens, the Registrar General in Australia when it was a colony of the England. The Torrens system differs from the Deeds system in that, in the former, the registry of land ownership is updated with each transactions while in the latter, all instruments and documents related to the land are compiled and must be reviewed to determine legal facts about the land in question. The Torrens systems is now used in Australia, Canada, the United Kingdom, Ireland, Israel, Singapore, and the United States.

Chapter 3 provides both a unique index and data driven examination of a country's suitability for blockchain land administration and a thorough rebuttal of the prior academic research that contended that blockchains were technically insufficient instruments for use in land administration. It is likely that nations that are most suitable for an implementation of blockchain for land administration are the least likely to be in need of that kind of transparency, but it is also true that nations on the top of the list stand to gain commercially from the prospect of such a program. Conversely, nations on the bottom of the index are not fertile soil for blockchain in land administration, but they stand to benefit tremendously from the transparency that such a system might provide. Chapter 4 examines the political challenges for implementation of blockchain for land administration which is where the crux of the challenge lies.

CHAPTER 4

OVERCOMING THE POLITICAL OBSTACLES TO A BLOCKCHAIN REGISTRY

There have been many blockchain land registry pilot programs across the developing and developed world. The initial pages of Chapter 4 are dedicated to a brief overview of the majority of those pilot programs. This overview is followed by a discussion of the theoretical explanations for the differences between developed and developing world pilot programs. The tables below provide a quick reference guide for the various pilot programs in the developing and developed world. The first column contains the country name (and state if more than one pilot took place in that country). The second column is the name of the technology provider that was enlisted for the pilot. The third column provides a brief description of the results of the pilot and obstacles encountered. The fourth and final column shows the results of the Ease of Blockchain Factor Analysis Score. It is interesting to note that none of the pilots cited technical concerns as it relates to the failure of any of these efforts.

The technology partners range from established Fortune 500 companies to small startups. The primary reason that many of these companies are small startups is that most developing nations are not in a position to pay large consulting firm prices for a pilot program of this nature. It is common practice for a startup to provide near free services for a pilot program in order to receive press coverage and be in the running for larger implementations in the future. Factom, Bitfury, Chromaway, Medici, and Propy are all similar in that they are blockchain startups that received venture capital funding in the mid-2010s to work on enterprise blockchain applications. Chromaway has their roots in Sweden while Propy, Medici, and Factor are U.S. based. IBM is certainly an outlier here but they did have a substantial blockchain practice for many years.

BenBen, Peersyst, and Seso are local startups with little public information known about them.

Table 9. Developing Country Blockchain Land Registry Pilots

Country	Company Contracted for Pilot	Major Obstacles	Ease of Blockchain Factor Analysis Percentile
Honduras	Factom	Political and business resistance	-1.26; 29th percentile
Georgia	Bitfury	Political resistance, conflict with Russia	1.19; 79th percentile
India	Chromaway	Delayed by the pandemic	-0.76; 40th percentile
Zambia	Medici Land Governance	Project "in progress" Few details available	-2.39; 10th percentile
Brazil	Ubiquity	Political resistance and cost concerns	1.05; 70th percentile
Ghana	IBM and BenBen	Moderately successful pilot	-0.74; 41st percentile
Rwanda	Medici Land Governance	Moderately successful pilot	0.02; 51st percentile
Bolivia	Chromaway	Moderately successful pilot	-1.27; 28th percentile
Peru	Chromaway	Moderately successful pilot	0.29; 60th percentile
Paraguay	Chromaway	Moderately successful pilot	-0.76; 42nd percentile
Liberia	Medici Land Governance	Political and funding obstacles	-2.99; 4th percentile
Colombia	Peersyst (Spanish)	Still underway as of 2022	0.46; 65th percentile
South Africa	Seso Global (Nigerian Company)	Political and funding obstacles	0.20; 59th percentile
Nigeria	Seso Global (Nigerian Company)	Political and funding obstacles	-1.85; 22nd percentile
Kenya	No technology partners named	Unknown results	-1.13; 31st percentile

Table 10. Developed Countries Blockchain Land Registry Pilots

Country	Company Contracted for Pilot	Major Obstacles	Ease of Blockchain Factor Analysis Percentile

Sweden	Chromaway	Moderately successful pilot	2.79; 96th percentile
United States, WY	Medici Land	Political and funding obstacles	2.04; 85th percentile
United States, VT	Propy	Political and funding obstacles	2.04; 85th percentile
United States, IL	No technology partner named	Moderately successful pilot	2.04; 85th percentile
Ukraine	Propy	Derailed by conflict	-0.36; 38th percentile
Russia	No technology partners named	Derailed by conflict	1.31; 74th percentile
Netherlands	No technology partners named	Unknown results	3.491997 99th percentile
Japan	Propy	Unknown results	2.54; 91st percentile
Bermuda	Landfolio	Political and funding obstacles	Not available
Australia	ChromaWay	Moderately successful pilot	2.31; 88th percentile
Canada	ChromaWay	Political and funding obstacles	2.35; 89th percentile

The Case of Honduras

One of the earliest blockchain land registry pilot programs kicked off in Honduras in 2015. Honduras scored a -1.26 and was in the 29th percentile on the Ease of Blockchain Factor Analysis. This score positions Honduras, with its low internet penetration rate and rule of law scores as a country that is not predisposed to have a successful implantation of a blockchain land registry pilot. Factom, a Texas based blockchain company, announced that the blockchain land registry pilot would “allow for more secure mortgages, contracts, and mineral rights” and decrease opportunities for corruption (Chavez-Dreyfuss, 2015). The project stalled as soon as it began with the Honduran government essentially refusing to comment to the press. Paul Snow, the Founder of Factom told reporters that the project stalled for "political reasons" (CoinDesk, 2015). Your author called Factom in 2018 to ask for more details about the difficulties of the pilot program and he was told that certain elements within the Honduran government, when made aware of the project, asked that it be discontinued. One could be forgiven for thinking that various "veto players" (Tsebelis, 2002) in the real-estate industry put pressure on their counterparts in the Honduran government when they realized that such a system with radical transparency and accountability would limit their profit margins.

The Case of Georgia

The next major pilot took place in the Republic of Georgia also in 2016. Georgia scored a 1.19 and was in the 79th percentile on the Ease of Blockchain Factor Analysis. Georgia is a small, somewhat homogenous country with high internet penetration which all bode well at first glance. Russian military aggression ranges from a menacing to existential threat which is an external factor simultaneously working for and against a successful pilot. Many former Soviet states have turned to blockchain to secure voting and other government functions with the Baltic States being the best example of that. On the other hand, Russia's destabilizing effect can create urgent priorities potentially stifling research and development on a variety of non-essential fronts including land administration. Land administration in Georgia previously straddled two departments both with opaque systems which led to rampant corruption (Shang, n.d.). In 2004 the government replaced these two entities with the National Agency of Public Registry which quickly turned the registry system into a world class operation. By the time of the pilot, the World Bank recognized Georgia as 3rd out of 189 countries in ease of property registration (World Bank, 2016). In mid-2016, Bitfury, an Amsterdam based bitcoin mining company, signed an agreement for a one-year pilot with the Georgian government to provide the technology stack and implementation of a blockchain land registry. Bitfury then set out to create a blockchain based “time stamping laying on top of the NAPRs existing land registry system” (Shang, n.d.). During a webinar that your author attended, former Georgian land registry officials commented that, in addition to efficiency and transparency benefits, the Georgian land registry system would be more secure against cyber-attacks. It is not a stretch to surmise that this official was referring to Russian destabilization tactics of which land registry and other public registry systems are often targets. Academics at the New America think tank surmised that the project was a success due to an educated land administration bureaucracy and the quality data obtained years beforehand as a result of institutional and political reforms (Shang, n.d.). The political pressure for transparency and clean government heaped on President Saakashvili likely contributed along with the geopolitical tensions with their neighbor to the north.

The Case of India

India is an interesting jurisdiction for blockchain land registry pilots and policy experimentation based on the history of land reform in the various Indian states. India scored a lower than expected -0.76 and was in the 40th percentile on the Ease of Blockchain Factor Analysis. India is like China in that it is a large multi-ethnic nation with swaths of impoverished regions and cities mixed in with pockets of wealth and development making it a challenging jurisdiction for a successful pilot. However, the pilot took place in the state of Andhra Pradesh which is more homogenous and has a higher GDP per capita than the average Indian state. As alluded to in the literature review, India offers a natural experiment in which certain states have traditionally administered land by allowing private property rights and some have more communal or traditional land administration legacies. What is more, approximately 40% of all litigation in India civil courts relates to “illegal encroachments and title disputes” (Thakur, 2020). Whereas Georgia ranked 3rd out of 189 countries in the World Bank study of ease of property registration, India ranked 154th (World Bank, 2016). This is likely due to the heterogeneity of Indian systems across various states and jurisdictions. While several Indian states are piloting blockchain based land registry systems, Andhra Pradesh’s partnership with Chromaway is the most notable. In late 2017, the government of Andhra Pradesh inked a deal with the Swedish blockchain real estate company, Chromaway. The government of Andhra Pradesh estimated that 70% of civil court cases relate to land disputes, much higher than the country average. Deputy Chief Minister Pilli Chandra Bose stated that “At present, everyone, right from the data entry operator, is changing land records, which ultimately lead to land disputes. But once getting purification of land records and implementing the blockchain technology, it will be impossible to tamper” (The New Indian Express, 2019). The Deputy Chief Minister also commented that anytime a land record is changed, the landowner will receive a text message notifying them of the change and asking if the change is warranted. There are several open source articles that reference the use of a private blockchain in the Andhra Pradesh pilot, but details about the technology stack are scarce. The purification of land records was to be complete by May of 2020 but it remains unknown if this process was delayed by the Covid-19 pandemic.

The Case of Zambia

Zambia has incredibly low levels of participation in the country’s formal land registry. In fact, over 80% of real estate in Zambia is not registered with the Ministry of Land and Natural

Resources (Tembo, 2016). Technically, all land in Zambia belongs to the state and the authority over it is delegated to the more than 200 traditional chiefs in a customary land tenure arrangement (Huth, 2017). Zambia scored a -2.39 and was in the 10th percentile on the Ease of Blockchain Factor Analysis. Zambia is not a homogeneous nation, there are more than fifty tribes in the country, but it is relatively conflict free and stable especially compared to its neighbors. Developing a comprehensive blockchain based land title system in Zambia was always going to be a tall order.

In 2014, the government kicked off a National Land Titling Program with a focus on private property rights. In the fall of 2018, Medici Land Governance, signed a memorandum of understanding with the Lusaka City Council to deliver "250,000 certificates of title related to real property" (Overstock.com, 2019).

The Zambian case highlights an important issue with blockchain land registry pilots in the developing world. Privatizing communally held land is a treacherous endeavor. Some of the pilot programs, in India and Zambia specifically, encountered problems with corruption on the data entry side (Currier, 2020). In the process of cleaning up land records, elites and unscrupulous actors paid bribes to data entry clerks to change the title in their favor. While the technology provides an immutable ledger, garbage data on the front-end risks entrenching corruption further. Thankfully, the Zambian pilot focused on urban residential property where private property rights are already well understood and expected. The Oakland Institute classifies the Zambian pilot as a "large scale project in-progress," but details are hard to come by. The author's contacts at Medici Land Governance could not be reached for comment on the progress of the pilot.

The Case of Brazil

Brazil scored a 1.05 and was in the 70th percentile on the Ease of Blockchain Factor Analysis. Brazil's modest internet penetration rate of 73% is pulled down by rural communities in the hinterland which were not the focus of the pilot.

Brazil is another instructive example of a moderately successful pilot program that failed to profess to full scale implementation. In 2017, Ubiquity, a US based blockchain firm, entered into a services agreement with the Real Estate Registry Office of Brazil. Ubiquity uses a SaaS model and they hoped to license their blockchain based land registry software to other cities and municipalities throughout Brazil. A reporter at ABC Money claimed that the full-scale implementation was "halted because of opposition from the officials who would be displaced, and the costs associated with implementation" (Preece, 2018). While the source that inspired that quote was not listed, the sentiment aligns with most other pilots that failed to be extended to full scale implementation. It is interesting to note that a reporter was made aware, through a source that he deemed to be legitimate, that the displacement of legacy land administration officials was one of the main reasons that the pilot failed to progress. This is yet another example that the politics of various veto players, and silent veto players, are an underappreciated obstacle.

The Case of Ghana

As in much of Sub-Saharan Africa, 80% of Ghana's land is not formerly recorded (Mwanza & Wilkins, 2018). Ghana scored a -0.74 and was in the 41st percentile on the Ease of Blockchain Factor Analysis. Ghana is relatively more prosperous than many of its neighbors in the region but struggles with a minor north-south ethnic conflict. Despite this, it is well placed amongst its peers to see a successful implementation of a blockchain based land registry nationwide.

In 2018, the Ghanaian Ministry of Land and Natural Resources signed a memorandum of understanding with IBM to conduct a land registry pilot. Over the past fifteen years, Ghana has been working to improve private property rights in three stages; institutional land tenure reforms, strengthening of “urban and rural land administration and management systems for efficient and transparent land service delivery” (Ghana Web, 2018), and the blockchain land registry partnership with IBM. This data cleanup and institutional reform process was essential to laying a foundation for future innovation. A Ghanaian company called BenBen is also associated with the pilot. BenBen extended the partnership to the Ghana Real Estate Developers Association to develop a pilot for end-to-end housing transactions (BenBen, n.d.). With only 45% internet penetration and lower land administration and transparency scores, Ghana came in at 124th on the Index in Chapter 3. This pilot appears to be one of the more successful in Africa likely because it is part of a broader property rights improvement push by the government and the fact that the pilot is spearheaded by a Ghanaian company.

The Case of Rwanda

Rwanda, despite its tragic recent history, is starting to be known as Africa’s Silicon Valley (Forbes Africa, 2023). It scored a 0.02 and was in the 51st percentile on the Ease of Blockchain Factor Analysis.

The Rwanda Land Management and Use Authority signed a memorandum of understanding with Medici Land Governance (Medici is also working in Zambia) in late 2018. The CEO of Medici Land Governance, Dr. Ali El Husseini, had this to say about the partnership, "We appreciate the clear objectives and strategic road map the Rwandan government has outlined toward economic empowerment. By using our expertise in blockchain, mobile apps, and other technologies, we can help Rwanda fulfill the goals of its major land reform efforts in standardizing land ownership on a digital, secure, user-friendly system that provides equal access for all people in a timely, responsive manner." The Rwandan government plans to develop applications that create a purely paperless land governance system. This pilot is promising because Medici Land Governance specializes in blockchain land registries, and Rwanda has a unique blend of stable politics and effective institutions. Rwanda ranks 37th globally, and only behind Namibia in Sub-Saharan Africa, on the World Justice Project Rule of Law Index. Rwanda also scores just under South Africa and above Botswana on a respect for property rights index. Still another factor that bodes well for blockchain in Rwanda Kigali's growing vibrancy in technology focuses businesses.

The Cases of Bolivia, Peru and Paraguay

Bolivia, Peru and Paraguay are combined here for reasons explained further below but, other than geographic proximity, they have somewhat divergent scores on the index. Bolivia scored a -1.27 and was in the 28th percentile, Peru scored a 0.29 and was in the 60th percentile and Paraguay scored a -0.76 and was in the 42nd percentile on the Ease of Blockchain Factor Analysis.

Chromaway, a Swedish blockchain company, and the Inter-American Development Bank partnered with the land registry offices of Bolivia, Peru and Paraguay to pilot land reforms that included a blockchain based land registry. This project is part of a larger initiative called LACChain, a consortium of public and private institutions and businesses in Latin America seeking to harness blockchain for social good (LACChain Alliance, 2020). This cluster of pilots is interesting because they are funded by the Inter-American Development Bank and they are utilizing a public blockchain platform called Chromia. Chromia was developed by Chromaway but has split off into a separate company. It combines relational database technology with blockchain technology with an easy-to-use programming language called RELL. In contrast to many of the other pilots, “ChomaWay is trying to develop a solution for three different countries, with a focus on sustainable governance and incorporating W3c standards such as Verifiable Claims and Decentralized Identifiers (DIDs)” (Ledger Insights, 2019). This pilot is especially promising as it has the backing of the Inter-American Development Bank and several municipalities in the aforementioned countries.

In 2018, the Bolivian National Agency for Land signed a services agreement with UST Global, a blockchain company based in Spain (Coin Rivet, 2018). This pilot involves uploading hashes of land registry documents to the Ethereum blockchain using the Interplanetary File System (IPFS). As Ethereum is a public blockchain, the hash of the data is the only thing that will be stored on it. The user interface of the land registry will allow those with the appropriate permissions to access sensitive information.

The Case of Columbia

The Colombia government is bankrolling the pilot and President Ivan Duque has explicitly stated that blockchain technology is part of his policy plan for increasing efficiency in government (Coin Rivet, 2018). At 77th out of 128 the Colombian Rule of Law Index score is slightly below average, but the political support behind this pilot makes it promising. Colombia scored a 0.46 and was in the 65th percentile on the Ease of Blockchain Factor Analysis. The land registry system was developed in collaboration with the Spanish blockchain company Peersyst and is aimed at helping the more than “100,000 Colombians who do not have proper documentation of the land they currently inhabit” (CNBCTV 2022). The outcome of this pilot is yet unknown but the change of administration to President Gustavo Petro in 2022 may have derailed it.

The Case of Liberia

With its litany of challenges it is unsurprising that Liberia scored a -2.99 and was in the 4th percentile on the Ease of Blockchain Factor Analysis. The structural facts on the ground make any successful blockchain implementation in Liberia extremely unlikely.

Medici Land Governance is conducting a pro bono pilot in Liberia (Medici, 2019). While not much is known about this pilot, Medici lists one of its goals as knowledge transfer to the Liberian land administration workforce. Liberia ranks 98th out of 128 countries indexed by the World Justice Project. Given that this pilot is pro bono and Liberia’s HDI score of 0.4 indicates more pressing and present challenges, this pilot is unlikely to develop into full scale implementation.

The Case of South Africa and Nigeria

Seso Global, a Nigerian blockchain real estate company, is piloting their platform in Makhaza South Africa and in parts of Nigeria. The South African pilot is unique in that the one thousand properties in the pilot are new government subsidized residential properties that have not yet been entered into the registry (Seso Global, n.d.). For this reason, there is likely to be little to no disagreement about the data to be entered and about the ownership of the properties. To further secure the data capture process, Seso Global spent two months going door to door and collecting data from the residents of the neighborhood. The mobile enabled Seso Global platform integrates with third parties so that mortgages and conveyances can be conducted digitally. South Africa's ranking of 45th on the World Justice Project Rule of Law Index and the unique nature of the pilot makes this one promising. An additional factor to watch is that Seso Global is an African based company run by African entrepreneurs conducting a pilot in Africa. This dynamic may increase the likelihood of the pilot moving to a full-scale implementation since Seso Global has the advantage of greater regional cultural intelligence and lower operating costs. South Africa scored a 0.20 and was in the 59th percentile on the Ease of Blockchain Factor Analysis.

The Case of Kenya

There is little known about the blockchain land registry pilot in Kenya. It was announced in 2020 but no technology partners have been named and it is still in the planning phase according to The Oakland Institute (Currier, 2020). Kenya scored a -1.13 on the Ease of Blockchain Factor Analysis. Kenya is well known for the rapid adoption of mobile banking and other technologies so it likely would hit above its weight when it comes to blockchain adoption.

Summary of Developing Nation Pilot Programs

In the developing world, "the technological product cannot resolve a pre-existing institutional malaise, including lack of transparency, corruption and lacking accountability" (Eder, 2019). Several political and institutional factors are at play that require further study once more data is available. First, the level of government that authorized the pilot gives an indication of the level of internal support. How strong is the commitment to a transparent registry when incumbent firms, certain members of the bureaucracy, and connected politicians lobby for the project to be killed? Institutions and norms are another important factor to consider in any endeavor relating to property rights (Acemoglu & Robinson 2006; North 1973 & 1991; and DeSoto, 2000). The following questions should be considered when searching for a jurisdiction in which to conduct a blockchain land registry pilot: What is the state of the current registry? Is it digitized? Are property boundaries effectively demarcated? Is the land currently governed under traditional law in a communal fashion? Is the land occupied by a homogenous ethnic group? What is the perception of the courts and their ability to handle land disputes? What kind of services agreement has been reached between the technology partner and the government body leading the pilot? Is this a pro bono effort? Is the application to be built on a public or private blockchain (there are political implications here)? What is the form of government in the country in question? How organized and powerful are interest groups that benefit from the current system?

The questions to consider in a developing world pilot are going to be different, or at least the level of emphasis placed on each question will change, than those in the developed world context. Questions around interest groups and political process will increase in importance while questions about customary land practices and rule of law will decrease in importance. The following section summarizes the pilot programs in the developed world. Saint Kitts and Nevis, Mexico, and the Ukraine are technically still developing countries by human development index standards, but because of a semi-respectable history of private property and their proximity to the U.S. or the E.U., they have been included in the developed world section. In other words, these countries are more similar to developed nations like Japan, Australia and the United States than to developing nations like Liberia, Rwanda and Paraguay. The pilots are presented in chronological order from when a public announcement was issued.

Pilot Programs in the Developed World

Blockchain based land administration provides varying benefits in each context but there are some broad observations to be made with regard to the efficiencies seen in the developing and developed worlds. In the developing world, blockchain land administration is more likely to be addressing issues of corruption and rule of law while in the developing world, the common refrain is one of driving business efficiency. The transaction costs of purchasing property vary greatly from country to country but most developed countries have transaction costs between 5% to 15% of the value of the property. Outlier examples include Iceland at around 3% and Belgium at nearly 16% (Global Property Guide, n.d.). With global real estate transaction volume coming in around $3.8 trillion annually in 2022, even a 10% reduction in transaction costs on real estate transaction at the low end of the transaction cost range, say 5% of each property sold that year, indicates a potential market of $19 billion (Markets and Research, 2023). The wholesale elimination of transaction costs in real estate transaction could be worth $190 billion annually. Wholesale elimination of transaction costs is unrealistic in the short and medium term, but there are signs that things are moving that direction. In March of 2024, the National Association of Realtors announced a court settlement that essentially ended the practice of 3% commission for both the buy and seller’s realtor. Those commissions will now be negotiable and set by market forces (Bahney, 2024).

The Case of Sweden

Sweden was the first developed nation to conduct a blockchain land registry pilot and was the first country to digitize land records in the 1970s. The Swedish Lantmäteriet, the land registry authority, actively pursued several technology and banking partners including: Chromaway, SBAB Bank, Landshypotek, consultancy Kairos Future, “real estate search portal Svensk Fastighetsförmedling, telecom Telai Sverige and IT firm Evry” (Kim, 2018). Sweden is well positioned for blockchain innovation in the land administration space with a 2.79 score on the Ease of Blockchain Factor Analysis putting it in the 96th percentile of all countries measured. Sweden is also famous for its homogeneity and efficiency. The pilot was conducted on a private blockchain network, a reasonable choice for a country with trusted institutions like Sweden. In 2017, the Lantmäteriet began conducting blockchain anchored real estate transactions. In conversations with the Lantmäteriet’s Chief Innovation Officer Mats Snall, the author gained the impression that the Swedish pilot was a mixed success. The expected benefits materialized in a slightly diminished form than expected and the obstacles to full-scale implementation did not justify the investment. Further complicating matters, “Swedish law does not allow for the use of electronic signatures for property transactions” (Bennett, 2021, p. 14). Thus far, the political will to allow electronic signatures for property transactions has not materialized. One could speculate that there are entrenched interests whose business model depends on a more manual property transaction process.

The Case of The United States

There are four notable blockchain pilots in the United States that are either ongoing or that have been completed. Medici Land Governance has two pilots in Wyoming. The first in 2018 in Teton County and the second in 2020 in Carbon County. Propy, a California based blockchain real estate firm, has a pilot in South Burlington, Vermont and Cook County (Chicago), Illinois conducted a blockchain land registry pilot internally with the county clerk and the land registry office. The United States is moderately well positioned for blockchain innovation in the land administration space with a 2.04 score on the Ease of Blockchain Factor Analysis putting it in the 85^{th} percentile of all countries measured. In my own experience working on this issue in the United States, particularly in States like Texas, there are powerful incumbents that are not incentivized to innovate. I recall a meeting on the topic of a blockchain land registry pilot in which the county clerk included several title companies in the meeting. It was implicitly clear that any pilot program would need the approval of several incumbent players such as title companies. Needless to say, this pilot program was not approved.

The Teton County pilot was the first of its kind in the United States. Medici built the land registry application on the Open Index Protocol using the Flo Blockchain. The Flo blockchain uses the Bitcoin source code and is a public chain. The Teton County Clerk indicated that the information that is currently available to the public is the same amount of information that will be available on the new blockchain enabled registry (Baydakova, 2018). In other words, there will not be sensitive information or PII, at no more than is visible on the current system, floating around on the blockchain for all to see. The pilot programs in Wyoming have overwhelming political support in the Wyoming State House but it is unknown what kind of opposition exists at the local level or among title companies. Not only does the County Clerk support it, but the Governor of Wyoming and a Wyoming Senator actively advocated for this collaboration. The Wyoming State Legislature has passed thirteen bills clarifying regulatory guidance around blockchain and cryptocurrency and paving the way for cryptocurrency banks. Kaken, a cryptocurrency exchange, and Avanti Bank both received banking charters from Wyoming in 2020 (Boot, 2020). Furthermore, in November of 2020, Wyoming elected the first U.S. Senator who openly owns cryptocurrency. Senator Cynthia Loomis is a proponent of the technology and the first woman to be elected to the U.S. Senate from Wyoming.

The Teton County pilot is complete, and a full-scale implementation is in progress. Carbon County Wyoming signed a memorandum of understanding with Medici in April of 2020. The commissioning of a second pilot in a neighboring county bodes well for the future of blockchain land registries in Wyoming.

Propy's South Burlington, Vermont pilot begin in early 2019 with the support of Vermont's Governor Phil Scott and his staff (Propy, 2019). Although not to the level of Wyoming, Vermont's Legislature is supportive of blockchain technology and passed legislation in the 2018 session that mandated the study of blockchain technology for use in land administration.

Cook County, Illinois conducted their pilot in 2016 and 2017 and released a report of their findings later that year. Given that this report is the most in-depth, publicly available assessment of a pilot program, it is prudent to provide a summary of the report.

The report correctly identifies that "blockchain technology is a known method for permanently storing transactional records that in a number of respects is superior to locally-isolated client-server models, and can provide a method of recordkeeping that is resistant to alteration, even by government officials" (CCRD, 2017). The researchers and civil servants in Illinois concluded that a proof of work style public blockchain is not idea for land administration in the developed world context. They found that distributed ledgers or private blockchains would be better suited.

With the benefit of hindsight, we can observe that the tokenization of real world assets is likely to skip the county land office and be injected directly into the capital stack through the tokenization of equity in real estate, bonds, and treasury bills. In fact, BlackRock CEO Larry Fink stated that "tokenization is the next generation for markets" (Heaver, 2024). It is not clear if real estate tokenization will land on public blockchains like Bitcoin, Ethereum, and Chainlink or if it will be done on private blockchains. There is more tokenization activity on public chains but private blockchains remain dominant in the world of blockchain based land administration. Another interesting observation from the Cook County report is that "blockchain can provide a mechanism to combine the act of conveyance and the act of providing notice (recordation) of the conveyance into one event" (CCRD, 2017). The concept of digital property abstracts have the potential to aggregate real estate data that is traditionally siloed in multiple government agencies, "empowering residential and commercial property buyers, as well as lenders and other interested parties while creating a framework for a digital property token" (CCRD, 2017).

Pilot Results:

> Result: The participants designed a blockchain real estate conveyance software workflow that can be a framework for the first legal blockchain conveyance in Illinois (and possibly the US.) (CCRD, 2017).
>
> Result: CCRD has successfully used components of blockchain technology (file hashing and Merkle trees) to secure government records on a site maintained by an authorized non-government reseller (CCRD, 2017).
>
> Result: CCRD used the concept of "oracles" to build the most informative property information website in Cook County, with a dedicated landing page for each parcel.

These landing pages can be conceptualized as “digital property abstracts,” which help people see the benefits of consolidating important property information (CCRD, 2017). Result: CCRD’s current enterprise land records software vendor, Conduent (formerly Xerox/ACS) has agreed to incorporate some of the technology used in blockchains, particularly file hashing and data integrity certification, into the new land records system currently being installed at CCRD. Both parties will work together over the next year to explore further possible uses (CCRD, 2017).

The Case of Ukraine

Propy builds its real estate smart contracts on Ethereum, a well-known public blockchain. They signed an agreement with the Ukrainian Government in 2017 to pilot their blockchain land titling solution (Ngo, 2017). The CEO of Propy, Natalie Karayaneva, is a Bulgarian entrepreneur with a track record of success in previous ventures. It is possible that her network in Eastern Europe provided her with the connections needed to cement the deal with the Ukrainian Government. Just as Estonia, Georgia, and other former Soviet states have turned to blockchain to increase security in anticipation of Russian hacking, Ukraine may have made similar calculations. Ukraine is poorly positioned amongst developed countries for blockchain innovation in the land administration space with a -0.36 score on the Ease of Blockchain Factor Analysis putting it in the 38th percentile of all countries measured. The Russian invasion likely overshadowed any progress made on this pilot.

The Case of Russia

Not much is known about the Russian land registry pilot other than the announcement from the Ministry of Economic Development which stated that Russia will “run a pilot project in

Moscow in the first half of next year, to see how reliable blockchains really are for land registry purposes" (Meyer, 2017). The Economic Development Minister, Maxim Oreshkin, is quoted as saying, "The future of the public administration lies in this [blockchain] area." Russia is moderately well positioned for blockchain innovation in the land administration space with a 1.13 score on the Ease of Blockchain Factor Analysis putting it in the 74th percentile of all countries measured. Their military expansionism likely curtailed any efforts to innovate in land administration.

The Case of the Netherlands

Even less is known about the pilot in the Netherlands, but the Netherlands did commit to "integrating the blockchain solution into the country's land registry ecosystem in one to three years (Takyar, 2019). The Netherlands was also one of the twenty-two EU countries who signed on to a declaration to establish a European blockchain association. The Netherlands is the ideal jurisdiction for a blockchain land administration pilot with a score of 3.49 on the Ease of Blockchain Factor Analysis which puts them in the 99th percentile of all countries measured. They are second only to Singapore on the index.

The Case of Japan

Propy, the California based venture-funded startup mentioned previously, is part of the

pilot in Japan. The Propy platform successfully hosted two real estate transactions in 2019 in which Hong King property investors purchased two residential plots in Niseko, Japan. This is significant because market participants are driving adoption in Japan. Japan has taken a welcoming stance towards blockchain technology and cryptocurrency. Japan is well placed for a blockchain land administration pilot with a score of 2.54 on the Ease of Blockchain Factor

Analysis which puts them in the 91st percentile of all countries measured. Japan, being an island and one of the most homogeneous countries in the world should be an ideal jurisdiction for blockchain innovation assuming they can overcome incumbent interests.

The Case of Bermuda

Bermuda's blockchain land registry pilot was shelved in November of 2020. The decision makers came to the conclusion that "it did not make economic sense to invest more funds into changing the database to a blockchain-based one, when the existing electronic database was up to the task" (Strangeways, 2020). The Bermudan government had just purchased expense land registry software called Landfolio and the implementation establishing digital land records and putting them on a blockchain proved to be too much. Bermuda was missing data in some of the categories measured so I was unable to obtain a Blockchain Factor Analysis for them.

The Case of Australia

Australia scored a 2.31 on the Ease of Blockchain Factor Analysis which puts them in the 88th percentile of all countries measured. Australia governs their land through a Torrens system, coincidentally named after an Australian by the name of Sir Robert Torrens. A Torrens system registers ownership with the state rather than requiring the purchaser to prove chain of title for previous transactions (Black v Garnock, 2007). Torrens systems lend themselves to blockchain based pilots because the information in the registry is assumed to be accurate and the title insurance industry is less powerful and is often a government sponsored insurance scheme.

Australia's pilot took place in 2018 in the state of New South Wales in coordination with the NSW Land Registry Office, ChromaWay Asia Pacific and ChromaWay AB (Bennett, 2021). This particular pilot did not focus on the conveyance of land but rather the process of adding or removing mortgages from a land title. According to those implementing the process on the ground, there are more "discharge of mortgage lien" transactions in any given month than there are property conveyance transactions in this particular jurisdiction (Bennett, 2021). Australia gives each state the authority to determine land administration so there is no standardized method for recording transaction data. Some states use the national PEXA e-conveyance platform, but many do not. Currently fewer than one fifth of mortgage lien transactions are fully digital which provides ample scope for efficiency gains (Bennett, 2021). While the pilot program was successful, NSW Land Registry Services has not yet announced whether it will move to a full-scale implementation.

The Case of Canada

Canada scored a 2.35 on the Ease of Blockchain Factor Analysis which puts them in the 89th percentile of all countries measured. Like Australia, Canada also governs their land through a Torrens system. The title industry is not as strong in Canada as in other jurisdictions so in addition to a strong score on the index, there are likely fewer well placed incumbents to oppose a blockchain land administration pilot.

The Canadian pilot followed the Australian example by attempting a small niche use case within the full land administration context. ChromaWay partnered with the Land Title and Survey Authority of British Colombia (LTSA) to organize the "re-sale" of condominium properties. This process is required during the construction of condominiums as the bank often requires the developer to pre-sell many of the units in order to release funding for construction (Bennett, 2021). According to the team of authors who wrote up the academic analysis, some of whom work for ChromaWay, "the prototype project was completed, but due to scaling, and change management constraints with all the stakeholders and various agencies, the prototype approach was not deployed" (Bennett, 2021).

The Theoretical Explanation

The adoption and success of blockchain-based land registry systems in developed countries compared to developing countries can be analyzed through multiple lenses, including technological infrastructure, governance, legal frameworks, and socio-economic factors.
With regard to technological infrastructure, developed countries are typically more advanced with assets such as widespread internet access, high rates of digital literacy, and existing digital government services. This infrastructure provides a solid foundation for implementing and scaling blockchain technologies. On the other hand, developing countries may lack the necessary technological infrastructure, including reliable internet access and digital services, making the implementation of blockchain systems more challenging.

Another factor is that of governance and political will. Governance and political will are the most significant factor in the success or failure of a land registry pilot as demonstrated by this research. Still, the theory suggests that the governance and political will factor is more pronounced in developing countries. Developed countries generally have more stable political environments and stronger governance structures (Bethell, 1999). There is often greater political will to invest in innovative technologies like blockchain for public services, driven by a desire to increase efficiency and transparency. Developing Countries endure more political instability and have weaker governance structures which can hinder the adoption of new technologies. Corruption and a lack of political will to improve land registry systems can also be significant barriers.

Developed Countries have well-established legal and regulatory frameworks that can be more readily adapted to new technologies like blockchain (DeSoto, 200). These countries are often more proactive in creating legal clarity around blockchain, facilitating its adoption. There's generally a higher level of trust in digital technologies and a willingness among the populace to engage with digital government services in developed countries. The socio-economic environment, including high levels of education and digital literacy, supports the adoption of blockchain technologies. Citizens are more likely to understand and trust blockchain-based systems.

Cultural and social barriers, including mistrust in digital systems and a preference for traditional land registry methods, can limit the adoption of blockchain technologies in developing countries (Smith et al., 2010). Lower levels of education and digital literacy can also hinder the population's ability to engage with and trust blockchain-based systems.

The theory posits that while blockchain technology has the potential to revolutionize land registry systems by enhancing transparency, security, and efficiency, its adoption and success are heavily influenced by a country's technological infrastructure, governance, legal and regulatory frameworks, and socio-economic factors with governance and political considerations being the most prominent. Developed countries, with their more favorable conditions in these areas, are better positioned to implement and benefit from blockchain-based land registry systems compared to developing countries, which face more significant barriers to adoption. The success of blockchain based land registry pilots varies by region. In countries with high digital literacy and strong institutions, the pilots have been more successful. In lower-income countries with weaker institutions and less digital literacy, the pilots have met with fewer successes. Chapter 4 demonstrates the complexity of technology implementation and innovation in the public sector especially as it relates to blockchain for land administration. The true barrier to adoption for this technology does not depend on software tweaks or the technical prowess of the implementation company, but rather the stakeholder management process and political realities on the ground. Chapter 5 unpacks areas of future research that may benefit practitioners as they navigate the political challenges of innovating in land administration.

CHAPTER 5

CONCLUSIONS, DISCUSSION, AND FUTURE CONSIDERATIONS

While there are still questions to be answered about the preconditions necessary for blockchain technology to underpin land administration recordkeeping, the obstacles that lay in the path to success are far more often political than technological. Change management is difficult especially for overworked and underpaid public officials and civil servants. Overcoming objections from incumbents and those that have incentives to resist efficiency is no small feat especially when the benefits of such a transition accrue to the public at large rather than a concentrated group of economic actors with an incentive to push for change. There are classic collective action and free rider problems associated with change in the public sector especially related to public goods. I would contend that an efficient and transparent property registry is a public good since it is both nonexcludable, in functioning democracies, and non-rivalrous.

The functionality of various blockchains, especially public blockchains, is increasing at a rapid rate. Even during the span of time in which this research was conducted, there has been tremendous progress. In the period from 2015-2020 there were many academic articles, highlighted previously in this paper, that raised technical questions about the functionality of blockchains for land administration and the technical challenges that precluded the possibility of blockchains being used in that way. Those voices have largely disappeared. It is more common now to read that blockchains are falling out of favor for such a use case. If that is true, it is primarily a result of many failed attempts at implementing the technology for the purpose of securing land records and certainly not the result of a technological shortcoming. The Bitcoin blockchain just surpassed 1 billion transactions with tens of trillions of US dollar value transacted on that chain. Essentially, Bitcoin is a form of digital property rights and blockchains are distributed, digital ledgers. Both at the philosophical level and the granular level, we observe that blockchain for land administration is a daunting task due to challenges in process and politics, not for challenges in technology. Blockchain for land administration will progress only at the pace of land reform in general. Blockchains cannot fix poor data collection or data that is missing altogether. Blockchain is not a panacea for the challenges of land governance but rather a tool to be employed only when a jurisdiction reaches a certain level of sophistication. This paper provides a guide to what forms that sophistication can take but certainly further research is needed. The most important conclusion to draw from this research is that technical challenges are not the primary obstacle for blockchain based land administration. Rather, it is the political and social obstacles to technological disruption, the locus of which is likely to be centered on stakeholders who benefit from the status quo. There is a small, determined group of land administration officials, title companies, and, in certain cases, corrupt elected officials who are the primary obstacles to this change. This group retains the upper hand due to a power imbalance between them as incumbents and the entrepreneurs and innovators who may have a foothold but little influence in local government. Land reform that incorporates technology may not necessarily take advantage of blockchain technology. With technology adoption in the public sector there are always points of friction. However, blockchain technology creates increased threats to rent seekers and corrupt elected officials due to the transparency of public ledgers and the transparency of traction history. “Immutable transactions mean that the transactions or data stored in the blockchain are impossible for anyone (government, organizations, or individuals) to manipulate, modify, or falsify” (Ledger, 2023). Blockchains are distributed, digital ledgers and ledgers are how we execute land administration. This does not mean that all jurisdictions will one day use blockchain for land administration but one would think that jurisdiction globally should have researched it and have well-articulated reasons why they are not, or not yet, contemplating using blockchains on the backend.

The survey of global land administration civil servants conducted as part of this research further demonstrated that even the civil servants themselves understand where the main obstacles are to be found. When asked, who would most likely oppose a blockchain land registry, one of the respondents from India thought it would be "Politicians and bureaucrats [since] this is one area where corruption exists and blockchains will remove middlemen. Middlemen are created by politicians in the system to bring back money to their table. Blockchains will eradicate and can remove redundancy and duplication of data. land records are forged sometimes for political gains. So, advocating [for] this will be a challenge." This quote is anecdotal but telling. A greater body of evidence is found when we examine the case studies of the pilot programs across the developed and developing world. Not in one instance was technological shortcomings listed as the primary cause of failure or the cause of a pilot proceeding to full implementation. Sweden is the jurisdiction that has found the most success and progressed the farthest, but there is not yet a country with a fully operational blockchain land administration system.

The development of an index and the factor analysis of the variables in the index brought further observations to the fore. The internet penetration rate was clearly the most dominant factor in the five factors analyzed in the Suitability for Blockchain Land Administration Index. Polling and market analysis from the broader digital asset industry confirms that digital literacy and internet penetration rates are key to adoption. Having younger populations is an interesting indicator of propensity for blockchain adoption. One recommendation for future study is analyzing the impact of age demographics as one might expect that countries with younger populations would be more likely to see successful blockchain land administration projects. It is not a coincidence that countries like Nigeria and Vietnam are seeing the highest per capital bitcoin adoption and they could just as easily be jurisdictions where blockchain land administration takes hold the fastest.

Another area for future study is theorizing on ways to overcome the collective action challenge of incumbent and political obstacles to a more efficient and transparent land administration process. A study that compares other cases of technological innovation to examine ways in which obstacles were overcome in those historical cases would be interesting. Is there a coalition that might be built that could help provide the basis for building sufficient political capital to withstand the objections of entrenched interests and rent seekers. There has been only modest innovation in land administration for many decades if one counts GIS as a major innovation or even centuries if we take the 1858 introduction of the Torrens system as the last major innovation. What kind of a coalition would have the proper incentives to push for more transparency and efficiency? This would not only be an interesting theoretical exercise but one that would have immediate practical implementation opportunity.

At the conclusion of the process of writing this paper, I received exciting news from Ebony Thompson, City Solicitor for the City of Baltimore. She found me at a conference and told me that she heard me speak at a Blockchain and Real Estate conference several years ago and that my talk inspired her to pursue her vision of using blockchain technology to help Baltimore with the challenge of managing and tracking vacant property throughout the city. The

American Land Title Association issued a press release on the topic on January 11, 2024. The CEO of Medici Land Governance, Ali El-Husseini, said of the project, “the blockchain will make it more efficient for title companies to issue policies. He added that accurately identifying vacant properties and their ownership will augment the city’s targeted interventions and community development efforts (ALTA.org, 2024).

Imagine a future where real property is secured through code, math and cryptography instead of corruptible, or merely error prone officials. Imagine a future where one can conduct a real estate deal with the transaction cost accounting for just 1% of the value of that transaction. Imagine a future where everyone, not just those the well off, could seamlessly secure their property rights in the oldest and most ubiquitous asset in history. We are currently not near this end state. Much work is yet to be done, but there is great prosperity to be gained by such an outcome. The title of Tom Bethell’s book on property rights provides a fitting aspirational charge; The Noblest Triumph: Property and Prosperity Through the Ages. Another book that inspired this research, Hernando DeSoto’s Mystery of Capital, highlights the underperformance of much of the world’s real estate. As was noted in the abstract to this research, there are $20 Trillion dollars of real estate owned by the world’s poor that is illiquid, underproducing, and ineligible to be used as collateral for loans because it is either improperly titled or not titled at all. The potential to unlock tremendous improvements in human flourishing around the world necessitates further research and experimentation to incorporate technology into the governance and administration of the world’s oldest asset class.

REFERENCES

Acemoglu, D., & Robinson, J. (2006). Economic Backwardness in Political Perspective. American Political Science Review, 100(1), 115–131. https://doi.org/10.1017/S0003055406062046

Akkermans, B. “Property Law.” Introduction to Law: Second Edition. Springer International Publishing, 2017. 79–108. Web.

ALTA.org. (2024). Baltimore to Establish Blockchain Platform for Vacant Properties. Retrieved from https://www.alta.org/news-and-publications/news/20240111-Baltimore-to-Establish-Blockchain-Platform-for-Vacant-Properties

Andhra government to adopt blockchain tech to end land record tampering. (2019). The New Indian Express. Retrieved December 30, 2020, from https://www.newindianexpress.com/states/andhra-pradesh/2019/dec/15/andhra-government-to-adopt-blockchain-tech-to-end-land-record-tampering-2076359.html

Aristotle. (350 B.C.E.) The Politics of Aristotle, translated by E. Barker (Oxford: Clarendon Press, 1946).

Aristotle, & McKeon, R. (1941). The basic works of Aristotle. New York: Random House.

Avantaggiato, M. and Gallo, P. (2019). "Challenges and Opportunities using MultiChain for Real Estate," IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), Sochi, Russia, 2019, pp. 1-5, doi: 10.1109/BlackSeaCom.2019.8812780.

Avramov, Yuriy Valentinovich et al. (2017). “Registering Property: Using Information to Curb Corruption.” World Bank, December 1, 2017. Available at http://documents.worldbank.org/curated/e n/270331513854675950/Registeringproperty-using-information-to-curbcorruption

Baird, L., Harmon, M., and Madsen, P. (2018). Hedera: A Governing Council and Public Hashgraph Network. Whitepaper v.1.4 https://www.hedera.com/hh-whitepaper-v1.4-181017.pdf Accessed 12/3/18.

Barbieri, M. & Gassen, D. (2017). Blockchain: Can this new technology really revolutionize the land registry system? World Bank Conference on Land and Poverty.

Barnes, G., Stanfield, D., & Barthel, K. (1999). LAND REGISTRATION MODERNIZATION IN DEVELOPING ECONOMIES: A DISCUSSION OF THE MAIN PROBLEMS IN CENTRAL/EASTERN EUROPE, LATIN AMERICA, AND THE CARIBBEAN. URISA Annual Conference. Retrieved May 30, 2019, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.522.6053&rep=rep1&type=pdf

Baum, A. 2017. “Oxford Future of Real Estate Initiative | Saïd Business School.” https://www.sbs.ox.ac.uk/research/centres-and-initiatives/oxford-future-real-estate-initiative (February 13, 2020).

Bahney, Anna and Goldman, David (2024). Retrieved from https://www.cnn.com/2024/03/15/economy/nar-realtor-commissions-settlement/index.html

Baydakova, Anna. (2018). Wyoming County Moves to Put Land Records on Blockchain. CoinDesk. https://www.coindesk.com/wyoming-county-moves-to-put-land-records-on-blockchain

BenBen. (n.d.). Retrieved December 30, 2020, from http://www.benben.com.gh/services

Bennett, R.; Miller, T.; Pickering, M.; Kara, A.-K. Hybrid Approaches for Smart Contracts in Land Administration: Lessons from Three Blockchain Proofs-of-Concept. Land 2021, 10, 220. https://doi.org/10.3390/land10020220

Besley, Timothy. (1995). "Property Rights and Investment Incentives: Theory and Evidence from Ghana," Journal of Political Economy 103, no. 5 (Oct., 1995): 903-937.

Besley, T. J., & Burgess, R. (2000, May). Land Reform, Poverty Reduction, and Growth: Evidence from India. The Quarterly Journal of Economics, 115(2), 389–430.

Besley, T. and Ghatak, M. (2009) Property rights and economic development. In: D. Rodrik and M. Rosenzweig, eds., Handbook of Development Economics, 1st ed. Elsevier, pp.4525–4595.

Bethell, Tom. (1999). The Noblest Triumph. New York: St. Martin’s Press.

Bjørnskov C., Foss N. (2010) Economic Freedom and Entrepreneurial Activity: Some Cross-Country Evidence. In: Freytag A., Thurik R. (eds) Entrepreneurship and Culture. Springer, Berlin, Heidelberg.

Black v. Garnock (2007). HCA 31 (2007) 230 CLR 438 at pg. 461 Australian High Court.

Blockchain Land Title Project “Stalls” in Honduras. (2015, December 26). CoinDesk. https://www.coindesk.com/debate-factom-land-title-honduras

Boot, Patrick. (2020). Wyoming Issues Second Crypto Bank Charter. The National Law Review. Retrieved December 31, 2020, from https://www.natlawreview.com/article/wyoming-issues-second-crypto-bank-charter

Brasselle, A.-S., Gaspart, F. and Platteau, J.-P., (2002) Land tenure security and investment incentives: puzzling evidence from Burkina Faso. Journal of Development Economics, 67(2), pp.373–418

Brasselle, A.-S., Gaspart, F. and Platteau, J.-P., (2002) Land tenure security and investment incentives: puzzling evidence from Burkina Faso. Journal of Development Economics, 67(2), pp.373–418 Casey, Michael and Vigna, Paul. (2018). The Truth Machine: The Blockchain and the Future of Everything. New York: St. Martin's Press.

Bratcher, Lee and Sullivan, Rob. (2021). Blockchain land registry best practices. Submitted to the World Bank Land and Poverty Conference. Retrieved from https://mycoordinates.org/blockchain-land-registry-best-practices/

Buterin, V. (2017, February 6). *The Meaning of Decentralization*. Medium. https://medium.com/@VitalikButerin/the-meaning-of-decentralization-a0c92b76a274

Casey, Michael. & Vigna, Paul. (2018). The truth machine: the blockchain and the future of everything. New York : St. Martin's Press

CCRD Releases Blockchain Pilot Final Report. (2017). Cook County Recorder of Deeds - Edward Moody. https://www.cookrecorder.com/ccrd-releases-blockchain-pilot-final-report/

Ceyhun Haydaroğlu, The Relationship between Property Rights and Economic Growth: an Analysis of OECD and EU Countries, DANUBE: Law and Economics Review, 6, 4, (2015).

Chavez-Dreyfuss, Gertrude. 2015. "Honduras to Build Land Title Registry Using Bitcoin Technology." Reuters India. Accessed 13 August 2015. http://in.reuters.com/article/2015/05/15/usa-honduras-technologyidINKBN0O01V720150515.

Clague, C., Keefer, P., Knack, S. et al. Contract-Intensive Money: Contract Enforcement, Property Rights, and Economic Performance. Journal of Economic Growth (1999) 4: 185. https://doi.org/10.1023/A:1009854405184

CNBCTV (2022). Blockchain & Governments: A Look at How Colombia is using Blockchain Technology to Store and Maintain Records of its Land Deeds. Retrieved from https://www.cnbctv18.com/cryptocurrency/blockchain--governments-a-look-at-how-colombia-is-using-blockchain-technology-to-store-and-maintain-records-of-its-land-deeds-14338822.htm

Coin Rivet. (2018). Colombia launches time-saving blockchain land registry pilot project. https://coinrivet.com/colombia-launches-a-time-saving-blockchain-land-registry-pilot-project/

Coit, C. S. (1989). Introduction to real estate law. Chicago: Real Estate Education.

Collindres, J., Regan M., Panting, G. (2016). Using Blockchain to Secure Honduran Land Titles. Fundacion Eleutera.

ConsenSys. 2019. “Deloitte: 80% of Businesses See Blockchain as a Strategic Priority.” Medium. https://media.consensys.net/deloitte-80-of-businesses-see-blockchain-as-a-strategic-priority-e8c89cb0a57f (February 13, 2020).

Copeland, Rick. (n.d.). Transitioning to a Strong Sustainable Host Country Economy. U.S. Army Peacekeeping and Stability Operations Institute.

Copeland, Rick. (n.d.). Strategic Imperative for Host Country Economic Capacity Building: “Unity of Understanding.” U.S. Army Peacekeeping and Stability Operations Institute.

Currier, Andy. (2020). Land Unchained? Will Blockchain Technology Unlock the Economic Value of Land? Oaklandinstitute.Org. Retrieved December 30, 2020, from https://www.oaklandinstitute.org/blog/land-unchained

Davidson, Sinclair, Primavera De Filippi, and Jason Potts. 2016. “Economics of Blockchain.” In Public Choice Conference, Fort Lauderdale, United States. https://hal.archives-ouvertes.fr/hal-01382002 (February 14, 2020).

Deininger, K., Augustinus C., Enemark S., and Munro-Faure, P. (2010). Innovation in Land Rights Recognition, Administration, and Governance. The International Bank for Reconstruction and Development/The World Bank. Washington, D.C.

Demarest, G. (2009). Property & peace: insurgency, strategy and the statute of frauds. Fort Leavenworth, KS: Foreign Military Studies Office.

DeSoto, H. (2000). The mystery of Capital: Why capitalism triumphs in the West and fails everywhere else. New York: Basic Books.

DeSoto, H. (2013). Thoughts on the Importance of Boundaries. Proceedings of the American Philosophical Society, 157(1), 22-31.

Eckstein, H. (n.d.). Case Study and Theory in Political Science. Case Study Method, 118-164. doi:10.4135/9780857024367.d11

Eder, G. (2019). Digital Transformation: Blockchain and Land Titles. 12. OECD Global Anti-Corruption and Integrity Forum.

Fenske, J. (2011) Land tenure and investment incentives: Evidence from West Africa. Journal of Development Economics, 95, pp.137–156

Field, E., & Torero, M. (2006). Do property titles increase credit access among the urban poor? Evidence from a nationwide titling program. Harvard University.

Forbes Africa. (2023). RWANDA: Africa’s Silicon Valley. Retrieved from https://www.forbesafrica.com/contrarian/2023/02/20/rwanda-africas-silicon-valley/

Frankenfield, Jake. (2019). “Smart Contracts: What You Need to Know.” Investopedia. https://www.investopedia.com/terms/s/smart-contracts.asp (February 20, 2020).

Frumkin, Daniel. (2022). The Bitcoin Mining Handbook. Braiins Systems. ISBN 978-80-907975-9-8

Ghana Web. (2018). Blockchain technology to revolutionise land administration processes. https://www.ghanaweb.com/GhanaHomePage/business/Blockchain-technology-to-revolutionise-land-administration-processes-666920

Gonzalez, Francisco. (2005). Effective Property Rights, Conflict and Growth. Department of Economics, University of Calgary, Calgary, AB, Canada T2N 1N4.Received 21 August 2003, Revised 15 July 2005, Available online 7 November 2005.

Gonzalez, Mary Lisbeth. 2018. *Honduras - Land Administration and Information Systems Project (English)*. Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/879981516734844931/Honduras-Land-Administration-and-Information-Systems-Project

Graglia, J. M., & Mellon, C. (2018). Blockchain and Property in 2018: At the End of the Beginning. Innovations: Technology, Governance, Globalization, 12(1-2), 90-116. doi:10.1162/inov_a_00270

Guide, G. P. (n.d.). Search Global Property Guide. Retrieved from https://www.globalpropertyguide.com/transaction-costs

Hanus, P. (2013). Correction of location of boundaries in cadastre modernization process. Geodesy and Cartography, 62(1), 51-65. doi:10.2478/geocart-2013-0003

Haydarolgu, Ceyhun. (2015). The Relationship Between Property Rights and Economic Growth: An Analysis of OECD and EU Countries. Law and Economics Review 6 (4), 217-239 DOI: 10.1515/danb-2015-0014

Hayek, F. A. (1973). Law, legislation and liberty: A new testament of the liberal principles of justice and political economy. Chicago (Ill.): University of Chicago Press.

Heaver, I. (2024). What Crypto Investors Need To Know About Tokenizing Real World Assets. Retrieved from https://www.forbes.com/sites/irinaheaver/2024/03/14/what-crypto-investors-need-to-know-about-tokenizing-real-world-assets/?sh=11f72d2a5a96

Hardin, Garrett. (1968). The Tragedy of the Common. Science, Vol. 162, Issue 3859. pp. 1243-1248. DOI: 10.1126/science.162.3859.1243

Heitger, B. (2004). Property Rights and the Wealth of Nations: A Cross-Country Study. The Cato Journal 23 (3): 381-402.

Henley, Giles. (2013). Property Rights and Development Briefing: Property Rights and Rural Household Welfare. UK Overseas Development Institute (ODI). London, United Kingdom.

Hobbes, T., edited by: Malcolm, N. (2012). Leviathan. Oxford: Clarendon Press.

"IBM Blockchain - Enterprise Blockchain Solutions & Services | IBM." https://www.ibm.com/blockchain (February 13, 2020).

Hines, B. (2021). *Digital finance: Security tokens and unlocking the real potential of blockchain*. Hoboken, NJ: John Wiley & Sons.

Huth, M. (2017). ZAMBIA CUSTOMARY LAND DOCUMENTATION TENURE ASSESSMENT. 35. USAID Tenure and Global Climate Change Project. https://land-links.org/wp-content/uploads/2018/02/USAID_LAND_TENURE_TGCC_ASSESSMENT_ZAMBIA_CUSTOMARY_LAND_DOCUMENTATION.pdf

Kaczorowska, M. (2019). Blockchain-based Land Registration: Possibilities and Challenges. *Masaryk University Journal of Law and Technology*, *13*(2), 339–360. https://doi.org/10.5817/MUJLT2019-2-8

Japan's first blockchain real estate transactions recorded by Propy. (2019, April 11). CryptoNinjas.Net. https://www.cryptoninjas.net/2019/04/11/japans-first-blockchain-real-estate-transactions-recorded-by-propy/

Kanojia, Sanjay. (2015). Why the Modi Government must work on Land Reform before Land Acquistion. Scroll.in. Accessed December 8, 2018. https://scroll.in/article/741036/why-the-modi-government-must-work-on-land-reform-before-land-acquisition

Kim, Christine. (2018). Sweden's Land Registry Demos Live Transaction on a Blockchain. CoinDesk. https://www.coindesk.com/sweden-demos-live-land-registry-transaction-on-a-blockchain

Kirby, T. (2015). *A Humble Update on the Honduras Title Project*. Factom. https://www.factom.com/uncategorized/a-humble-update-on-the-honduras-title-project/

Konashevych, O. (2020). General Concept of Real Estate Tokenization on Blockchain, *European Property Law Journal* , *9*(1), 21-66. doi: https://doi.org/10.1515/eplj-2020-0003

Konashevych, O. (2020). "Cross-blockchain protocol for public registries", International Journal of Web Information Systems, Vol. 16 No. 5, pp. 571-610. https://doi.org/10.1108/IJWIS-07-2020-0045

Konashevych, O. (2020). "Constraints and benefits of the blockchain use for real estate and property rights", Journal of Property, Planning and Environmental Law, Vol. 12 No. 2, pp. 109-127. https://doi.org/10.1108/JPPEL-12-2019-0061

Konashevych, O. and Poblet, M. (2019). Blockchain Anchoring of Public Registries: Options and Challenges. In Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance (ICEGOV2019). Association for Computing Machinery, New York, NY, USA, 317–323. DOI:https://doi.org/10.1145/3326365.3326406

Kusago, T. (2005). Post-conflict pro-poor private-sector development: The case of Timor-Leste. Development In Practice, 15(3/4), 502-513. doi:10.1080/09614520500075995.

LACChain Alliance. (2020, March 5). What is the LACChain global alliance? Medium. https://medium.com/@lacchain.official/what-is-the-lacchain-global-alliance-and-what-does-it-consist-of-861cb76257b1

Lapuente, V. and Suzuki, K. (2020), Politicization, Bureaucratic Legalism, and Innovative Attitudes in the Public Sector. Public Admin Rev, 80: 454-467. https://doi.org/10.1111/puar.13175

Larsson, G. 1991. Land Registration and Cadastral Systems. New York: Longman Scientific and Technical.

Ledger Insights. (2019, October 29). Inter-American Development Bank contracts ChromaWay for blockchain land registry. Ledger Insights - Enterprise Blockchain. https://www.ledgerinsights.com/inter-american-development-bank-idb-blockchain-land-registry-chromway/

Lemieux, Victoria Louise. (2016) "Trusting records: is Blockchain technology the answer?", Records Management Journal, Vol. 26 Issue: 2, pp.110-139, https://doi.org/10.1108/RMJ-12-2015-0042

Research and Markets. (2023). Global Real Estate Market Report 2023: A $6.13 Trillion Market by 2030 - Size, Share, Growth Analysis, Competitive Analysis, & Industry Forecasts. Retrieved from https://www.globenewswire.com/news-release/2023/05/29/2677723/0/en/Global-Real-Estate-Market-Report-2023-A-6-13-Trillion-Market-by-2030-Size-Share-Growth-Analysis-Competitive-Analysis-Industry-Forecasts.html

Meyer, D. (2017). *Russia experiments with using blockchain tech for land registry*. ZDNet. Retrieved January 21, 2021, from https://www.zdnet.com/article/russia-experiments-with-using-blockchain-tech-for-land-registry/

Milgrom, P. R., North, D. C., & Weingast, B. R. (1990). The role of institutions in the revival of trade: The law merchant, private judges, and the champagne pairs. Stanford, CA: , Hoover Institution, Stanford University.

Moyo, Dambisa. (2009) Dead aid :why aid is not working and how there is a better way for Africa. Vancouver : Douglas & Mcintyre,

Mwanza, K. & Wilkins, H., (2018). Reuters.com. [Online] Available at: https://www.reuters.com/article/us-africa-landrights-blockchain/africanstartups-bet-on-blockchain-to-tackle-land-fraud-idUSKCN1G00YK

Nakamoto, S. (2009). Bitcoin: A peer-to-peer electronic cash system. Accessed 11/24/18. https://bitcoin.org/bitcoin.pdf.

Ngo, Diana. (2017). Blockchain Proptech Startup Propy Signs Deal With Ukraine Government. Coin Journal. https://coinjournal.net/news/blockchain-proptech-startup-propy-signs-deal-ukraine-government/

North, D. C., & Thomas, R. P. (2009). The rise of the Western world: A new economic history. Cambridge: Cambridge Univ. Pr.

Olson, M. (2000). Power and Prosperity: Outgrowing Communist and Capitalist Dictatorships. Basic Books. New York, NY.

Olson, M. (1993). Dictatorship, Democracy, and Development. American Political Science Review, 87(3), 567-576. doi:10.2307/2938736.

Olson, M. (1965). The Logic of Collective Action. Harvard University Press. 9780674537514

Ostrom, E. (2003). How Types of Goods and Property Rights Jointly Affect Collective Action. Journal of Theoretical Politics, 15(3), 239-270.

Overstock.com. (2019, May 22). Medici Land Governance Signs MOU with Lusaka City, Zambia to Develop and Deploy a Land Governance Platform and Support Property Title Issuance. GlobeNewswire News Room. http://www.globenewswire.com/news-release/2019/05/22/1840827/0/en/Medici-Land-Governance-Signs-MOU-with-Lusaka-City-Zambia-to-Develop-and-Deploy-a-Land-Governance-Platform-and-Support-Property-Title-Issuance.html

Popper, Nathaniel (2017). "Bitcoin price surges after deal on software updates". The Boston Globe. Retrieved March 8, 2021.

Preece, Elliot. (2018). Blockchain as the Future of Land Registry in Latin America. ABC Money. https://www.abcmoney.co.uk/2018/06/20/blockchain-as-the-future-of-land-registry-in-latin-america/

Pritzker, Y. (2019). *Inventing bitcoin: The technology behind the first truly scarce and decentralized money explained*.

Propy. (2019). Vermont Goes Blockchain Because of Propy. Propy Blog. https://propy.com/blog/vermont-goes-blockchain-because-of-propy/

RAND Corporation (2009). Guidebook for Supporting Economic Development in Stability Operations. RAND Corporation. Santa Monica, CA.

Richardson, C. J. (2005). The Loss of Property Rights and The Collapse of Zimbabwe. Cato Journal, 25(3), 541–565.

Ricketts, M. (2005). Poverty, Institutions, and Economics: Hernando DeSoto on Property Rights and Economic Development. Economic Affairs, 25: 49-51. doi:10.1111/j.1468-0270.2005.00552.x

Rodrik, D. (2004). Getting Institutions Right. CESIFO DICE Report, 2(2), 10–15.

Rodrik, D. (2000) Trade Policy Reform as Institutional Reform in Handbook on "Developing Countries and the Next Round of WTO Negotiations," edited by Bernard HoekmanSelvetti, C. 2012. Rapid review of the literature on Property Rights - 31 October 2012. DfID

Rizzo, Pete. (2015). *Blockchain Land Title Project "Stalls" in Honduras*. CoinDesk. https://www.coindesk.com/debate-factom-land-title-honduras

Scott, B (2016). How Can Cryptocurrency and Blockchain Technology Play a Role in Building Social and Solidarity Finance? United Nations Research Institute for Social Development No. 2016-1.

Seso Global. (n.d.) Blockchain-based Property Register – Cape Town, South Africa – SESO. Retrieved December 31, 2020, from https://seso.global/aboutus/index.php/2020/07/10/blockchain-based-property-register/

Shang, Q., & Price, A. (2019). A BLOCKCHAIN- BASED LAND TITLING PROJECT IN THE REPUBLIC OF GEORGIA. *Innovations: Technology, Governance, Globalization* 2019; 12 (3-4): 72–78.

Shuaib, Mohammed & Alam, Shadab & Ahmed, Rafeeq & Qamar, Shamimul & Nasir, Mohammed & Alam, Mohammad. (2022). Current Status, Requirements, and Challenges of Blockchain Application in Land Registry. International Journal of Information Retrieval Research. 12. 10.4018/IJIRR.299934.

Smita, Sinha. (2018). How Andhra Pradesh is emerging as India's blockchain hub. Analytics India. Accessed December 8, 2018. https://www.analyticsindiamag.com/how-andhra-pradesh-is-emerging-as-indias-blockchain-hub/

Small, M. L., Harding, D. J., & Lamont, M. (2010). Reconsidering culture and poverty. *The ANNALS of the American Academy of Political and Social Science*, *629*(1), 6–27. https://doi.org/10.1177/0002716210362077

Snall, M. (2017). Blockchain and the Land Register: A New “Trust Machine”? World Bank Conference on Land and Poverty.

Strangeways, Sam. (2020). Blockchain land title registry plan ditched. Retrieved January 21, 2021, from https://www.royalgazette.com/news/article/20201130/blockchain-land-title-registry-plan-ditched/

Sylwester, K. (2001). A Model of institutional formation within a rent seeking environment. Journal of Economic Behavior & Organization, 44, 169-176.

Takyar, Akash. (2019). Blockchain Land Registry Platform—Reducing Frauds and Delays. LeewayHertz-Software Development Company. https://www.leewayhertz.com/blockchain-land-registry-platform/

Tembo, E., Minango, J., & Sommerville, M. (2016). Zambia’s National Land Titling Programme- challenges and opportunities. 14.

Teng, J. (2000). Endogenous authoritarian property rights. Journal of Public Economics, 77, 81-95.

Thakur, V., Doja, M., Dwivedi, Y., Ahmad, T., & Khadanga, G. (2020). Land records on Blockchain for implementation of Land Titling in India. International Journal of Information Management, 52. https://doi.org/10.1016/j.ijinfomgt.2019.04.013

Themistocleous, M. (2018). Blockchain Technology and Land Registry. Cyprus Review, 30(2). Retrieved May 30, 2019.

The quest for secure property rights in Africa. (2020, September 12). *The Economist*. https://www.economist.com/middle-east-and-africa/2020/09/12/the-quest-for-secure-property-rights-in-africa

Thompson Reuters Foundation. (2016). Millions of land, property cases stuck in court. Accessed December 8, 2018. https://www.deccanchronicle.com/nation/current-affairs/090816/millions-of-land-property-cases-stuck-in-indian-courts.html

Transparency International. (2009). Global corruption barometer 2009. Berlin: Transparency International.

UN-FIG. (1996). Bogor Declaration on Cadastral Reform. Report from United Nations Interregional Meeting of Experts on the Cadastre, Bogor, Indonesia, 18-22 March, 1996. A joint initiative of the International Federation of Surveyors (FIG) and the United Nations. http://www.sli.unimelb.edu.au/research/publications/IPW_publ.html.

Van Valkenburgh, Peter. (2020). What is Bitcoin mining, and why is it necessary? Retrieved from https://www.coincenter.org/education/advanced-topics/mining/ on April 19, 2024.

Vos, J. (2017). Blockchain Based Land Administration: Feasible, Illusory, or a Panacea? World Bank Conference on Land and Poverty. Washington DC, March 20-24, 2017.

Who owns what? (2020, September 12). *The Economist*. https://www.economist.com/leaders/2020/09/12/who-owns-what

Williamson, Enemark, Wallace, and Rajabifard. (2009). Land Administration Systems for Sustainable Development. ESRI Press.

Williamson, P (n.d.). The Evolution of Modern Cadastres. Director, United Nations Liaison, International Federation of Surveyors. The University of Melbourne Victoria, Australia.

World Bank. (2017). “Why Secure Land Rights Matter.” World Bank text/HTML, March 24, 2017. Available at http://www.worldbank.org/en/topic/land

World Bank. (2016). Doing Business 2016: Measuring Regulatory Quality and Efficiency. World Bank, 2015, p. 211. Available at https://doi.org/10.1596/978-1-4648-0667-4.

BIOGRAPHICAL SKETCH

Lee Bratcher is the President and Founder of the Texas Blockchain Council. The Texas Blockchain Council is an industry association with more than 100 member companies and hundreds of individuals that seek to make Texas the jurisdiction of choice for Bitcoin and blockchain innovation. The TBC helped to research two pieces of blockchain legislation that were passed in the 87^{th} Legislative session and an additional two bills in the 88^{th} Session that were signed into effect by Governor Abbott. Lee and the TBC team have a specific focus on the regulatory environment around Bitcoin mining in Texas. The TBC hosted the Texas Blockchain Summit in Austin at which speakers like Senator Ted Cruz, Senator Cynthia Lummis and SEC Commissioner Hester Peirce addressed the sold-out audience. He is also a Captain in the US Army reserves working as Tech Scout for the 75^{th} Innovation Command that supports Army Futures Command. Formerly, Lee was a political science professor at Dallas Baptist University teaching international relations with a research emphasis on property rights.

Lee was awarded a master's in International Relations from St. Mary's University and is in his ninth year as a PhD candidate at UT Dallas with a research emphasis on blockchain land registries. Lee lives in Richardson, TX with his wife Becca and their three daughters.

CURRICULUM VITAE

Lee E. Bratcher

lee@texasblockchaincouncil.org

PROFESSIONAL EXPERIENCE

President and Founder, Texas Blockchain Council **Dec. 2019 - Present**

- Established and built the Texas Blockchain Council from its inception to an influential industry association that impacted policy and drafted legislation for the 87th and 88th Texas Legislatures.
- Recruited 100+ dues-paying corporate member companies and several hundred individual members to participate in the association driving triple digit revenue growth. 2019 Revenue $0 - 2023 Revenue $3M. Manage a team of 7 employees, lobbyists, and contractors.
- Built relationships with members of the Texas Legislature and heads of Texas State Agencies and established TBC as the authority on blockchain policy matters in Texas and the nation.
- TBC Videos: Conversation with Gov. Greg Abbott; TBC 2023 Summit Recap; What is the Texas Blockchain Council.

Executive Director, Institute for Global Engagement, Dallas Baptist University **2019 - 2021**

- Managed the Institute's team, budget, work product, and set strategic vision.
- Engage US military, political, and business leaders to speak at IGE-sponsored Leadership Lecture Series. Recent guests include Secretary of Defense Jim Mattis, Boeing Government Services President Ed Dolanski and Mathilde Mukantabana, the Rwandan Ambassador to the U.S.

Department Chair, Politics, Philosophy, and Economics (PPE), Dallas Baptist University Aug. 2015 - 2021

- Administer class scheduling, curriculum changes, and adjunct faculty recruitment for the PPE program.
- Recruit and advise all PPE students and develop curriculum and programming for the PPE Society.

Assistant Professor of Political Science, Dallas Baptist University

- Drove research initiative demonstrating blockchain technology's potential in the real estate space.
- Teach Political Science, International Relations, and Blockchain courses.
- Published papers include: "Blockchain Land Registry Best Practices" 2019 World Bank Annual Conference on Land and Poverty) and "Military Cooperation with UN Police" (2017, U.S. Army War College).

Army Officer, CPT: 75th Innovation Command July 2010- Present

- Served as a Tech Scout for the 75th Innovation Command supporting Army Futures Command.
- Previously: ROTC Instructor at UT Dallas and Dallas Baptist University. Three Office Evaluation Reports have been "top blocks" (above peers).
- Secret Security Clearance.
- Trained in personnel management, mediation, government contracts, convoy operations, and cross-cultural communication.
- Previous unit: 490th CA BN Dallas, TX.
- Air Assault Qualified.
- Graduated 2 (Distinguished Military Graduate) out of 100 on the OCS OML at Fort Benning in 2011.

EDUCATION

University of Texas Dallas

- PhD, Political Science. (ABD / all but dissertation)
- Dissertation: Blockchain and Property Rights – How Blockchain Technology Can Transform Land Registries.

IMB Watson Research Center: Blockchain instructors' certification. Weeklong training in New York, 2019.

St. Mary's University

- MA, International Relations (2014)

Dallas Baptist University

- BA, History (2010)

SKILLS

- Business development, sales, leading diverse teams in strategic and tactical discussions, project management, excellent written and oral communications skills, public speaking, and proficiency in a variety of productivity and contract management software.

MEMBERSHIPS

- The Politics, Philosophy, and Economics Society (2017 – Present)
- Richardson Chamber of Commerce
- Dallas Chamber of Commerce
- Texas Work Group on Blockchain Matters appointed by Speaker of the Texas House