Assessing the Merits of Blockchain Technology for Global Sustainable Development Initiatives

Assessing the Merits of Blockchain Technology for Global Sustainable Development Initiatives

Stacia L. Chamberlain

A Thesis in the Field of Sustainability

for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

May 2019

Abstract

This paper evaluated the claims that blockchain technology, a type of information and communications technology, is more efficient and sustainable in addressing sustainable development, and that as an innovation it changes the institutions that modulate these approaches. Governments, organizations and institutions come together globally, united by the need to fulfill critical humanitarian, social, or environmental goals. However, issues concerning transparency, trust, and gaming the system are persistent in an anarchic global environment. Blockchain technology practitioners boast its capacity for process improvement vis-a-vis traditional approaches for many cooperative global challenges, basing their arguments on the embedded trust and transparency functions of blockchain. However, these claims have not undergone a robust comparative analysis to determine whether these process changes provide measurable improvement to sustainable development.

My hypotheses were that blockchain technology can be a tool for leveraging greater sustainability in development practice, that the use of blockchain in development projects would manifest measurable improvements toward the United Nations Sustainable Development Goals, and that this technology influences the institutional dynamic of development practice. The hypotheses were tested using a critical review of the industry-led arguments for the potential of blockchain as a tool in the development sector with a focus on transaction cost economics. The research surveyed blockchain practitioners and researchers, compared the influence of blockchain and market behavior

according to New Institutional Economics theory, and related data on blockchain-for-development projects to the 17 U.N. Sustainable Development Goals (SDGs). I used a sample set of roughly a dozen robust blockchain-for-development projects and analyzed white papers, corporate documents, and reports for measurable change output. I then built a dataset of blockchain-for-development initiatives from the web to develop a picture of the manner in which the technology is being applied in projects geared toward specific SDGs. I analyzed these by identifying and compartmentalizing the projects based on their geolocation, the sector of the economy, and the particular SDG.

This research provides an admittedly mixed report on whether blockchain absolutely improves sustainable development outcomes. While the research identifies a robust catalogue of blockchain initiatives for global development impacts, many project results are presented without publicly accessible statistics, which are necessary for a comparative analysis and verification of impact. The totality of the robust blockchain-for-development projects did not provide comprehensive enough measurable outcomes to perform statistical analysis. Therefore I could not conclude that the technology provides measureable improvements to development practice for achieving the SDGs. I concluded that using blockchain for meeting sustainable development goals adds an acceptable degree of demonstration as a component of efficiency to collective action problems in managing the global commons. The research also supported my hypothesis that blockchain technology is a force for institutional change, based on the technology's impacts on transactions and market behaviors.

Dedication

This thesis is dedicated to Allen, my comfort and my joy.

Acknowledgements

First and foremost, a big thanks to my research director, Dr. Christian Martin, who accepted my research proposal and enabled this thesis. I am indebted to him for his encouragement to find balance and pursue work in fast-slow mode, and for his easy-going and candid demeanor. Thank you, Dr. Mark Leighton, my research advisor, for helping me to believe that I really knew what I was doing all along, even when I felt otherwise. Thank you to Benjamin Siegel, Giulio Coppi, Jorn Poldermans, Cara LaPointe, Katherine Foster, Andrej Zwitter, and Kate Dodgson for their input and participation in this research. Thanks to my family and friends for your collective encouragement, love, and support—all such critical verbs. And finally, thank you to everyone who provided the yeses and to everyone who provided the no's. Without the no's I would not have become proficient at proving my grit, and without which, the yeses would not have been such sweet relief. Without either, I would not be here.

Table of Contents

List of Tables

List of Figures

Definition of Terms

Blockchain technology: a decentralized data structure for hosting and managing a digital ledger. A blockchain database is distributed rather than held by any one data bank or repository. The premise is that the data is shared among many users and verified block by block as the data moves among nodes (or computers with a copy of the blockchain). Corruption and manipulation of the blockchain is said to be close to impossible, as the database is spread across all servers and not a central host. For more detailed information and examples of blockchain's applications, see: https://blockgeeks.com/guides/what-is-blockchain-technology/.

Bitcoin: a cryptocurrency, or financial product that is validated through a distributed ledger.

Distributed ledger: a shared database that is synchronized across networks involving many users (or nodes). It is the skeleton structure on which blockchain technology is used. Also a broader term for solutions including blockchain that record, create, store, and transfer data.

Global Goals: an alternative term for the Sustainable Development Goals

ICT: Information and communications technology

Open data: Data or a database that is freely accessible for viewing and adding to by anyone without permission necessary. It is part of the open-source data movement.

Smart contract: A programmable, self-executing digitized contract. Smart contracts govern the behavior of accounts on the blockchain through contractual agreements embedded in the code which then trigger if-then events in response to predefined conditions being met. Their function is to autonomously interpret terms of the contract and changing circumstances of participant behavior on the blockchain.

Transaction: an exchange meant to include the financial, social, and political sectors.

Chapter I

Introduction

The field of international development practice has a long tradition of collaboration in partnerships, although some collaboration contributes to asymmetries of information and power, and yield inefficiencies, specifically high transaction costs (Reinsberg, 2018). When multilateral organizations and governments, for example, collaborate to provide humanitarian relief and development aid, critical information and processes can become siloed or redundant. Funds or supplies for development assistance and humanitarian aid can and do get 'lost' or grafted in transition from organization to beneficiary, making projects more costly (Reinsberg, 2018). Other challenges exist for development practitioners, in that they collaborate in an inherently anarchic international legal system, in which trust and cooperation are arguably keystones of the enforceability of contracts. Practitioners in the field of international development have changed their tack over decades of evidence-based field work and assessment to try to compensate for some of these inefficiencies. Extensive scholarship has already been given to the subject of asymmetries and inefficiencies in development practice, the most pertinent treatments are those by new institutional economist Douglass North (1991), political economist William Easterly (2014) and development economist Esther Duflo (2011).

Advancements in the field of information and communications technology (ICT) in the last few decades have allowed stakeholders to share knowledge and make decisions equitably, thereby reducing information and power asymmetries. Increasing the quantity of information can help improve estimation and strategic decision making, because more information allows greater information computation and analytics. Some decision support ICTs have helped with multilateral negotiation and provided decision optimization. These ICTs are designed to maximize the input variables in a non-biased manner (Lepri, Oliver, Letouzé, Pentland, & Vinck, 2017). The quality of information also matters. Information asymmetries increase transaction costs and can negatively impact development outcomes because costly strategies are inefficient and unsustainable (Linders, 2013; Hilbert, 2016). The challenges of creating trust and equal power in global development transactions persists because despite advances in ICT, these transactions are still largely trust-based agreements and do not abide formal legal arrangements, which by law bind parties to their terms of agreement. These challenges are characteristic of what is colloquially known as the anarchic global development system. Deliberate efforts have been made by development practitioners to decrease information asymmetries and reduce inefficiencies in global collaborations with what is known as open data. According to Linders (2013), open data leads to dramatic improvements in the analysis of project impact. Open data platforms make sharing data, promoting and engaging in open data projects, coordinating aid efforts and data-driven analysis possible. It can also improve data-driven analysis and promote the transparency of governance systems. Open data projects, as described by Zambrano (2017) as shared "infomediaries", help advance data harmonization.

This thesis examined one specific up-and-coming ICT—blockchain technology—and its use toward improving global sustainable development outcomes. I evaluate only the particular aspects of blockchain technology that are pertinent to sustainable development practice. For a detailed explanation of the many facets of blockchain technology, I recommend Annex II of the International Development Research Centre's white paper (2017). Blockchain technology, also known as distributed ledger technology, is commonly understood to be a technology platform for cryptocurrency, but the uses for the technology extend far beyond the realm of the financial industry.

Is blockchain technology being utilized to achieve measurable efficiency in development practice, as defined by reduced transaction costs? Addressing this question requires comparison of the industry's specific claims to the reduction of transaction costs to the benchmarks set forth in the United Nations Sustainable Development Goals (SDGs), also known as the Global Goals. It is first necessary to define two contexts for the term efficiency. It is related to both how well development projects are implemented and achieve goals, and to how institutionalized rules and practices shape outcomes. One context of the definition is related to capacity in development in practice, which defines the efficiency of the project. In the second context, it means how rules constrain a group's behavior which, in turn, impact the way resources are allocated. I use the definition of development given by Elinor Ostrom, in which she defines the term as: "applying to the improvement of the material conditions for individuals; this occurs through improving the institutions they use to solve encountered problems of collective action" (Ostrom, 2017, p. 230).

Research Significance and Objectives

The significance of this research is that it challenges assertions that blockchain technology is superior for improving development practice outcomes. It is not only a study of the use of blockchain technology to achieve global sustainable development, but also a study of the potential implications that uses of blockchain applications have for traditional aid institutions. It is also meant to continue the conversation about what we need of our institutions, and to acknowledge that global society faces thresholds in organizational willingness and capacity.

My overall research objectives were:

- To offer insight on how efficiently blockchain technology may contribute to global sustainable development;
- To give available evidence of whether blockchain technology can improve development outcomes; and
- To continue the scholarship on blockchain technology through the perspective of institutional theory.

Background

A very basic description of blockchain technology is given succinctly in that it: ". . . .(C)ombines mathematical cryptography, open-source software, computer networks and incentive mechanisms" (Davidson, DeFilippi, & Potts, 2018, p. 5). Because of these security features, it is possible to reduce transaction costs and to eliminate violations like corruption (Ammous, 2015). There are two types of blockchains: public and private, and they are either permissioned or permission-less (Zambrano, Seward, & Sayo, 2017). Below is a table that summarizes the types of blockchains and their characteristics.

Table 1. Types of blockchains and their permissions.

	Permission-less	**Permissioned**
Public	Open participation. All peer-to-peer network nodes (or participants) have full access to the blockchain. It is open read, open write. Participants have an anonymous or pseudonymous identity.	Participants need to be authenticated to get read and/or write access to the blockchain.
Private	All participants in a previously defined private network have full access to the blockchain.	Nodes must to be authenticated to have read and write access to the private blockchain. Only some authorized nodes can write to the blockchain, while all others have read access only. Participants have a known identity.

Sources: Zambrano, Seward, & Sayo, (2017); Mercy Corps (2017).

Within development practice, blockchains are predominantly private (Zambrano, Seward, & Sayo, 2017). While private chains do not afford the transparency of a public blockchain (as we can see that one must have permission and a known identity to read and write to the blockchain), they are designed to protect data related to its participants (Mercy Corps, 2017). This is especially important for blockchains that manage sensitive data, such as personal identities and financial account information. There is such a thing as a hybrid blockchain, which incorporates aspects of public, private, and consortium blockchains. Governments can implement hybrid blockchains that allow public, permissioned access. These hybrid blockchains can facilitate public goods and services delivery (Zambrano et al., 2017).

A design feature of blockchain that is arguably very important to development practice is the smart contract (Reinsberg, 2018), which enables consensus-based, automatically executed contracts. As a result, people no longer need to rely on trust to uphold the mandates of an agreement. The nature of a smart contract is an embedded contractual agreement that pre-defines what automatic actions will be triggered, as defined within what is sometimes called a "business logic layer" (Mercy Corps, 2017) that conditions if-then events. Smart contracts present opportunities to transform agreements that formerly required high levels of interpersonal trust but also carried risk. In a smart contract, stakeholders cannot deviate from the terms of contract if they expect to see the fulfillment of its mandate. Smart contracts are useful for transactions that occur outside of formal legal frameworks.

The term transactions in the context of this research can include financial, social, and legal interactions. Conversely, transactions outside of formal legal frameworks allow for uncooperative practices and participants are often incentivized by low risks of non-compliance and a flexible threshold for corruption (Reinsberg, 2018). An example of a smart contract in development practice is in the rural agriculture industry, in which smart contracts can facilitate payments to farmers and producers and monitor the food supply chain (Zambrano, 2017). Blockchain technology departs from a priori development practice methods in that blockchain platforms are trustless and unalterable. The technology is attributed to the reduction of transaction costs in global development practice, which is relevant for improving the efficiency and sustainability of global development projects.

Blockchain Technology for Global Sustainable Development

Drawing from Ashford and Hall (2011), I use a definition of sustainability as the co-optimization of dynamic and innovative efforts to provide market needs, to decrease resource depletion, and to ensure the realization of full human potential. The definition of sustainability can extend to the optimization, or maximized efficiency, of systemic processes. This definition encompasses sustainable development as identified in the SDGs. It can include making development practice sustainable, or capable of being sustained, or fostering environmentally- and technologically-optimal practices in climate change initiatives.

Blockchain technology is a structurally different method for coordinating and transacting in the development sector in ways that are a significant departure from how development practitioners have previously coordinated their efforts. Blockchain is a fundamentally different platform for facilitating the trade of information and humanitarian aid. The technology departs from the traditional, hierarchical nature of incumbent multilateral institutions and intermediaries that facilitate global development transactions. A few examples may demonstrate how meaningful blockchain's potential impact on development practice can be. Providing humanitarian relief and aid are some of the first major, successful blockchain-for-development projects. Several of the United Nations' divisions have created projects supporting financial transfers to refugees and aid recipients globally in Jordan, Pakistan, and Serbia (Coppi & Fast, 2019; Zambrano, 2017). Responsibilities that typically are the explicit job of governments, like enabling voting in elections and providing access to public services, are in some cases now the custodianship of blockchains in Estonia and Ukraine (Coppi & Fast, 2019). Blockchains are also being utilized for property verification. The country of Ghana is using a land titling registry so that citizens and officials can verify legal ownership of property, whereas before blockchain, the analog ledger system was unreliable and easily manipulated (Zambrano, 2017; Zwitter & Herman, 2018).

However efficient blockchain is purported to be in development practice, the energy use of blockchain has been questioned extensively. Can blockchain provide energy efficiency while contributing to sustainable development initiatives? Maintaining and adding to the blockchain, in the case of cryptocurrency, requires what is known as hashing blocks. Hashing blocks for cryptocurrency is known as Proof of Work (PoW) (Tillemann, Price, Tillemann-Dick, & Knight, 2019) and requires high computational demand, which is energy-intensive. Hashing blocks is not the only way to add to the blockchain, as there are other mechanisms which allow for users to add to the blockchain. These mechanisms are known as consensus mechanisms, and include Proof of Stake (PoS), Proof of Authority (PoA), and Proof of Impact (PoI) (Tillemann et al., 2019; ixo Protocol, 2017). In short, these mechanisms are less energy-intensive and more environmentally sustainable. Some research shows that blockchain can be more energy efficient than brick-and-mortar institutions, even when taking into account the energy necessary to operate a blockchain (Cocco, Pinna, & Marchesi, 2017). Overall, the savings on operational infrastructure for central financial reporting, compliance, and business operations was reported to be significant (Accenture Data, in Mercy Corps, 2017).

From ICT Systems to Blockchain: Opportunities and Challenges

Centralized information and communications technology (ICT) can include organization-based software for systems optimization and environmental simulation and modeling, programmed and/or operated by a field or practice specialist. The use of ICT in the global development sector, or what is sometimes called ICT for development, can include programs to conduct sophisticated cost benefit, life cycle, or risk analyses, or other types of utility analysis and attribute aggregation. Data-for-development initiatives in use include geospatial information system (GIS) tools to monitor and evaluate humanitarian disaster response strategies on the ground. One example of this is the Ushahidi online disaster response platform, which enables people to geo-cache precisely where and when events take place, like leaking water pipes or human rights violations.

Recently, data platforms that host openly-accessible data have emerged in the development sector. Open data is defined as being interoperable, as enabling universal participation and distribution, and is freely accessible and reusable (http://opendatahandbook.org/guide/en/what-is-open-data/). The World Bank has an online, open data platform known as World Bank Open Data. The platform hosts databases which are available for free to anyone interested in accessing data that the World Bank has collected.

Blockchain technology has been applied primarily to the deployment of financial services, and it is also being applied to increase the effectiveness of aid funds, with more opportunities within the financial sectors of the least developed at hand (Linders, 2013). Because blockchain is designed to be decentralized, it may offer greater opportunities for peer-to-peer transactions in many market functions, such as micro-lending and insurance, which can increase a citizen’s autonomy. However, there are concerns that users will be limited by their ability to connect to online services and to share in equitable access of the technology. Zambrano (2017) argued that uneven technological diffusion will persist due to shortcomings in physical capital, including structural problems like energy infrastructure, and stunted fiscal and/or human resource capacity. However, others (Humanitarian Blockchain Summit, Plenary Session II, December 2018) counter that there may be ways to circumvent the unevenness of technological diffusion of blockchain technology. One such solution, proposed by Julie Maupin, Director of Social Impact & Public Regulatory Affairs at IOTA Foundation, is a modular blockchain platform that is partition-tolerant: ”Partition tolerance means that the cluster continues to function even if there is a "partition" (communication break) between two nodes (both nodes are up, but can't communicate)”, (https://stackoverflow.com/questions/12346326/cap-theorem-availability-and-partition-tolerance), or where internet is spotty but distributed ledger technology can be used by small devices in the field (Humanitarian Blockchain Summit 2018).

Blockchain as a Consensus Technology

Development practitioners face challenges in making projects sustainable, efficient, and transparent because global development practice is laden with adverse incentives and high transaction costs. Specific problems identified within the practice are the failure of host governments in making credible commitments to adhere to aid contracts, high transaction costs due to the need for aid intermediaries, principal-agent problems, coordination problems, and information asymmetries within the aid governance architecture (Reinsberg, 2018). Using a self-executing consensus mechanism may curtail self-incentivized behavior. Ammous (2015) asserts that blockchain will address at least one of these issues, claiming that blockchain will supersede third-party agencies as a consensus mechanism and transaction ledger. He uses the example of bitcoin, a cryptocurrency, to illustrate the potential for restructuring transactions based on mutual consent through an automated, consensus mechanism technology.

Consensus is important for ensuring trust and accuracy in group decisions. Establishing consensus is a way of increasing the chances that decisions are made equitably among stakeholders, are negotiated in good faith, and that all major parties have had their grievances heard and addressed. Therefore, an essential element of the blockchain is that it has a consensus protocol built in. In a Mercy Corps white paper (2017), Richard Brown, head of technology at R3, stated "Distributed ledgers–or decentralised databases–are systems that enable parties who don't fully trust each other to form and maintain consensus about the existence, status and evolution of a set of shared facts". As defined by Mercy Corps:

> A smart contract is a digitized contract that is stored on the blockchain; it is "smart" because it contains programming logic that can automatically execute the terms of the contract. . . .Given that smart contracts function without an intermediary to interpret contract terms and deal with changing circumstances, the application of this technology needs to be assessed and implemented carefully. Smart contracts need to be error free, or at least error tolerant. (p. 13)

Smart contracts enabled through blockchain can be advantageous for mitigating trust issues in development practice, as they embed contractual agreements in the code, triggering events in response to certain predefined conditions being met.

Stakeholders may still harbor hidden preferences, but if they are not coded into the blockchain at the initial stage of creation, these preferences cannot be executed within the formalized contract.

Even with smart contracts, however, there is no guarantee of a perfect outcome, as "decentralized and depersonalized trust does not imply enhanced governance and impartiality" (Zambrano, 2017, p. 11) and human consensus is replaced with algorithmic consensus. As promising as decentralization of decision-making may be in many cases, the concern for comprehensive inclusion in the details of the smart contract will remain, as the development of code protocol is in and of itself not necessarily unbiased. This issue is the concern of legal and public policy experts and practitioners globally are working toward standardization of a framework for ethical coding.

Blockchain for the UN Sustainable Development Goals

Blockchain has many types of initiatives that specifically address the Sustainable Development Goals (Kewell et al., 2017), and multilateral organizations like the U.N. are implementing blockchain technology in sustainable development projects. Some of the Global Goals that the blockchain projects are aimed to address include securing digital identities, improving land or property rights records, increasing gender equality, enabling equal access to finance and markets, achieving international peace and democracy, and empowering a targeted dispersal of humanitarian aid funds. The Results chapter provides a diagram of the types of blockchain initiatives that are aimed at addressing the Global Goals either explicitly or implicitly. The 17 specific Goals are illustrated in Figure 1.

Within the public sector, some of the projects in which blockchain is being leveraged include optimizing the humanitarian aid supply chain, providing digital identity for refugees, enabling women's empowerment through their participation in markets, and decreasing inequality (Zwitter & Boisse-Despiaux, 2018). There are several ongoing global initiatives and more continue to be developed. The website https://positiveblockchain.io/ lists over 600 projects whose goals are purportedly in line

Figure 1. The UN Sustainable Development Goals. Source: (United Nations Department of Public Information, 2017).

with ‘positive social impact’ (see Results). Some of the larger aid organizations have successfully developed the following operational initiatives:

- The World Food Programme is using blockchain technology to benefit Syrian refugees in Jordan, enabling refugees to redeem cash-based transfers.
- United Nations Women (UNWomen) is exploring the use of blockchain technology to promote gender equality by building a civil registration for sending and receiving digital assets directly.
- UNICEF is investing in the development of an open source digital identity and personal information platform to enable children’s access to social and welfare services.
- UNOPS launched a project to explore how blockchain can be used to increase the efficiency of aid transfers, especially intra-agency transfers.

- In Serbia, UNDP and AID:Tech are using blockchain technology to issue a Digital Identity to beneficiaries to enable the receipt of remittances directly.
- The World Bank launched Blockchain Lab, which is exploring land management, carbon trading, cross border payments, and payments in the education sector.

An archetypical application of the blockchain as a market mechanism is seen in initiatives for financing green investments such as carbon trading, renewable energy, and energy-efficient infrastructure (Solheim & Jung, 2017). At the other end of the market spectrum, blockchain offers people the opportunity to build and participate in decentralized digital marketplaces. The percentage of people in developing countries engaged in the informal economy is large and these communities thrive in socio-political environments with a thin institutional fabric. Decentralized digital finance and market access can provide critical small-scale economic opportunities, which in turn promote resilience and prosperity (The ixo Protocol, 2017).

Despite the plethora of claims that blockchain is a panacea for problems in global development, research published by Monitoring, Evaluation, Research, and Learning in Development (MERL) practitioners found no evidence of it (Burg, Murphy, & Petraud, 2018). After analyzing 43 blockchain use cases, including humanitarian aid disbursement and land registries, they determined that the claims for radical improvements were undocumented. Additionally, their attempts to communicate with blockchain firms did not manifest conclusive data, as they found the industry members unwilling to share results. The fact that there are no comprehensive studies with quantitative data may be because privacy concerns are critically important for the types of data contained within the initiative(s) and their owners. Indeed, private blockchains dominate the technology's landscape. These practitioners question whether the quest for data is premature, given the newness of the practice field.

Blockchain as an Institutional Disruption

Relevant research for an institutional argument begins with Davidson, De Filippi, and Potts (2016 & 2018) and extends to New Institutional Economics (NIE) theory. This line of inquiry expands to include the work of Elinor Ostrom, who analyzed institutions through her framework for policy analysis, known as the Institutional Analysis and Development (IAD) framework. This framework maps the interrelatedness of incentives, behaviors, institutional stability, and policy design. Within this framework, the question of how institutional incentives or rules affect global sustainable development outcomes can be explored.

First, how do we frame the term institution for our understanding in the context of this research? According to the school of thought known as institutional theory, institutions can be defined as: "formal and informal rules that constrain individual behavior and shape human interaction" (Eggertson, 1996, in Johannessen, 2008). According to Matutinovic (2007, p. 1112), "(I)nstitutions provide a set of habits, rules and norms that govern socioeconomic system dynamics and regulate its behavior with respect to the larger metasystem". His interpretation for the term institution derives from Geoffrey Hodgson (1993), who defined institutions as: "commonly held patterns of behavior and habits of thought, of a routinized and durable nature, that are associated with people interacting in groups or larger collectives..." (in Matutinovic, 2007, p. 1112).

In sum, institutions can be thought of as formal or legal, as we see in property titles and regulations; but also as informal or behavioral, as in social norms.

The effects of technological change on organizations and institutions have been studied since the impetus of the industrial revolution. In one argument for technological change causing institutional change, Matutinovic (2007) identified with Karl Polanyi's definition that markets (an economic institution) are strategic in shaping all types of transactions. Market transactions can be as formal as economic exchanges but also informal, social practices like consumer behavior. Everett Rogers' (2003) research on the diffusion of technological innovations speaks to diffusion and organizational change. He makes the generalized statement that: "Both the innovation and the organization usually change in the innovation process in an organization" (p. 425). Radical or disruptive innovations that can cause major change to organizations such as restructuring, because of the uncertainties new technology presents as a new paradigm for carrying out tasks. Sometimes, he says, this paradigmatic shift can create new industries, as we have seen with blockchain in creating new market mechanisms. Blockchain technology is argued to be a mechanism for institutional change in the economy by Davidson, De Filippi, and Potts (2016 & 2018), who asserted that blockchain is an institutional technology, not solely a general purpose technology. They defined it as: "is as the emergence of a new species of economic coordination" (p. 3) that competes with other mediums for coordination such as governments and firms as an institutional alternative.

Some of the most thought-provoking applications of blockchain technology challenge how we interact with non-market institutions. Similar to the way that rules, as a functional element of institutions, shape socio-economic behavior, technology interacts as an element in an institutional framework. Ostrom (2005 & 2017) wrote extensively on institutions, rules and incentives, and her work can be applied to analyze blockchain through an institutional lens. This provides the basis for the critical analysis of blockchain as part of the institutional framework administering rules and behaviors in society. From the vantage point of political science, this involves how rules affect incentives and behaviors in collective action problems. Rules are one exogenous variable to be analyzed, but they are not the only factor affecting collective action outcomes. The background research on the institutional framework, as is presented later, provokes a question: Can make the logical extension that blockchain, beginning as a market mechanism and extending to a wider scope of transactions in socio-political realms is an element in the institutional framework that can affect change from within?

Blockchain and institutional change. As mentioned before, research on blockchain technology vis-à-vis institutions has focused on the technology as an economic institution (Davidson, DeFilippi, & Potts, 2016 & 2018), or in implicating technology as an end result of institutional change (Matutinovic, 2007). However, some research shows that blockchain may enhance existing institutions in development practice by making them more effective (Reinsberg, 2018; Zambrano, 2017). Institutional change happens when the institution's capacity to render gains or maximize resources becomes limited, and interest in reforming the institution as a system is necessary to evolve to resist shocks to the holistic environment (Aligica, 2005). Such external forces as technological progress, changes to bureaucratic or administrative capacity, or a lack of responsive dynamism to current conditions can catalyze change to institutional behavior. Ergo, institutions are not strictly static but are adaptive systems. Considering the changes to development practice that blockchain technology may provide, and as rapidly as they are being implemented, does this suggest that blockchain technology may play a pivotal role as a catalyst in changing institutional behavior?

Research Questions, Hypotheses and Specific Aims

The overarching questions of this research focused on how a reliance on blockchain technology will impact and retool the development sector, and if it is fundamentally reshaping traditional institutional and organizational frameworks in development practice. These questions were:

- Can the use of blockchain technology manifest global sustainable development outcomes more efficiently and sustainably than traditional approaches?
- Does its use in development projects decrease transaction costs and increase transparency, as it has been claimed?
- Does blockchain in development practice effect significant change in the existing institutional framework?

These required looking at the following specific sub-questions:

- What types of indicators can be used to compare blockchain technology initiatives with traditional approaches to development practice?
- Which indicators or definitions of transaction costs can help us determine changes in outcomes in development practice? Can we measure the impact of blockchain technology versus traditional methods in development practice based on these definitions?

- Is blockchain technology affecting change in the institutions of development practice? If so, can a systems framework be applied to blockchain to help us understand the changes we see?

Based on these research questions, the hypotheses I examined were as follows:

1. Blockchain technology is more efficient at meeting the SDGs. This claim is based on the premise that using the technology reduces transaction costs and increases transparency in sustainable development initiatives.
2. Blockchain technology is a force for institutional change beyond the institution of the economy. This was examined through observations of changes in behaviors and rules within development practice.

Specific Aims

To address these questions and hypotheses, the research required that I:

1. Provide a comprehensive list of existing blockchain-for-impact initiatives.
2. Illustrate how transaction costs are an important gauge for the relative efficiency of leveraging blockchain technology for sustainable development initiatives.
3. By using the IAD framework for institutional analysis, show how blockchain is a technological catalyst for institutional change.

Chapter II

Methods

The initial research methodology was based on the ambitious premise that there was a plethora of quantitative data openly available. In reality, what I encountered was inaccessibility to quantitative performance indicators that would be necessary to substantiate reported claims about the purported efficacy and superiority of blockchain in development practice. While a comparative study of impact measurement between development approaches would be helpful, the barrier of accessing data prevented comprehensive conclusions. Therefore, this project engaged qualitative methods to demonstrate how blockchain and its counterpart in traditional approaches work to reach benchmarks set forth in the SDGs. For clarification, traditional approaches include third party banks, independent consultants, and hierarchical organizations that are used for transacting essential processes such as aid dispersal and contract enforcement.

In order to manage the scope of this paper, some pertinent topics could not be included in this research. This research excludes financial technology (fintech) and the banking sector in developed countries. It is not meant to look closely at how economies in developed countries are changed by the advent of cryptocurrencies, or how the elite banking sector in particular may be changing. This paper focuses specifically on how blockchain technology is changing sustainable development and humanitarian efforts and outcomes. To this specific end, the research focuses on developing countries and vulnerable populations. This research also does not touch on other critical topics common to research on blockchain in the development sector, such as concerns for data ownership, the right to be forgotten, scalability, and ethics in coding. These are very important issues that are being vigorously pursued and discussed in legal and public policy research circles, such as at the Beeck Center for Social Impact and Innovation at Georgetown University, the think tank Blockchain for Good, and the Blockchain Commission for Sustainable Development. Concurrently, no discussion is given here to decentralized autonomous organizations (DAOs), which are complex smart contracts governing a group of people which manage governance operations based on a set of tokenized rules (Shermin, 2017): essentially, DAOs are a decentralized, digital government and citizenry.

The majority of the information I was able to gather about blockchain initiatives for the development sector was found through blockchain forums, newspaper articles, and the websites of blockchain technology companies. Some websites referenced included the online newspaper Coindesk.com, the online forum on blockchain technology, Medium, and Consensys, a blockchain software technology company. I concluded that there are many blockchain-for-development projects, with varying degrees of sophistication or completeness. There were many examples that were newly implemented or were still in the latent stage of planning; many were documented as having been closed or abandoned. There were only a few projects that have thus far exhibited successful implementation. The cases compiled in the data excluded failed projects, so this research does not accurately address variance among the projects.

To test the first hypothesis I researched a voluminous quantity of official summaries of performance indicators found on blockchain technology company websites, asserting how their blockchain initiative is working to achieve the sustainable development goals. I corresponded with practitioners working on blockchain initiatives at the UN and World Food Programme, to acquire access to data points to compare the old with new techniques in the development sector. Some blockchain technology websites listed email contacts for which inquiries can be made, others had inquiry boxes built into the webpage, eliminating the possibility that you could track a message or response or know to whom you are addressing your inquiry. I was not given responses at all in many cases. Of the few contacts in the industry I heard from, the World Bank sent me their latest progress report, which is freely available online. The document mentions blockchain technology for their development efforts but offers no statistics or comparisons. It was suggested to me by a respondent from the World Food Programme that I use the general information found on their program website, which provided a similar lack of robust data. I was told by a blockchain technology company that the information I was seeking was proprietary and therefore unavailable to me, since the blockchain initiative operated on a private blockchain. According to the ixo Foundation (2017) website:

> Anyone will be able to access the Global Impact Ledger through the ixo Portal. All projects on the ixo Network will have a portion of standardized information recorded on the ledger (from the Impact Claim Template) such as date, location, SDG, and claim capture (initially to be determined by ixo) with a pointer to the underlying data. The underlying data will be project-specific such as number of immunizations received, tonnes of CO eliminated, or GPS coordinates of planted forest. If someone wanted to gain access to the underlying data, they would have to request access from the owner of that data. The owner of the underlying data can then determine with whom they share the data and at what price, if any.

As a response to this barrier, I sent out a questionnaire to blockchain-for-development practitioners and scholars as a way to collect more data on this phenomenon. To test the second hypothesis, I sent a questionnaire with six questions to several blockchain practitioners, researchers, and developers designed to probe their understanding and beliefs on blockchain for development practice and the institutional framework through which we solve collective problems.

As an extension of data collection for the first hypothesis, I referenced the database Positiveblockchain.io. One feature of this database is the ability to track the status of each project. From the list, it can be determined that there are few live or active programs. I compiled a dataset of projects that were particularly in line with the Global Goals, and then cross-referenced this to a database in the research of Galen et al. (2018). Through a careful process of elimination, I established a list of projects that were valid to the best of my knowledge for the basis of further data analysis. These data were integrated into a new dataset that was used to compare how the blockchain projects were addressing the SDGs.

My master dataset was sourced primarily from one large dataset with more than 800 blockchain humanitarian projects. This dataset were downloaded as csv files, culled, and cleaned to streamline understanding of the applicability of each blockchain initiative to individual Global Goals. Once 'inactive', 'closed', duplicate projects, and those not pertaining to the Goals were removed, the dataset included a total of 501 projects. There are many coins or tokens associated with monetizing (or tokenizing) natural capital assets, donation platforms for nonprofit fundraising, and mobile payment platforms that could not be included. I analyzed these data points through the open-source data visualization platform RawGraphs.io, using data drawn from the online open-source database PositiveBlockchain.io. and then cross-referenced this list with that of the dataset of 193 projects compiled by Galen, et al. (2018).

I also gathered information from blockchain summits and conferences, either attended in person at universities including Fordham University, or online through the Oxford University Center for the Internet and Society. The Humanitarian Blockchain Summit in December 2018 in New York City proved some useful qualitative guidance for my analysis. Some of the discussion contemplated whether researchers were pursuing the right kind of data. Was measurable quantitative comparison really necessary? Some practitioners at the Summit discussed that the theory of blockchain as a technological agent for change may be more relevant discussions in the future.

Chapter III

Results

The results relevant to testing the first hypothesis include the knowledge gleaned from the practitioner’s survey, followed by inferences gathered after editing and collating the dataset with all the other quantitative information gathered.

Blockchain and Development Practice: The Practitioners’ Response

The information gathered for this first part of the results is comprised of responses to questions in call-and-response format. The questionnaire yielded a variety of responses, as each gave a different perspective based on their expertise. The answers of the respondents are those of Benjamin Siegel, Impact Policy Manager at Consensys; Giulio Coppi, Digital Specialist at the Norwegian Refugee Council; Cara LaPointe, Senior Fellow at the Beeck Center for Social Impact and Innovation at Georgetown University; Katherine A. Foster, Executive Director of Blockchain Labs for Open Collaboration (BLOC); Andrej Zwitter, Professor of International Relations and Ethics and Dean of the University College Fryslân; and Kate Dodgson, Humanitarian Innovation Consultant at the Data Science Initiative.

Table 2. Responses from practitioners on questions 1 through 6.

	Question 1
Respondents	**I've been looking for quantitative data to perform a comparative analysis of how blockchain for development may or may not be more impactful than traditional development practice. But there seems to be no quantitative data to do this study. When academics are looking at claims to the superiority of blockchain for development, how should they judge the performance of such technology?**
Benjamin Siegel	Honestly, it's too early. There is no real quantitative data yet. We are just starting to see solutions get implemented (with WFP Building Blocks being the most advanced). It will take years before appropriate quantitative data is avaliable. Honestly, the blockchain space should stop claiming it is more impactful than traditional. We simply do not know yet, we just believe it will be.
Giulio Coppi	They shouldn't. As underlined (way too dramatically) by a recent MERL report, DLT projects lack the absolute minimum level of transparency. This, however, doesn't mean anything more than this is a bad practice. It doesn't unfortunately says anything at all on the tech itself.
Cara LaPointe	Social impact and development effectiveness are traditionally difficult areas to quantitatively measure. In some ways, technology provides a quantifiable metric through technology adoption. By measuring how widely adopted a technology is and whether that adoption is sustained, one can start to get a rough estimate metric of impact.
Katherine A. Foster	Data is difficult to come by because 1) measurement (metrics) of success are lacking, 2) cases are relatively new and only now reaching mainstream attention, 3) academic rigour is lacking, and 4)differences between ICOs and blockchain applications. Start by subcategorizing and differentiating between ICOs and actual blockchain builds.
Andrej Zwitter	Social science: Case studies based on qualitative data mostly, a lot of hypothesising, and conjecture. Alternatively in IT, testing / analysing existing protocols for consistency, data leakage, hackability etc. Regarding quantitative Data, I would not know what there is to quantify, but if you have an idea, create your own database. Why not!?
Kate Dodgson	You're right - there is very little quantitative or persuasive data out there. When judging performance of blockchain over the original or traditional system being used, I first consider whether the original system was broken or seriously lacked something. In humanitarian innovation, this is the "problem recognition" phase, and if you can't formulate a clear problem statement, then you shouldn't be looking at solutions such as blockchain. If you're satisfied that there is a definable problem and that blockchain is a potential solution for it, you should consider the costs and shortcomings of blockchain and weigh up whether they're worth the supposed benefit it would bring. Costs aren't just financial though, they're also the risk of experimenting with a new technology, hiring a new team, diverting budget etc.

	Question 2
Respondents	**Considering that many blockchains are private, what can academics reasonably expect to gather in terms of raw data for the basis of comparison in the future?**
Benjamin Siegel	Realistically, we should avoid private blockchains for development - the data can be obfuscated, and it is possible to only release what you want to be seen. On a public blockchain, the academics (and public) can see whatever data is recorded, referenced, or stored on-chain. It's important to note that academics SHOULD be involved/consulted in the development of public blockchain solutions so that they can guide success metrics, and data reports. If the teams building the platforms do not communicate with academics and researchers, they won't know what type of data to aggregate for long-term studies.
Giulio Coppi	The private or public nature of the technology doesn't have anything to do with the open data policy adopted (or rather, not adopted) by the organization. Private or public platforms can allow external scrutiny, but this doesn't equate to raw data access. Data shown often relates to transactions, and require extremely high knowledge of DLT data to actually make some (not a lot, but some) sense of what kind of data is it. The focus should rather be on the data model adopted.
Cara LaPointe	The frustrating answer to most blockchain questions is " It depends." Here I would say that it depends on exactly what you are trying to compare, and to what end.
Katherine A. Foster	Careful about conflating private chains (as in blockchain use case setup per permissions and data being used in the network and data about the use cases themselves). Again, start by creating categories for analysis and reaching out to those with pracitcal cases in operation.
Andrej Zwitter	Same as above. What is available, can be analysed, studied and tested. Academics can build their own blockchain, develop their own protocols, find their own applications, etc.
Kate Dodgson	Only what they're willing to give us! Which I'm not confident is much. NDAs and commercial competition mean many are either barred or disincentivised from sharing data. In the humanitarian and development sectors, organisations fear losing funding and donations should they admit any shortcomings or failures, which means we might never get to hear the truth about how a pilot went.

	Question 3
Respondents	**Development practitioners and researchers have been discussing the issue of technology inequality due to on-the-ground infrastructure shortcomings. What solutions can be seen on the horizon to improve ICT infrastructure, or how otherwise can these shortcomings be minimized?**
Benjamin Siegel	Having experienced these issues first hand, I can confirm that it is maybe the largest issue stopping blockchain from succeeding in development. Look for blockchain and mobile integration as a key development. Connectivity is huge as well - projects like RightMesh that are focused on bringing connectivity to underserved areas are going to be key to the success of blockchain. Beyond that, look at any piece of technology that connects the digital to the real (oracles). IoT, Data Analysis, etc.
Giulio Coppi	The integration of IoT and DLTs, but only if IoT security features improve substantially. In any case, connectivity is expanding exponentially, chances are that in a few years most urban and semi urban areas will be decently covered.
Cara LaPointe	Digital technologies already create a leapfrog opportunity for communities and society to bypass traditional wired communications infrastructure. Thoughtfully creating digital technologies to require limited bandwidth or to operate on SMS networks helps to minimize the effect of infrastructure shortcomings.
Katherine A. Foster	Electricity, access to technology, and business models all need work, but also in terms of who is setting up ICT infrastructure and their motivation and bias--we have to be sure we are checking assumptions.
Andrej Zwitter	Depending on the context, the technology and the organisation this question has to be answered differently. In general, invest more in ethical R&D in non-emergency settings before applying in the field.
Kate Dodgson	I think (and hope) that technology companies wanting to work with NGOs or in developing countries are slowly learning about these infrastructure shortcomings and therefore start developing tools that can cater to them. Sikka.me for example did a study of the phone usage by Nepalese and found that while only 30% had access to a smart phone, 100% had access to a feature phone. They therefore built a blockchain application which can be utilised through a feature phone.

	Question 4
Respondents	**The term 'disintermediation' is used a lot when talking about blockchain, but so is the topic of scaling. Do you envision a mesh of large and small-scale blockchain operations? (For example, one such concept I have heard of, from a representative at Consensys, is blockchain "sub-tangles" that are partition-tolerant.)**
Benjamin Siegel	It totally depends, this is protocol level stuff that is beyond my expertise. My best assumption is that we will see a network of side chains (smaller blockchains focused on specific solutions / dApps / issues) that will sync up to the main chain when appropriate.
Giulio Coppi	Two options make sense: A unique protocol adopted by everyone in different declinations, or several protocols and subprotocols adopting shared interoperability standard. Only the latter option seems realistic to me as of today.
Cara LaPointe	Interoperability is the most important challenge facing the future of blockchain. Blockchain is really a concept that actually encompasses a wide range of technologies in practice. Different blockchain architectures are better suited to different problems/systems. However, in order for blockchain in general to scale in a way that will have large scale impact, these different architectures will have to be interoperable.
Katherine A. Foster	This type of technical question is more about the engine of blockchains and still not addressing the sense of competition and garnering position rather than interoperability and collaboration. Scaling of blockchain use cases is more about the data available, the legacy systems and new tech interfaces (how to bridge with IOT, GIS, etc.)
Andrej Zwitter	There are a lot of assumptions that do not equally apply to the field. Yes, that could be an interesting option for large scale programmes with several sub-projects, but right now most organisations are glad if they get it to work. The added value of many blockchain solutions, beyond what can be achieved with conventional means (incl. Cloud solutions), remains to be seen.
Kate Dodgson	Sorry, I can't answer this question.

	Question 5
Respondents	**We have heard of the potential development of an online knowledge platform to identify blockchain use-cases in the development sector. Are you as a practitioner, researcher, or technologist actively contributing to such a database?**
Benjamin Siegel	No, but I definitely would love to. Unless this is the UN project my team was working on before, in which case I did participate, haha.
Giulio Coppi	There are several of these, none of which has a minimum degree of authority, as no DLT project in the aid sector is fully transparent or fully developed. I am contributing to a few, but mostly with a specific focus.
Cara LaPointe	I have contributed to NYU GovLab's BlockChange initiative which is building a database of case studies of blockchain for social impact focused in the digital identity field.
Katherine A. Foster	Have not found one that accurately distinguishes between theoretical use cases and practical application use cases. I am part of Climate Chain Coalition, but here again, there is no categorization and use case capture. Beware that the platforms may be provider-specific. These will not give neutral and robust sampling.
Andrej Zwitter	Not directly.
Kate Dodgson	I was interested in setting one up myself in a previous job (researcher at TU Delft and HumanityX). However, it wasn't clear who would pay for such development, nor for the maintenance. Instead we ended up making a decision tree which mapped all the known use-cases but in a decision tree format rather than descriptive manner (blockchain.humanityx.nl)

	Question 6
Respondents	**Building on the concept of a philosophy of distributed ledger technology, do you see behavior changes within blockchain use cases that could be analyzed through the new institutional economics perspective?**
Benjamin Siegel	Absolutely, but again we will need to see successful deployments and long-term studies to uncover what these actually are. Right now we can only hypothesize.
Giulio Coppi	I thought so, now I'm not that sure anymore.
Cara LaPointe	The distributed nature of blockchain theoretically displaces many institutions. However, institutions play multifaceted roles that go far beyond simple transactions. Therefore, the replacement of these institutions with blockchain technologies is not a simple or easy process. To me, the interesting behavioral changes will be those that are indicative of whether blockchain can drive new behaviors to replace the other, lost functions of institutions. Then, blockchain technologies replace transactional processes.
Katherine A. Foster	Yikes, a big question. Behaviour change of users, providers and orgs in the space could all be analyzed through an economic perspective. The Silicon Valley approach and pitching style is an economic model that actually goes against the fundamental ethos of blockchain of being collaborative and part of a sharing economy. It is old paradigm on new tech.
Andrej Zwitter	I cannot answer this question. I lack the knowledge of how the protective would answer it.
Kate Dodgson	Sorry I can't answer this either!

Source: Author's make.

The overall findings from analyzing the questionnaire responses were that blockchain pilot projects have not been supported with robust metrics. This could suggest that researchers who have written the few detailed reports on a very small cohort of major blockchain initiatives have preferential access to data or may be part of a closed network in the development field. It may also suggest that public data access of annual or quarterly reports are forthcoming as these projects are relatively new or are in development. Open access to data is still restricted to practitioners working on a private blockchain, where performance metrics are meant to be kept private among users with permissioned access. Researchers and practitioners also suggested that it not be beneficial to press for open data on projects that operate under strict privacy to its users. There also appears to be a lack of a framework for evaluating and sharing data on blockchain project outcomes, although as the interviewees said, these are arriving piecemeal to the practitioner space. Comprehensive and perfect smart contract creation also remains a concern of the researchers, as the code protocol assumes the shape of power relations as predefined in the ledger.

Blockchain for Development Projects Data

I compartmentalized the projects in the dataset by their complementary goals to the SDGs. I then organized theses in a diagram that illustrates how each type of Goal is populated by initiatives and which Goals were addressed by the projects. The data from blockchain-for-development projects dataset was compartmentalized based on the particular SDG it aims to address (Figure 2). Each SDG was clustered by its respective color and the size of each box reflects the quantity of blockchain initiatives that have attributes of that Goal.

Overall, the blockchain projects by Global Goal break down as follows:

1) No Poverty—7; 3 donation & philanthropy, 1 energy, 2 finance, 1 impact investing
2) Zero Hunger—1, agriculture & food
3) Good Health and Well-being—35; 1 environment, 3 finance, 4 health, 27 personal data
4) Quality Education—9; 1 donation & philanthropy, 6 education, 2 personal data
5) Gender Equality—7; 6 in finance, 1 people & peace
6) Clean Water and Sanitation—2, both donation and philanthropy
7) Affordable Clean Energy— 63; 48 in energy, 15 in finance
8) Decent Work and Economic Growth—28; 8 agriculture & food, 2 donation and philanthropy, 1 energy, 1 environment, 5 finance, 6 impact investing, and 3 people and peace, 1 digital identity, 1 no poverty
9) Industry, Innovation and Infrastructure—142; 6 agriculture & food, 1 clean water and sanitation, 1 democracy & voting, 2 donation & philanthropy, 2 education, 23 energy, 2 environment, 23 finance, 4 government and public, 41 health sector, 4 humanitarian relief, 2 infrastructure, 2 land & property, 1 people & peace, 29 supply chain
10) Reduced Inequalities—1, digital identity
11) Sustainable Cities and Communities—20; 9 energy, 4 environment, 4 finance, 1 government & public, 1 people & peace, 1 land & property

12) Responsible Consumption and Production—31; 8 agriculture & food, 4 environment, 4 health, 1 people & peace, 14 supply chain
13) Climate Action—15; 3 in energy, 6 in environment, 6 in finance
14) Life Below Water—4; 1 environment, 1 finance, 2 supply chain
15) Life on Land—14; 1 agriculture & food, 8 environment, 3 finance, 2 supply chain
16) Peace, Justice and Strong Institutions—40; 19 Democracy & voting, 2 digital identity, 1 education, 2 finance, 7 government and public, 1 humanitarian relief, 6 land & property, 2 people & peace
17) Partnerships for the Goals—47; 24 donation & philanthropy, 2 energy, 4 environment, 12 finance, 1 health, 1 humanitarian relief, 3 impact investing
18) *Digital Identity—34, 1 donation & philanthropy, 2 health, 1 humanitarian relief, 1 land & property, 29 personal data. (Note that Digital Identity is not a UN-sanctioned goal, it is added here because it encompassed a large number of blockchain initiatives.)

Analysis of the dataset paired with the SDGs yielded some interesting associations. The largest share of blockchain-for-development initiatives is aimed at meeting Goal 9: Industry, Innovation and Infrastructure. We can see that within Goal 9, there are 16 different sectors in which blockchain initiatives are being employed to achieve improvements toward the specific Goal. For example, there are six blockchain initiatives focused on improving the agricultural industry. Some of these include a solution for food supply chain management, and an industry platform for integration among growers, brokers, and buyers. Affordable and clean energy, Goal 7, is the second most populated, with the vast majority of initiatives aimed at addressing clean energy access and supporting local energy trading markets.

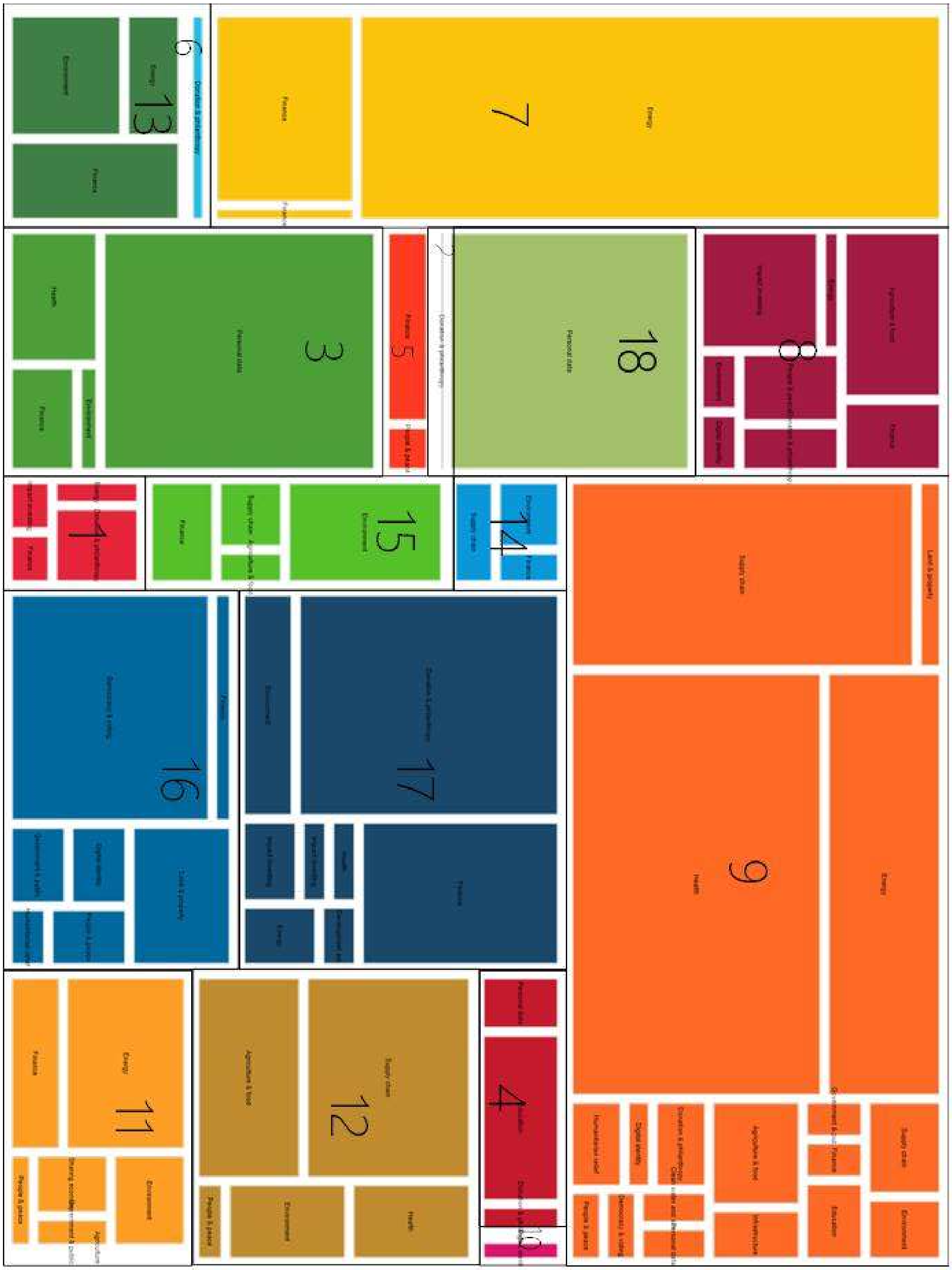

Figure 2. The intersection of the SDGs and the survey of blockchain initiatives.

Figure 3 is an alluvial diagram illustrating the relationship between the Global Goals and categories of the market where blockchain initiatives are being focused. It shows, for instance, that Goal 9: Industry, Innovation and Infrastructure, hosts a vast array of blockchain initiatives, impacting nearly all market categories including health, finance, and supply chains. Looking at the impact categories tells another story as well. Private supply-side industries feature prominently in the cohort of blockchain initiatives. We see that the energy, finance, personal data security, and health sectors of the market are receiving the bulk of the efforts of blockchain initiatives.

All of these data are available for further viewing at: https://sites.google.com/view/slcmastersthesis19/home

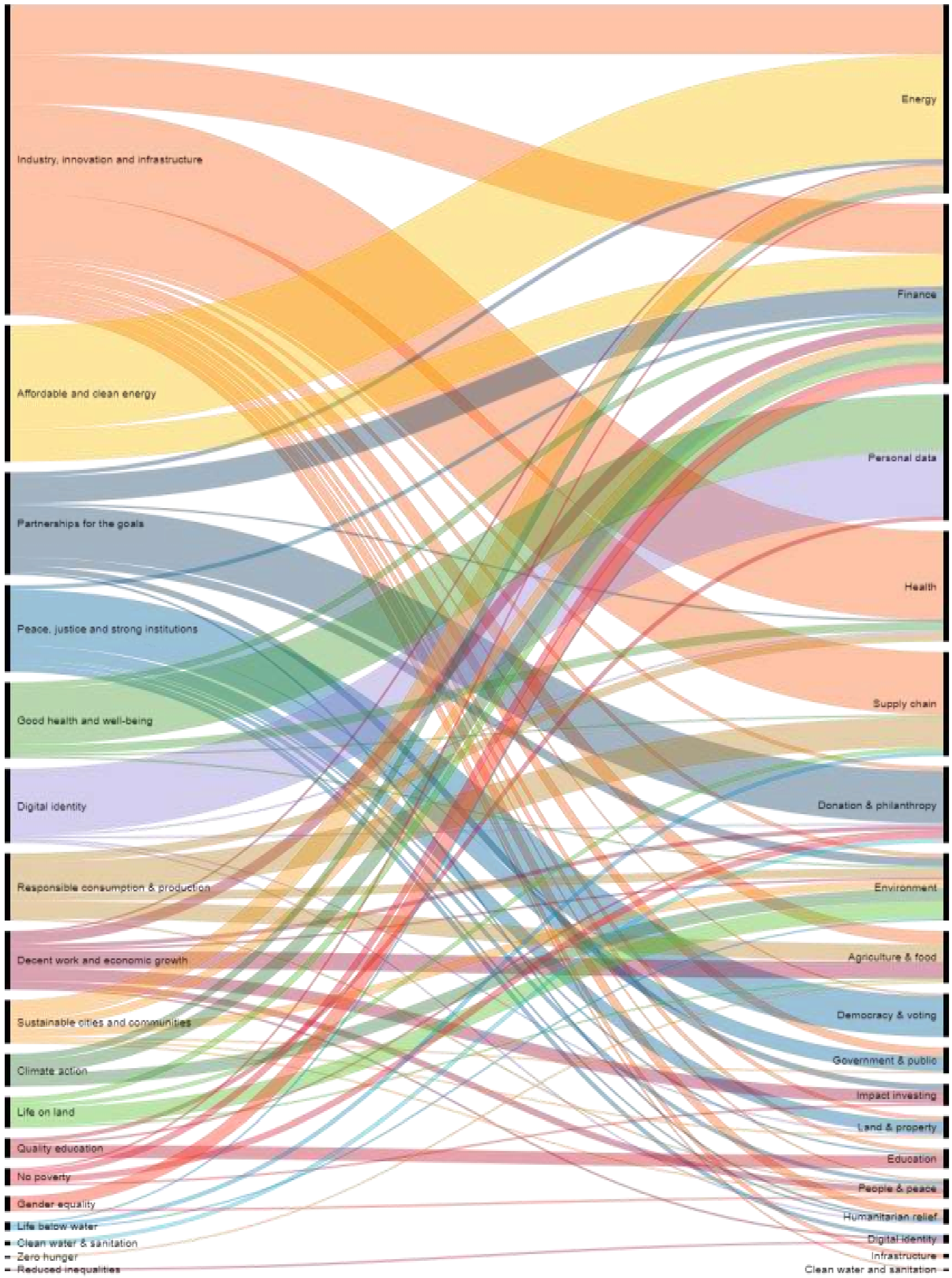

Figure 3. Alluvial diagram matching the Goals with sectors of impact.

Chapter IV

Discussion

I first present the findings from testing the second hypothesis, which gives context for the topic of transaction costs relative to the application of blockchain technology, and analyzes whether these projects fit criteria for the reduction of transaction costs, through a literature analysis of blockchain-for-development initiatives. The analysis provides evidence that blockchain technology is being applied in ways that deliberately reduce transaction costs in projects that can be directly linked to the achievement of SDGs. Then the discussion focuses on blockchain technology as a tool for shaping institutional behavior, through New Institutional Economics (NIE) theory and within the Institutional Analysis and Development (IAD) framework. The final section presents some of the broader theoretical implications of blockchain technology for global sustainable development.

Blockchain Technology and Transaction Cost Economics

It is important to understand how transaction costs are shaped by incentives and behavior when people transact in imperfect markets, as well as the costs that development institutions have to bear when transacting in an anarchic global development environment. Below I give my evaluation of the hypothesis that blockchain technology is reducing transaction costs in these environments. Further, I link blockchain-for-development initiatives to the SDGs in a way that makes tangible the link between transaction cost reduction and specific Goals. This may be helpful for future researchers in their efforts to demonstrate measurable outputs in blockchain-for-development projects.

Transaction Costs & Development Practice

According to Williamson (1987), transaction cost analysis examines the "comparative costs of planning, adapting, and monitoring task completion under alternative governance structures" (p. 2). In essence, transaction costs are the friction produced from transacting in imperfect markets, where "behavioral uncertainty" features as a prominent source of friction. Measuring the value of transaction costs is not explicitly the same as measuring direct costs, but is usually determined by examining whether contracts or governance structures are aligned to enable frictionless transactions. Williamson therefore proposed that it is not a question of quantity but of quality. There are different costs arising from initial project development, and the resultant outcome. Williamson distinguished ex ante transaction costs as those which are involved in initial contract development and negotiation; these costs are highest for project development and execution (Reinsberg, 2018). Uncertainty in terms of how or whether a project is a success defines ex post transaction costs. They relate to costs resulting from a misalignment of the intent of contracts and transactions. Glatz (2014) pointed out that smart contracts operating on blockchain technology can reduce costs, or friction, of ex post contract enforcement in international development practice. We should not be quick to assume that a smart contract is equivalent to the rule of law per se, as Glatz said, since smart contracts offer ex ante solutions but do not explicitly exclude the potential for ex post legal resolution.

Transaction cost economics is an important gauge for measuring impact in development practice because transaction costs greatly affect the entire chain of practice (Reinsberg, 2018). Donors and aid institutions are concerned about whether their money is spent appropriately, and beneficiaries may on the other end not receive the full amount of aid intended. North (1997) defined transaction costs as “the costs of measuring agreements” (p. 9) and can include inflated costs due to lack of trust, transparency, and incentives for compliance. Transaction costs can also involve financial constraints related to monitoring, measurement and reporting, and tracking the movement of funds through various payment management institutions.

In global development practice, a great deal of trust and the presence of high-quality institutions are necessary for efficient delivery of goods and services. However in reality, the development sector suffers increased social and political costs due to shortcomings in trust and quality institutions (Easterly, 2002). Based on the historical body of research, Ammous (2015) concluded that the development sector suffers from imperfect information and markets, which execute high costs in transacting. In the absence of trustworthy or accessible institutions, such as banks conducting fair practices, vulnerable populations have paid high prices for market participation (Banerjee, Banerjee, & Duflo, 2011). Ammous asserted that blockchain offers vulnerable populations a competitive market alternative that circumvents the high transaction costs of financial inclusion. This is because as an alternative market mechanism, blockchain allows an escape from the high costs of market participation. He suggested the potential for this type of financial exit to coerce institutional reform may challenge the authority of the incumbent market system and development practice.

Shermin (2017) also concluded that blockchain technology is reducing transaction costs of coordination by reducing the associated moral hazard through smart contracts. In a statement linking technological change to decreased transaction costs, Davidson, DeFilippi and Potts (2016) suggested that distributed ledger technology, or blockchain, is:

> (A)n evolution of the basic institutions of capitalism, as a new variation that competes with the existing institutional species. . . .From the new institutional economics (i.e. transactions cost) perspective, the relevant analytic criterion is comparative institutional efficiency (Williamson 1979, 1991; North 1990; Ostrom 2005). The most efficient institution to coordinate economic activity—cf. markets, hierarchies, relational contracting, blockchains—is one that achieves the desired outcome at lowest transactions costs. (2016, p. 22).

Imperfect information generally results in a margin for opportunism but blockchain offers a mechanism for controlling opportunism. The following section discusses transaction costs in the literature. It presents blockchain-for-development case studies in which a discussion of transaction costs is prominently featured. The analysis that follows collates use cases in the literature where the potential for transaction cost reduction, technology, and institutions overlap.

Blockchain-for-development and Transaction Costs: Results from the Literature Survey

The information in this section is not comprehensive. As seen in the Results chapter, the list of blockchain initiatives for humanitarian relief and socioeconomic development is greater than can warrant extensive examination here. Further, not all blockchain initiatives offered enough information for consideration in this study. The literary cases which follow are similar in that they include transaction costs as a key measure of the efficiency of blockchain in development initiatives. Each of the following seven literary analyses also links the study's particular blockchain-for-development focus to specific SDGs, which can help identify the impact of blockchain in achieving the SDGs more efficiently.

Cryptocurrency, which operates on the blockchain, is a prime example Ammous (2015) used to demonstrate how access to financial services by the unbanked circumvents incumbent economic systems, forcing change to institutional behavior and practices. The focus of his argument is the costs of financial intermediation in developing countries, where high costs include not only fees, but trust and accountability. High transaction costs associated with using financial services are an obstacle to the unbanked and their economic development in general. Ergo cryptocurrency, or financial services on the blockchain, for microfinance has shown to provide the drastic reduction or even the elimination of, transaction costs for loans for the poor. In addition to financial transaction costs, Ammous suggested that the use of cryptocurrencies by lenders and borrowers can make financial accounting transparent for both parties. Banking through blockchain can automate repayments, addressing the associated cost of risk. As seen in the Results chapter, blockchain initiatives that are positioned to change the financial industry of the underbanked, part of Goal 9, make up a robust list of initiatives, at 69 projects in the data. Based on the microfinance model, development aid transactions for vulnerable populations are also becoming more efficient. By utilizing peer-to-peer, or direct lending, cryptocurrency in this sector can provide disaster relief by drastically shifting the manner and speed of funds delivery. Currently, there are three blockchain initiatives specifically aimed at providing disaster and humanitarian relief with cryptocurrency-enabled lending and direct aid.

Through two use cases, blockchain for digital identification and health care supply chain management, Pisa (2018) showed how gains can be made in the operational efficiency of development practice by offsetting transaction costs. Pisa's first use case described the current difficulty in scaling socio-political development initiatives such as providing voter identification, developing personal credit and establishing financing, and efficiently allocating public goods and services. The first use case showed that blockchain can provide a platform for legal, self-sovereign identity to refugees, and verification of identity can be a stepping stone for claiming social and financial services. A wide variety of information can be stored in tandem with identity, such as a credit score and educational and hospital records.

The second use case showed that blockchain can reduce friction and vulnerabilities in the delivery of humanitarian relief in healthcare supply chain networks. In particular, supply chains for medical products in developing countries, especially in Africa, contain falsified or substandard products. Blockchain can give data on the provenance of medical supplies that local health clinics are receiving. The transparency and tamper proof quality of blockchain within the supply chain improves inventory management capabilities. It also eliminates opportunities for counterfeit, which result in costs borne by both consumers as well as medical facilities. Health care is one of the largest sectors for blockchain initiatives, with 53 initiatives working toward making operations in the sector run more efficiently and transparently. While blockchain is being used to improve the health sector globally, it is at the same time addressing a Global

Goal. For instance, some blockchain initiatives for improved health come from the angle of achieving responsible consumption & production (Goal 12) or providing direct care to promote good health & well-being (Goal 3), while others are innovations to the industry and infrastructure (Goal 9).

Conflicts can and do arise in the process of property registration in these cases, like the deliberate alteration of titles for the benefit of government officials at the expense of legitimate land holders. Costs can include fees associated with the legal intermediation to register, alter, or determine the validity of a property rights claim. Less conspicuous costs are in many cases already borne by the rightful property owner, such as the inaccessibility to obtaining credit using property as collateral. Enforcement of contracts such as property registration is a particular challenge to developing countries, whose relevant enforcement mechanisms, usually the state, are often lacking efficacy and legitimacy. Instead, blockchain can strengthen enforcement mechanisms and disable breaches and problems associated with high transaction costs of contract breach. With an expansive discussion of blockchain for property registration, Kshetri (2017) showed that blockchain reduces transaction costs associated with registering property and/or land titles in developing countries. The cases he discussed include the Honduran government implementing a blockchain-based property registration system in partnership with the US-based startup company Factom, the Ghanan government and US-based platform Bitland for land registration, and the Georgian government in partnership with Bitcoin's BitFury to create a similar system. In sum, there are eight blockchain initiatives documented in the Results which enable recording and the verification of land and/or property titles.

The costs of doing business in financially and politically unstable countries are disincentives for large financial institutions because they are unwilling to bear the high transaction costs associated with instability (Banerjee & Duflo, 2011). Instead, blockchain for remittances and microfinance lending for unbanked populations is an opportunity to leap-frog through developmental stages through technology, skirting some of the risks and costs associated with doing business the traditional way. For unbanked and underbanked populations, accessing financial services via blockchain technology is a legitimate avenue for financial inclusion. Blockchain offers an escape to financially-vulnerable populations from the predatory lending and monopolistic behavior sometimes used by financial institutions (Ammous, 2015). The predatory activities of financial institutions are unproductive and inefficient for the consumer and the economy at large, by depreciating currencies and limiting financial services. More broadly, blockchain can facilitate improvements to what Acemoglu, Johnson, and Robinson (2001) called "private property institutions" of the economy, judiciary, monetary and institutional sectors, which are transformative for a society. Blockchain, as a virtual economy platform, can reduce the opportunity for institutionalized, extractive practices to be placed upon captive populations. Therefore international peer-to-peer capital transfer on the blockchain is not only a competitor to the financial industry structure. It not only can be a tool for the reduction of financial transaction costs, but can disrupt international remittance and microfinance systems that reverberate to wider sectors of development. Access to finance represents a large proportion of the blockchain initiatives, with 62 on the list. They vary in focus from establishing affordable and clean energy (Goal 7) to addressing climate action (Goal 13), preserving life on land (Goal 15) and life under water (Goal 14). In fact, finance-focused blockchain initiatives are some of the most diverse of all categories of initiatives, demonstrating versatility in helping address, in all, a phenomenal 13 out of the 17 Global Goals (Figure 2).

The case of the partnership between the United Nations International Children's Emergency Fund (UNICEF) and Amply has been examined by a few scholars. A study by Fabian (2018) explained how UNICEF improved outcomes for students and their teachers in South African early-childhood development centers. Fabian described the positive benefits of the project, including improved aid fund transparency and improved service delivery, made by recording subsidized payments for students and pay for teachers on the blockchain. The ixo Protocol, which hosts the Amply project, explained in its white paper how it is automating digital claims management, or the ability to manage and process claims digitally. In the Amply project, the blockchain allows educators to log student attendance, which establishes a claim. These claims generated Impact Tokens, which can be redeemed for government subsidies for the education centers. This method of claims management was argued to be scalable and demonstrated to be more efficient at processing claims quickly, replacing paper-based claims management (ixo Protocol, 2017). Blockchain initiatives to improve access to and quality of education (Goal 4) total 9, ranging from direct philanthropy to hosting personal educational credentials, to knowledge sharing.

Trading and offsetting carbon credits on the blockchain can contribute more efficiently to the development goal of taking climate action. As per the Paris Climate Agreement, carbon markets can be used for the international transfer of climate mitigation outcomes. The State and Trends of Carbon Pricing 2016 report suggested the potential for blockchain to support transactions and provide for the reduction of global carbon market implementation costs. This can be accomplished through carbon market synchronicity and smart contracts for market transactions. These methods can also support transparent monitoring and tracking of the kinds of sustainable development co-benefits that come with actions for carbon reduction (Fuessler, 2018). The Report claimed that the global costs of implementing the prescribed Nationally Determined Contributions (NDCs) for carbon reduction can be potentially reduced by one third by 2030 and by half in 2050. Indeed, as the data in the Results chapter show, innovation in energy is one of the largest groups of blockchain initiatives, with 85 projects geared towards realizing sustainable cities and communities (Goal 11), providing affordable and clean energy (Goal 7), taking climate action (Goal 13), providing decent work and economic growth (Goal 8), and innovation in industry and infrastructure (Goal 9).

Streamlined data provision facilitated on the blockchain can increase the credibility and transparency of climate change mitigation efforts while reducing the costs of measuring, reporting, and verifying (MRV). The Climate Ledger Initiative's report (2018) outlined how blockchain, when integrated with a suite of other ICTs, can reduce transaction costs involved with climate change mitigation efforts and MRV. Using blockchain for collecting and hosting impact data can reduce time and costs associated with data collection. Blockchain may enhance quantification and reporting through smart contracts and the Internet of Things, and data verification may be made more efficient and accurate. To demonstrate the increase the quality of data and reduce the cost of its collection and processing using blockchain, examples in the Climate Ledger report included protecting forests, distribution and monitoring of improved cook stoves, and maintaining a renewable energy grid. The authors maintained that all project parameters and indicators are data with market value, which policy makers can use to assess climate mitigation impacts. There are 15 blockchain initiatives addressing climate action (Goal 13) which span from the energy sector to the finance industry and to the environmental field.

Unanswered questions within the literature. Some researchers also presented potential shortcomings and downsides to using blockchain for sustainable development. Pisa (2017) pointed to how blockchain as an approach to securing digital identity will likely require a single approach or platform, which has yet to be agreed upon. If digital identity data protocols are not universalized, it could cause a host of problems in integrating the data and making it useful among multiple blockchains. Pisa also claimed that in many cases, the costs of implementation of the new technology were greater than the perceived benefits, for example, where decentralization of governance increased complexity for the local authorities. He noted that there will be resistance from the pharmaceutical industry to open data for medical supply chains because of data privacy demands. Kshetri (2017) also expressed a concern for the high degree of the complexity that decentralizing data and processes can be. Kshetri was concerned that technological diffusion may not happen rapidly or equally. Whether physical infrastructure is in place—such as internet technologies, cellular towers, and fully-operational electric grids—is based on capital constraint and presents equitability concerns. If the barrier of connectivity is overcome, then inputting accurate data becomes a concern because the task is in itself time consuming and costly. This is a human capital concern. Ensuring the accuracy of data is paramount, as the data on the blockchain is largely unalterable once coded. If there is sufficient impetus and expertise, rapid technological diffusion could still be blocked by unwilling bureaucrats, agencies, and others in positions of power due to the potential for blockchain to cause changes to the traditional hierarchies of control in the development sector. Despite the political/institutional challenges of implementing blockchain, there seems to be a trend toward decommissioning the intermediaries involved in the transaction economy. The transaction economy, or the trades that occupy the transaction economy, include lawyers and accountants, and can be large and complex (North, 1991). Where the transaction economy is robust, dismantling it may destabilize the economy if it is not offset by economic growth. If increased efficiency and transparency in the transaction economy can achieve sustainable growth is one question; how these changes may affect the labor market is yet to be seen—or even fully acknowledged, as far as research is available. Ultimately, most research presented here showed that the advantages and disadvantages of blockchain for development is mostly still in early stages and not fully understood.

Blockchain and Institutional Development

I will refer back to Hodgson's definition that institutions are "commonly held patterns of behavior and habits of thought, of a routinized and durable nature, that are associated with people interacting in groups or larger collectives" (1993, p. 253; quoted in Matutinovic, 2007, p. 1112), and Polanyi's definition (in Matutinovic, 2007, p. 1127) that markets are shapers of institutions and all types of transactions, be they economic or societal. These scholars helped lay the groundwork for our current understanding of the relationship between institutions, market function, and technology. By providing a set of norms and rules governing a social system's behaviors, institutions define how our social systems interact within the larger meta-system of our environment. Other institutional theorists including Max Weber and Friedrich Hayek expounded on the characteristics of institutions and in general, their theories hold firm to the tenet that institutions are systems of rules, either codified or implicit (Hodgson, 2006). Can institutions, then, be simplistically defined as rules that shape, or constrain and enable, behaviors? While the research on institutions may seem broad or ambiguous about what exactly an institution can encompass, said Hodgson (1988), delineating institutions by legal, nonlegal, and explicit structural systems may be more precise.

The majority of the collective institutional research also identified how important incentives are for shaping behaviors in socioeconomic systems (North, 2001; Williamson, 1987). The literature impressed that incentives are critical variables in determining market behaviors and consequently, transaction efficiency (or transaction costs). Transaction costs, as mentioned before, are one in the same as friction, and are the costs of doing business within conditions of uncertainty (Williamson, 1987). The aforementioned institutional theorists looked critically at changes in the modern world in explaining that the institution of markets is pervasive in shaping and mediating socio-economic, political and environmental inter-relations. This is perhaps obvious to the contemporary layperson, as globalized capitalism is ubiquitous in international relations and news cycles, reflecting a broadly held worldview. Institutional change, according to Johannessen (2008), is caused by changes to the influential elements of the institutional system. In addition to transaction costs, these influential elements are transformation costs, system performance, and technology. Once again, changes in efficiency (costs) feature prominently in the theory of the transformation of an institutional system. The importance of transaction costs and their role in shaping institutions are expanded on in the literature survey of the following first sub-section.

Ample scholarly research supports the predication that transaction costs are important factors that demarcate the relative efficiency of institutions. The New Institutional Economics (NIE) theory, also understood as a transaction cost perspective, and the following criterion for institutional analysis, are based on comparative efficiency. The lens of NIE theory has been applied to blockchain technology in wider behavioral contexts. The foremost scholars on this subject are Davidson, De Filippi & Potts (2016 & 2018) and they explored in depth the concept of the new institutional approach. Davidson, De Filippi and Potts (2016) asserted that blockchain is a new institutional technology of governance rather than solely as a technological change. From the new institutional approach, as well as research by the prominent institutional economics researchers North (1990) and Ostrom (1990), it can be argued that institutional change is more sensitive to technological change in the current era. The dominance of ICT in the global market makes technology a vital catalyst for change in an entrenched economic system that is slower to evolve.

Institutional Analysis: Literature Survey

This section presents arguments relating blockchain to transaction cost economics and applied institutional analysis to blockchain technology. Each author touched upon a subject relevant to institutional analysis and blockchain technology specifically. First, research on the concept of the social contract, and evidence of blockchain technology working to support the social contract, is presented. Then, how transaction costs affect individual capacity to participate in various market institutions is discussed, followed by bourgeoning theories on institutional change catalyzed by blockchain. This is followed by the subject of directional change in institutional development. The section comes to a close on the subject of polycentrism, as identified and defined by Ostrom (2010), from the perspective of the benefits of decentralization.

Reijers, O'Brolchain and Haynes (2016) discussed how blockchain technology can shape the social contract by maintaining governing functions such as voting processes, currency systems, and property and identity regimes, which exhibit or "mimic institutional processes that enable society governance" (p. 137). They distinguished the "social contract" with much of the same understanding that can be recognized in describing institutions: as the under-structure that constrains rules of principle for economic transactions and political organization. They noted how historically, the social contract had to bear the transaction costs of establishing contractual agreements. With blockchain, the social contract is altered. The decentralized ledger technology facilitates individuals to advocate for and empower themselves, through transactions such as validating and voting on contracts for the collective good. Thus, Reijers et al.'s (2016) research invited new thoughts on political organization, or the social contract, as they say—organizations in which the system is built first at the technological level. This is an enabling institutional environment that can support adaptation, compete for success, and enable cooperation, which are argued as necessary conditions for development practice (Aligica, 2005).

Johannessen (2008) provided an understanding of the transition from the industrial economy to the knowledge economy and resultant institutional changes. He argued that transaction costs are influenced not only by institutions but also the technology surrounding the larger system. He distinguished transaction costs as those pertaining to a transaction taking place where information passes "from one information process to another information process in, or between systems" incurring an expense on social systems. Other types of transaction costs are those related to the political, social, cultural, and economic fields, as transaction costs are "linked to the establishment, maintenance, and change of (operations or relations) internally in systems between the system and the environment" (p. 28), including market transactions, incentives, proprietary rights, innovation, and behavior. This definition of transaction costs fits well with the understanding of how blockchain operates. It manages information in these environments by decreasing transaction costs, because costs associated with trust, risk, fees, and information asymmetry can be mitigated by the code of the blockchain. In Johannesen's research, reducing transaction costs requires focusing on the costs of information exchange, which can hinder participation in expanding markets, which in turn affect greater economic development and the division of work. Hence, innovative technology can decrease transaction costs and invite participation in economic institutions. Expanded participation in markets for the underbanked is an area where blockchain initiatives show growth, as already presented here. The opportunities for reducing transaction costs within and among institutions that conduct development work are growing as well.

In their paper, Davidson et al. (2016) asserted that blockchain is an institutional innovation that imparts revolutionary change to economic coordination and a paradigmatic change to the institutions of capitalism. What they meant by economic coordination encompasses a variety of archetypes of institutions that rely on coordination including not just markets but also governments and society—wherever there is coordinated action amongst people. This vision of the institution of capitalism, and its immersion in a social context, reflects new economic sociologist Karl Polanyi's concept of economic embeddedness. Embeddedness is the interdependencies of institutional rules and social context, and is part of NIE theory (retrieved from https://www.britannica.com/topic/embeddedness). Expanding on this concept further, it defines economic activity as being shaped by social interactions (Ashford & Hall, 2011) rather than rational choice theory, or the idea that people behave in a way that maximizes their own individual interests. The traditional, or historical, pillars of economic coordination are centralized, hierarchical constructs, which host transaction ledgers and act as repositories of collective trust and risk. Davidson et al. (2016) afforded the term institutions with the same properties as transaction costs—or rather, that they absorb transaction costs that would otherwise be prohibitively inefficient in decentralized economic coordination (2016; 2018).

Additional research by Davidson et al. (2018) put forth that, because blockchain "make possible new institutional orders that operate at the micro-scale" (p. 15), blockchain technology is pushing the directionality of change from technology toward the larger institutional system. They suggested that there exists an inherent fragility in social systems as they grow, and the system can become overwhelmed due to increasing costs of coordinating and transacting. What can be taken from their argument is that the institutional rules which govern behavior and conduct transactions perhaps grew to a critical mass. The resultant change toward the decentralization of social coordination was arguably a radical yet natural institutional progression, nurtured by technological innovation.

They are not the only scholars to point to the value of decentralization of organizations. Elinor Ostrom wrote extensively on polycentricity (2010) and managing the global commons. Polycentric systems are evident in the context of collaborative partnerships for climate change mitigation, and her work is based on evidence of success in disintermediated governance systems in collective action problems. Her work, with her colleagues at the Workshop in Political Theory and Policy Analysis at Indiana University, concluded through analysis of governing systems for the provision of public goods and services that a heavy reliance on large-scale governance units for solving global collective-action problems is misguided. Instead, small- and medium-scale units are very relevant and necessary components in a governing framework. As for blockchain and governance, the deployment of blockchain as a decentralized technology for the enhancement and support of local government is an opportunity for governments that lack robust fiscal and human resources on a sustained basis (Zambrano, 2017).

Blockchain Through the Lens of the IAD Framework

It is useful to examine the term ‘sustainability’ from another angle, where we are not only discussing sustainable development but also the sustainability of the development project itself. The IAD framework is relevant for this research and blockchain technology might fit as a component within the IAD framework. The discussion continued with a definition of rules, how they interrelate with the other parts of the framework, and how blockchain may be used to change the rules. It concluded with the claim that blockchain technology is a tool that requires us to re-examine institutional arrangements of development practice. This is based on the literature and results which provide evidence that blockchain technology affect rules that are part and parcel to an overarching institutional construct.

There is an inextricable link conferred to the concepts of institutions and sustainability. Ostrom defined sustainability within development projects as the ability to persist where necessary and/or conclude a project that has reached self-sustenance (2017). From this perspective, institutions are important factors in enabling the sustainability of development projects. Blockchain technology as an innovation occupies a pivotal place in the institutional framework, or the Institutional Analysis and Development (IAD) framework. It is a model for comparing the composition of an institution in relation to its actors, rules, and outcomes (see Figure 4). From the vantage point of political science, I am concerned with just one factor affecting the actor arena: how rules affect incentives, and the relative transaction costs associated with different rules. I should be careful to point out that rules are just one single exogenous variable that is being analyzed here. It should not be taken that I believe they are the only factor affecting outcomes from such complex interactions. Analyzing the so-named action arena can help identify whether blockchain technology, as a disruptive innovation, is a critical determinant of change within the institutional framework. The research on blockchain and institutions thus far demonstrates that blockchain, when used in development practice for solving collective action problems, belongs in the framework as a key aspect of behavioral change.

The IAD framework is a flexible model in which variables relate to rules, actors, and outcomes. As such, there is no single standard framework for development practice. Rather, each particular set of variables for a development project or system will look like slightly different frameworks. Figure 4 shows Ostrom's general framework for institutional analysis.

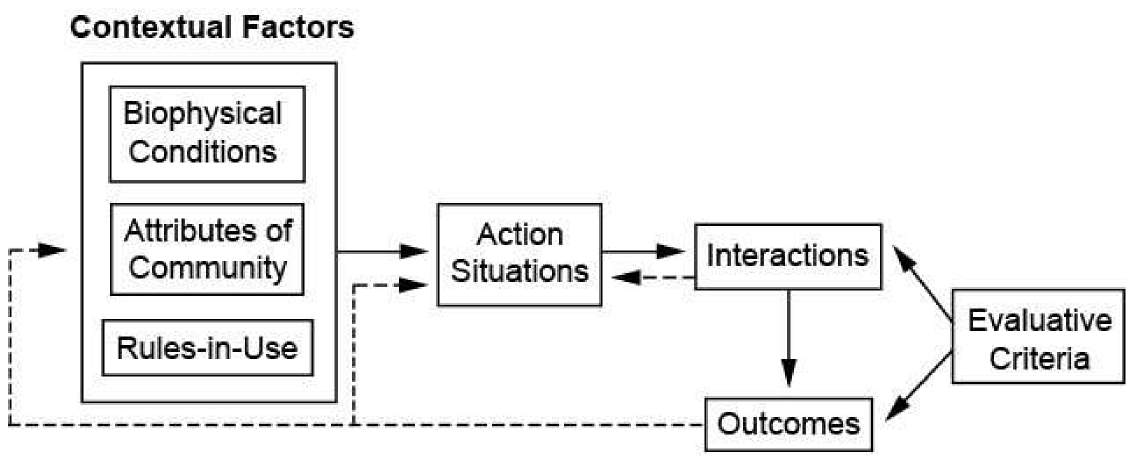

Figure 4. The IAD framework for institutional analysis (Ostrom, 2005, Figure 1.2).

Ostrom's rationale for the relevance of applying the framework for development cooperation and sustainability practice has three explanatory parts. First, the framework is multi-disciplinary, encompassing several branches of the social sciences, each addressing development assistance from different but complementary angles. Second, it is a practical method for compartmentalizing the various levels of analysis involved in the study of development aid, incentives, and sustainability. Lastly, the framework is configurable, which is helpful for analyzing the relationship among variables in the process being studied. This is especially prescient for the study of rules and their effect on incentives. If we look closely at technology in development practice, the body of research demonstrates the need for greater efficiency, better monitoring and service delivery, and to approach issues of ownership creatively. It is reasonable to assert that there is room for improvement in global development knowledge and practice. For policy analysis and recommendation then, the IAD framework can be helpful tool for beginning to organize analytical, prescriptive, and diagnostic capabilities. In fact, institutional frameworks are used extensively in contemporary policy analysis (Ostrom, 2005).

The characteristics of the IAD framework support the idea that perhaps blockchain technology is used to modify aspects or variables of the larger framework. First, several definitions are necessary for us to come to further conclusions about the placement of blockchain technology within the framework. The parts of the framework affecting outcomes include three main groups of variables: 1) rules used by participants, 2) the biophysical world containing the action arena, and 3) the community in which the action arena takes place, as seen in Figure 2. These three are exogenous variables that working in concert impact the action arena. The action arena is thus considered a cluster of dependent variables.

First we focus on rules, which Ostrom (2017) described as synonymous with institutions in the IAD framework. This distinction is made explicit here due to a commonality of conflating the concept of institutions with that of organizations. Conflating these concepts can also ignore that institutions-as-rules connotes a behavioral context. According the NIE scholars, including Ostrom, the concept of institutions includes norms, beliefs, and rules, imposed by laws. Going further, again—according to NIE scholars—rules are a kind of institution. Rules are prescriptions for behaviors. They obligate, incentivize, or prohibit actions or outcomes and are embedded with mechanisms for punishment if rules are broken. Ostrom outlined seven distinct types of rules that affect action situations. These include aggregation rules, authority (or choice) rules, boundary rules, information rules, payoff rules, position rules, and scope rules (2017, p. 71). These are seen at the perimeter of Figure 5.

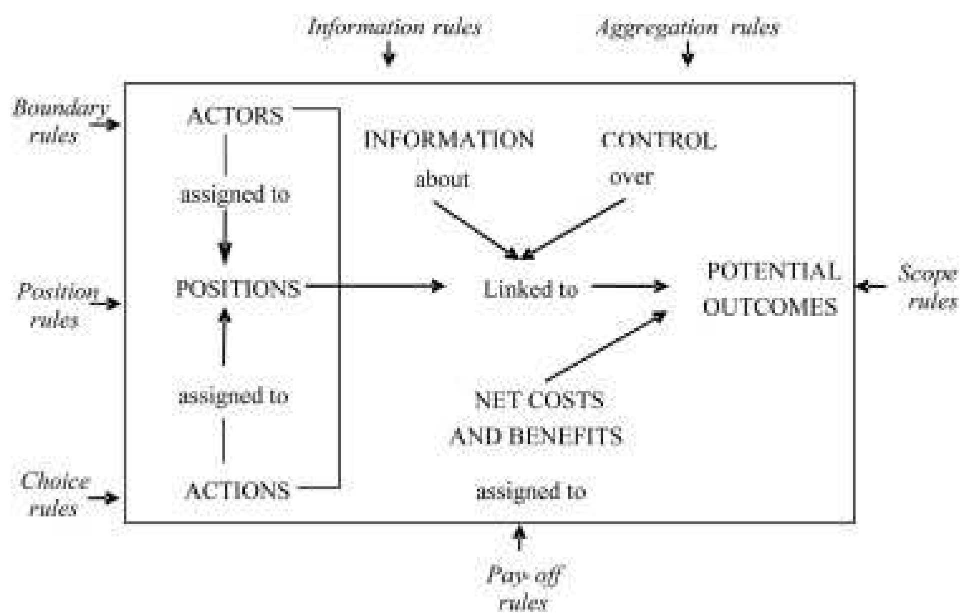

Figure 5. Classification of rules impacting the action situation. (Ostrom, 2005, p. 71, Figure 7.1).

Rather than going into full detail about the chapter in which Ostrom explained each type of rule classified in the framework, the following discussion focuses on certain types of rules. These are rules which could be directly impacted by technological innovation and subsequent behavioral changes. A brief outline, drawn from Ostrom's 2005 text, is as follows:

> Position rules create positions (e.g., member of a legislature or a committee, voter, etc.). Boundary rules affect how individuals are assigned to or leave positions and how one situation is linked to other situations. Choice rules affect the assignment of particular action sets to positions. Aggregation rules affect the level of control that individual participants exercise at a linkage within or across situations. Information rules affect the level of information available in a situation about actions and the link between actions and outcome linkages. Payoff rules affect the benefits and costs assigned to outcomes given the actions chosen. Scope rules affect which outcomes must, or may be affected within the domain (p 190).

Based on the characteristics of the case studies of fully-fleshed blockchain initiatives included in this research, I determined that blockchain technology in development practice operates in the same way as components of many of the rules. Predominantly, blockchain-for-development initiatives elicit changes in aggregation rules, payoff rules, and information rules. These assertions are analyzed in turn.

Blockchain technology can be identified as making changes in aggregation rules, as the aggregation of participants (or stakeholders) is exercised through control of decision-making. Aggregation rules clarify how persons may contribute to decisions about actions. One general form of aggregation rules is a particularly recognizable type of decision aggregation seen in blockchain's underlying behavior: symmetric aggregation rules. Symmetric aggregation rules give equilateral control of outcomes to all individuals: each participant or member of the blockchain has to agree (or meet the conditions of the code) in order for an action can happen. This is precisely what a smart contract enables—an if-then decision structure that establishes locked-in behavior and outcomes (Fuessler, 2018). Changes to payoff rules are also evident in blockchains. Payoff rules determine the rewards or punishments of actions. Again, smart contracts almost exclusively prohibit the alteration of the cost-benefit structure of the contract by the integrity of code. Costs and benefits are determined beforehand in blockchain code rather than being affected by a more complex, ex post decision environment. Blockchain changes the rules of information flow by regulating the availability of channels of information to participants. Blockchain also is claimed to increase the accuracy of information available to participants. Information rules have control over the frequency of information exchange, and it may be said that blockchain flattens the time frame in which information is exchanged, because as an open platform, information is exchanged in real-time and the timing of information distribution cannot be controlled. Less clear-cut are the ties between blockchain and position rules, where a blockchain database may still assign the positions that participants can hold and how egalitarian they may be. In private blockchains, the authority may be designated only to certain members on the chain. Boundary rules are still held intact in a blockchain platform because the open-ness of the chain is based on whether it is a private or public blockchain. Boundary rules are still in place in blockchains as long as stipulations to entry and exit (access to the chain or not) are defined and coded into the decision space. Choice rules in blockchain are evident—choices that participants can make are still based on previous actions taken in the action arena. Perhaps smart contracts offer greater clarity, as the if-then mechanism is additive and finite.

Does any of this mean that blockchain technology is a catalyst for institutional change because it changes the rules? Would this recognition mean anything for the social sciences? Institutional analysis invites inquiry about "rule-ordered relationships" (Ostrom 2017). In development practice, the measurement of impacts and outcomes can be difficult to observe and measure. For public policy analysis and formulation, looking closely at the institutional arrangements and the conditions that inform choices and outcomes can be a useful start toward the policymaking process. Thus: "policy studies must be conceived as having a basic relationship to the study of service delivery systems and their effect upon events in the world" (Ostrom 2017, p. 384). In this sense, blockchain technology presents an opportunity to re-examine the institutional arrangements that impart outcomes and policy prescriptions for collective action problems in global sustainable development. Continuing the critique of institutional arrangements, according to Ostrom, may offer a chance to advance the opportunity for self-government and equitable standards of conduct. Blockchain initiatives are attested to increase transparency of information in projects such as property rights, and to enable self-sovereignty in digital identities. They are enabling cooperative strategies for climate change mitigation and monitoring and enforcement of smart contracts. There are blockchain platforms that standardize trading carbon offsets and assets and for greater accountability and transparency in humanitarian aid. Arguably, the changes in rules are impacting outcomes in ways that are important to our understanding and assessment of the interaction between institutional structure and sustainable development practice.

Broader Implications

A more theoretical, global question this research encourages is: How will blockchain change the complexion of nation-state power? This question needs to be addressed by looking at how blockchain can change global power balance and local power balance. Some state authorities are highly decentralized due to various cultural and institutional factors, while others are highly centralized and hierarchical. By necessity, transactions occur within nation-states at both the micro- and macro-level. If local governments are empowered with a public permissioned blockchain for public service and goods delivery, will it diminish the scope of engagement between aid organizations and local government? Easterly (2002) pointed out that the field of global development often operates as a monopolistic provider in an industry with low competition. He proposed that the market for aid delivery should be expanded but it has been too difficult to implement a competitive market for development practices. Ammous (2015) proposed that blockchain can meet this challenge by introducing more market opportunities for foreign aid. Davidson et al. (2018) also made the case that blockchain presents a competitive advantage over traditional institutional hierarchies because blockchain can eliminate opportunism. Another theoretical question is that if a private permissioned blockchain is used at a national level in tandem with non-governmental agencies, will state sovereignty diminish or will institutional redundancies and inefficiencies be reduced? Further, if peer-to-peer blockchains are implemented from the bottom of society up through higher levels of social organization, will local and/or state authority be disrupted? Some of these questions are addressed by Zambrano (2017), who argued that new relationships and partnerships with governments for efficient service provision have emerged in the blockchain project space. Some nation-states have incorporated blockchain into the fabric of their governance institutions—in Honduras, Georgia, and Ghana, and most notably Estonia (Esposito, 2019; Kshetri, 2017). Implementation in these countries include e-governance to support the provision of public goods and services, open government for government archive data, and smart government for e-residency (Mougayar, 2016).

Blockchain offers a platform for so many applications discussed here, including humanitarian aid and the provision of goods and services, and it also provides a platform for alternative political governance structures, such as digital nations (DAOs). The variety of blockchain projects for a diverse landscape of users impresses on us the flexibility of the technology, spanning from private blockchain enterprises to vulnerable populations making a living in an informal economy (Lubin et al., 2018). However, does the research on blockchain show that there is a tendency toward the devolution of responsibility to the private market and end users to build out the infrastructure and regulatory framework for this technology? Despite the claim by Reijers et al. (2016) that: ". . . .(w)ithin the blockchain, sovereignty is distributed at the technological level, rather than explicitly at the political level" (p. 145), it is difficult to imagine that there will not be a governance institution involved to manage and regulate technology law and support its infrastructure. Smart contracts are not yet a substitute for the law or regulatory policies. Governments have historically shouldered the risks associated with research and development of innovative technologies, and the costs of building out the technological infrastructure and complementary regulatory environment (Ashford & Hall, 2011; Shermin, 2017). This is what Shermin referred to as the infostructure, or the "roles, policies and procedures needed to secure the electronic transfer of information" (p. 46), a web that is lacking in developing countries. Where infostructure is lacking, and the likeliness that people in developing countries will become nodes in the blockchain network remains low (Shermin, 2017), blockchain initiatives tend to support governing structures rather than supplant them. Zambrano (2017) argued that for the mean time decentralized, local governments and/or organizations can work in tandem as intermediaries for end users through a networked support for ownership and stewardship of access. Already the technology exists to address weak infostructure with partition-tolerance, as discussed, the Internet of Things (IoT), disintermediated digital networks, and what is known as a sidechain, a distinct and parallel blockchain that enables data to move between one chain and another (Mercy Corps, 2017). As awareness increases about the potential for blockchain to reduce transaction costs, interest in implementing blockchain may pick up among the various sectors of the private and public market.

Conclusions

Looking at this topic from different angles afforded a creative way of analyzing the theoretical and philosophical aspects of the technology for sustainable development through existing models and schools of thought. This research built on the scholarship on the relationship between technology and the social contract—the rules, or institutions—that governs our market behaviors and affects collective action outcomes. This research contributed to social analysis of blockchain technology and how blockchain interacts and shapes the traditional institutional norms for development practice, and specifically sustainable development.

Considering that blockchain for global development is reaching the development practice mainstream, a standardized data framework for project analysis, data sharing and evaluation may be an important next step for purposeful and directional technology diffusion in specific contexts. The exploration and experimentation of public permissioned blockchains for public goods and services delivery is another promising area for development impact research for the future. It is still true for blockchain in development practice that participation from non-governmental organizations and governments have to work together for inclusion and diffusion of equitable sharing of blockchain's potential, which harkens back to the old adage from development practice that the implementation of supportive policy and coordination are still critical aspects for project success.

Through this research I saw the efforts of researchers and practitioners to define the technology practice space while managing the inertia of innovation and diffusion. Blockchain as a technological innovation is changing sustainability and development policy prescriptions in ways that can enhance global opportunities and standards, if perhaps unequally for now. Although, the decentralization of the technology could be a leveraging tool for growth among underserved populations as well as partnerships for the Global Goals. This innovative technology might reach all the way to the edges of the socioeconomic chain, where the last opportunity for fair market participation can be mired in the barriers of information asymmetries and disincentives. For further research, I recommend a scrutiny of the opportunities and challenges in public and private markets through the lens of political economy theory.

References

AID:Tech. (2017). Empowering Through Transparency: Transparency As A Service Token (TaaST). White paper. Retrieved from: https://static1.squarespace.com/static/5b35fc188f51300267a78d49/t/5b969800b8a045c01ce321c0/1536599277839/AIDTech%2BTGE%2BWhite%2BPaper%2BV1.3.pdf

Aligica, P. D. (2005). Institutional analysis and economic development policy: notes on the applied agenda of the Bloomington School: Extending Peter Boettke and Christopher Coyne's outline of the research program of the workshop in political theory and policy analysis. *Journal of Economic Behavior & Organization, 57(2)*,159-165.

Ammous, S. (2015). Economics beyond financial intermediation: digital currencies' possibilities for growth, poverty alleviation, and international development. *Journal of Private Enterprise, 30(3):* 19-50. Available at SSRN: https://ssrn.com/abstract=283273.

Andersson, A., Grönlund, Å., & Åström, J. (2012). "You can't make this a science!"—Analyzing decision support systems in political contexts. *Government Information Quarterly, 29(4)*, 543-552.

Ashford, N. A., & Hall, R. P. (2011). Technology, globalization, and sustainable development: Transforming the industrial state. Yale University Press.

Barbier, E. B., & Burgess, J. C. (2017). The Sustainable Development Goals and the systems approach to sustainability. Economics: *Economics E-Journal, 11(2017-28),* 1-23.

Banerjee, A. V., & Duflo, E. (2011). Poor economics: A radical rethinking of the way to fight global poverty. *PublicAffairs..*

Brunner, N., & Starkl, M. (2004). Decision aid systems for evaluating sustainability: a critical survey. *Environmental Impact Assessment Review, 24(4)*, 441-469.

Burg, J., Murphy, C., Petraud, J.P., (2018). Blockchain for International Development: Using a Learning Agenda to Address Knowledge Gaps. Retrieved from: http://merltech.org/blockchain-for-international-development-using-a-learning-agenda-to-address-knowledge-gaps/

Castells, M. (2000). Toward a sociology of the network society. *Contemporary Sociology, 29(5),* 693-698.

Clegg, A. G. (2014). Could bitcoin be a financial solution for developing economies? University of Birmingham.

Cocco, L., Pinna, A., & Marchesi, M. (2017). Banking on blockchain: Costs savings thanks to the blockchain technology. *Future Internet, 9(3),* 25.

Cole, D. H., & McGinnis, M. D. (2017). Elinor Ostrom and the Bloomington School of Political Economy: A Framework for Policy Analysis (Vol. 3). Lexington Books.

Coppi, G., & Fast, L. (2019). Blockchain and distributed ledger technologies in the humanitarian sector. HPG Commissioned Report.

Davidson, S., De Filippi, P., & Potts, J. (2016). Disrupting governance: The new institutional economics of distributed ledger technology. Available at SSRN 2811995.

Davidson, S., De Filippi, P., & Potts, J. (2018). Blockchains and the economic institutions of capitalism. *Journal of Institutional Economics, 14(4)*, 639-658.

De Filippi, P. (2015). Translating commons-based peer production values into metrics: Toward commons-based cryptocurrencies. In Handbook of Digital Currency (pp. 463-483). Academic Press.

De Filippi, P., & Loveluck, B. (2016). The invisible politics of bitcoin: governance crisis of a decentralized infrastructure. *Internet Policy Review, 5(4).*

Dahlman, C., S. Mealy & M. Wermelinger (2016), "Harnessing the digital economy for developing countries", OECD Development Centre Working Papers, No. 334, OECD Publishing, Paris, https://doi.org/10.1787/4adffb24-en.

Easterly, W. (2002). The elusive quest for growth: economists' adventures and misadventures in the tropics. MIT press.

Easterly, W. (2002). The Cartel of Good Intensions: Bureaucracy versus Markets in Foreign Aid. Center for Global Development Working Paper, 4.

Edelman, R. (2017). Edelman trust barometer: Executive summary. Retrieved from: https://www.edelman.com/research/2017-edelman-trust-barometer

Retrieved from: https://www.uaepublicpolicyforum.ae/wp-content/uploads/2019/01/Digital_Governance_SDG_Estonia.pdf

Fabian, C. (2018). Un-chained: Experiments and Learnings in Crypto at UNICEF. *Innovations: Technology, Governance, Globalization, 12(1-2),* 30-45.

Fuessler, J. (2018). Navigating Blockchain and Climate Action. Climate Ledger Initiative, White paper. Retrieved from: https://www.climateledger.org/resources/CLI_Report-January191.pdf

Galen, D., Brand, N., Boucherle, L., Davis, R., Do, N., El-Baz, B., ... & Lee, J. (2018). Blockchain for Social Impact: Moving Beyond the Hype. Center for Social Innovation, RippleWorks. Retrieved from: https://www. gsb. stanford. edu/sites/gsb/files/publication-pdf/study-blockchain-impact-moving-beyond-hype_0.pdf

Glatz, F., 2014. What are smart contracts? In search of a consensus. Retrieved from: https://medium.com/@heckerhut/whats-a-smart-contract-in-search-of-a-consensus-c268c830a8ad

Goertzel, B., Goertzel, T., & Goertzel, Z. (2017). The global brain and the emerging economy of abundance: Mutualism, open collaboration, exchange networks and the automated commons. *Technological Forecasting and Social Change, 114,* 65-73.

Griessmair, M., Strunk, G., Vetschera, R., & Koeszegi, S. T. (2011). Complexity in electronic negotiation support systems. *Nonlinear Dynamics, Psychology, and Life Sciences, 15(4)*, 477-511.

Hendrickson, J. R., Hogan, T. L., & Luther, W. J. (2016). The political economy of bitcoin. *Economic Inquiry, 54(2),* 925-939.

Hilbert, M. (2016). Big data for development: A review of promises and challenges. *Development Policy Review, 34(1),* 135-174.

Huckle, S., & White, M. (2016). Socialism and the Blockchain. *Future Internet, 8(4),* 49.

Humanitarian Blockchain Summit, Plenary Sessions I & II, 2018. Conference Proceeding Livestream. Retrieved from: https://youtu.be/IJi5AJVXkH8 and https://youtu.be/p4BF6sfRldo

Hodgson, G. M. (1988). Economics and institutions. *Journal of Economic Issues, 1*, 1-25.

Identification for Strategic Development, Strategic Framework, 2016. White paper. World Bank Group.

ixo Protocol. (2017). The Blockchain for IMPACT. version 3.0, 2017: Technical White Paper. ixo Foundation. Zug, Schweiz. Retrieved from: https://ixo.foundation/wp-content/uploads/2018/08/ixo-Technical-White-Paper-w-Cover-Version-3.0-8-December-2017-1.pdf, and https://ixo.foundation/faqs/.

Jensen, M. L., Lowry, P. B., Burgoon, J. K., & Nunamaker, J. F. (2010). Technology dominance in complex decision making: The case of aided credibility assessment. *Journal of Management Information Systems, 27(1),* 175-202.

Johannessen, J. A. (2008). Explaining institutional change: aspects of an innovation in the new institutional economy. *Kybernetes, 37(1),* 20-35.

Johns, F. (2016). Global governance through the pairing of list and algorithm. *Environment and Planning D: Society and Space, 34(1),* 126-149.

Karacaoglu, Y., Mocan, S., & Halsema, R. A. (2018). The world bank group's technology and innovation lab, from concept to development: A case study in leveraging an IT department to support digital transformation. *Innovations: Technology, Governance, Globalization, 12(1-2),* 18-28.

Kewell, B., Adams, R., & Parry, G. (2017). Blockchain for good?. *Strategic Change, 26(5),* 429-437.

Kshetri, N. (2017). Can blockchain technology help poor people around the world. *The Conversation, 1*.

Kshetri, N. (2017). Will blockchain emerge as a tool to break the poverty chain in the Global South?. *Third World Quarterly, 38(8),* 1710-1732.

Lepri, B., Oliver, N., Letouzé, E., Pentland, A., & Vinck, P. (2018). Fair, transparent, and accountable algorithmic decision-making processes. *Philosophy & Technology, 31(4),* 611-627.

Linders, D. (2013). Towards open development: Leveraging open data to improve the planning and coordination of international aid. *Government Information Quarterly, 30(4),* 426-434.

Lubin, J., Anderson, M., & Thomason, B. (2018). Blockchain for global development. *Innovations: Technology, Governance, Globalization, 12(1-2),* 10-17.

Matutinović, I. (2007). An institutional approach to sustainability: Historical interplay of worldviews, institutions and technology. *Journal of Economic Issues, 41(4),* 1109-1137.

Mercy Corps. (2017). A Revolution in Trust: Distributed Ledger Technology in Relief & Development. White Paper. Retrieved from: https://www.mercycorps.org/sites/default/files/Mercy-Corps-A-Revolution-in-Trust-Blockchain-May-2017_0.pdf

Mougayar, W., 2016. The Blockchain is Perfect for Government Services. Coin Desk. September 3. Retrieved from: https://www.coindesk.com/Blockchain-perfect-government-services-heres-blueprint

North, D. C. (1991). Institutions. *Journal of Economic Perspectives, 5(1),* 97-112.

North, D. C. (1992). Transaction costs, institutions, and economic performance (pp. 13-15). San Francisco, CA: ICS Press.

Ølnes, Svein, Ubacht, J., & Janssen, M.F.W.H.A. (2017). Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. Government Information Quarterly: An International Journal of Information Technology Management, Policies, and Practices, 34(3), Urn:issn:0740-624x.

Open Data Handbook. Retrieved from: http://opendatahandbook.org/guide/en/what-is-open-data/

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change, 20(4),* 550-557.

Ostrom, E. (2009). Understanding institutional diversity. Princeton university press.

Pierrot, C., & Wesolowski, B. (2018). Malleability of the blockchain’s entropy. *Cryptography and Communications, 10(1),* 211-233.

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

Pisa, M., & Juden, M. (2017). Blockchain and economic development: Hype vs. reality. Center for Global Development Policy Paper, 107, 150.

Reijers, W., O'Brolcháin, F., & Haynes, P. (2016). Governance in blockchain technologies & social contract theories. *Ledger, 1*, 134-151.

Reinsberg, B. (2018). Blockchain technology and the governance of foreign aid. *Journal of Institutional Economics, 15(3),* 413-429.

Ryk-Lakhman, Ira, (2019). Blockchain innovation key to solving humanitarian challenges. Cointelligence, 11 January 2019. Retrieved from: https://www.cointelligence.com/content/blockchain-humanitarianism/

Scott, B., (2015). Visions of a techno-leviathan: The politics of the bitcoin blockchain. Policy Paper. Berlin, Germany: Rosa-Luxemburg-Stiftung.

Scott, B. (2016). How can cryptocurrency and blockchain technology Play a role in building social and solidarity finance? (No. 2016-1). UNRISD Working Paper.

Shermin, V. (2017). Disrupting governance with blockchains and smart contracts. *Strategic Change, 26(5),* 499-509.

Swam, M., & De Filippi, P. (2017). Towards a philosophy of blockchain: a symposium. *Metaphilosophy, 48(5),* 603-619.

Taeed, Olinga., (2017). Seratio Blockchain Architecture: An open source blockchain transaction platform enacted by non-financial Proof-of-[…] metrics that govern the extent of the transaction and evaluate the benefits. 10.13140/RG.2.2.32002.68807.

Tillemann, T., Price, A., Tillemann-Dick, G., Knight, A., (2019). The Blueprint for Blockchain and Social Innovation. New America, white paper. Retrieved from: https://www.newamerica.org/bretton-woods-ii/blockchain-trust-accelerator/reports/blueprint-blockchain-and-social-innovation/100-key-terms-for-understanding-blockchain-for-social-impact/

Tonn, B., & Stiefel, D. (2012). The future of governance and the use of advanced information technologies. *Futures, 44(9),* 812-822.

United Nations Department of Economic and Social Affairs, (2017). Sustainable Development Goals report 2017.

U.S. Senate. (2017). Senate committee on foreign relations, subcommittee on multilateral international development, multilateral institutions, and international economic, energy, and environmental policy hearing on global philanthropy and remittances and international development: Multilateral International Development, U.S. Senate, (2017). Retrieved from: https://www.foreign.senate.gov/hearings/global-philanthropy-and-remittances-and-international-development-050317

Velasco, P. R. (2017). Computing ledgers and the political ontology of the blockchain. *Metaphilosophy, 48(5),* 712-726.

World Food Programme, (2017). 2017: A Year in Review. The wfp innovation accelerator world food programme. Retrieved from: https://innovation.wfp.org/year-review-2017/docs/WFP_Innovation_report2017-Static.pdf

Zambrano, R., Seward, R. K., & Sayo, P. (2017). Unpacking the Disruptive Potential of Blockchain Technology or Human Development; Report of International Development Research Centre. International Development Research Centre: Ottawa, ON, Canada.

Zwitter, A., & Herman, J. (2018. Blockchain for Sustainable Development Goals:# Blockchain4SDGs-Report, July 2018. In Blockchain4SDGs workshop. Rijksuniversiteit Groningen.

Zwitter, A., & Boisse-Despiaux, M. (2018). Blockchain for humanitarian action and development aid. *Journal of International Humanitarian Action, 3(1),* 16.