Understanding Smart Contracts as a New Option in Transaction Cost Economics

Completed Research Paper

Hanna Halaburda
New York University
Stern School of Business
44 W 4th St. New York, NY 10012
hhalaburda@gmail.com

Natalia Levina
New York University
Stern School of Business
44 W 4th St. New York, NY 10012
nlevina@stern.nyu.edu

Semi Min
New York University
Stern School of Business
44 W 4th St. New York, NY 10012
smin@stern.nyu.edu

Abstract

Among different concepts associated with the term blockchain, smart contracts have been a prominent one, especially popularized by the Ethereum platform. In this study, we unpack this concept within the framework of Transaction Cost Economics (TCE). This institutional economics theory emphasizes the role of distinctive (private and public) contract law regimes in shaping firm boundaries. We propose that widespread adoption of the smart contract concept creates a new option in public contracting, which may give rise to a smart-contract-augmented contract law regime. We discuss tradeoffs involved in the attractiveness of the smart contract concept for firms and the resulting potential for change in firm boundaries. Based on our new conceptualization, we discuss potential roles the three branches of government – judicial, executive, and legislative – in enabling and using this new contract law regime. We conclude the paper by pointing out limitations of the TCE perspective and suggesting future research directions.

Keywords: Smart contracts, Transaction Cost Economics, Government

Introduction

In the years since blockchain entered the mainstream conversation, enthusiasm for this technology has been remarkable in both industry and academia. Proponents of blockchain have celebrated its invention as a new technological revolution comparable to the invention of the steam engine or the Internet (Iansiti and Lakhani 2017). Blockchain technology was developed as part of Bitcoin's protocol. Bitcoin is a cryptocurrency developed amid the financial crisis of 2008 when trust in governments and corporation severely crumbled (Werbach 2018). The white paper written by Nakamoto (2008) proposed that Bitcoin would offer a new approach for addressing problems associated with central authorities by establishing collective trust based on decentralized foundations.

Since the publication of Nakamoto's famous Bitcoin paper, however, we have witnessed a wide variety of implementations and uses of blockchain technologies. For example, there are many implementations of blockchains within firms or under centralized control of several firms such as, for example, the Corda system developed and controlled by R3 consortium of financial institutions (Brown et al. 2016). Most famously, the Ethereum platform has been developed and popularized as an example of blockchain technology implementation other than cryptocurrencies (Fenu et al. 2018). Nowadays, the term blockchain is being used as a catch-all aggregation of different concepts, some of which have existed and been adopted by organizations well before Bitcoin (Halaburda and Sarvary 2016). At least three different concepts have been popularly associated with the term blockchain: cryptographic security of recorded history, smart contracts, and distributed ledger (Halaburda 2018).

Smart contracts, in particular, have been one of the key concepts popularized by blockchain technologies and especially by the Ethereum platform. The concept itself, however, predates blockchain technologies (Szabo 1997) and can be implemented without them. In this paper we unpack this concept within the framework of institutional economics, and, specifically, the Transaction Cost Economics (TCE) theory (Williamson 1985). According to TCE, governance is an effort to mitigate conflict and acquire mutual gains from transactions. The modes of governance (e.g., markets, hybrids, firms) are distinguished in part by distinctive contract law regimes (Williamson 2002). We propose that widespread adoption of the smart contract concept can create a new option especially relevant to the public (commercial) contract law regime. This new *smart-contract-augmented contract law regime* has a potent to shift economic activity between firms and markets. We will discuss specific tradeoffs involved in enabling such shifts and different considerations that may speed up or slow down adoption of this new contract law regime. Using our new conceptualization, we will discuss the potential roles the three branches of government – judicial, executive, and legislative – can play in enabling and using this new public contract law regime. We conclude by discussing the limitations of the TCE view of firm boundaries as well as suggesting future empirical research directions based on our conceptualization.

Concept of Smart Contracts

The idea of a smart contract was formulated by Szabo (1997) – a decade prior to the famous Bitcoin paper (Nakamoto 2008). Smart contracts are defined as automatically executable agreements between parties based on pre-defined codified criteria. Parties to such an agreement would specify obligations and rights that are expected to be automatically enforced based on digitally-encoded triggers. The execution of the agreement through a smart contract would technologically disable opportunities for renegotiation unless the agreement terms specifically allowed for that possibility. Szabo (1997) envisioned that the full cycle of the contractual process including search, negotiation, performance, and adjudication will be handled by hardware and software without involving human actions.

Szabo (1997) illustrated his concept of a smart contract with a car lease example. If the driver failed to make lease payments, the car would automatically lock itself based on a digitally recorded trigger, and the control would revert to the lender or the bank. Such a technology-enabled way of enforcing an agreement could avoid relying on a costly court system (Werbach 2018). A familiar example of a smart contract is an automatic cancellation of auto-insurance by an insurance company if a timely payment is not received. Another widespread example of digitally-enabled automatic contract execution is an automated recurring payment agreement that individuals commonly set up through their banks to pay bills (Halaburda 2018). We have witnessed a long history of such contracts being centrally executed by commercial and government institutions.

The success of Bitcoin encouraged advocates of the smart contract concept to start developing general-purpose contracting platforms that enable automatic execution of digitally encoded contractual terms outside of the Bitcoin system (Werbach and Cornell 2017). The most heralded platform is Ethereum. In 2013, the initial idea of Ethereum was proposed by Vitalik Buterin, who claimed that Bitcoin needed a general scripting language enabling the development of diverse applications (Werbach and Cornell 2017). After the rejection of his proposal by the Bitcoin community, he wrote an Ethereum whitepaper proposing the development of a new contracting platform:

> What Ethereum intends to provide is a blockchain with a built-in fully fledged Turing-complete programming language that can be used to create "contracts" that can be used to encode arbitrary state transition functions, allowing users to create any of the systems described above, as well as many others that we have not yet imagined, simply by writing up the logic in a few lines of code (Buterin 2014, p. 1).

In 2014, a small development team – Ethereum foundation – began to create the Ethereum platform (Hutten 2018). The scripting language of Ethereum is much more powerful than that of Bitcoin, and thus, any functions can be processed and executed by a computer. Given its much more powerful scripting language, the promise of Ethereum as described in one article is to "transform law, finance, and civil society" (Epstein 2015). The substantial number of followers ranging from developers to cryptocurrency enthusiasts are attracted by such a promise and became members of the Ethereum community. In a crowdsale of Ethereum, over 18 million dollars were raised by selling *ether*, the native token of Ethereum (Schneider 2015). Eventually, Ethereum became the second highest valued blockchain-based system with a market cap of over 17 billion dollars as of April 2019.

Increasing adoption of the Ethereum platform has provided a capacity for reliable and accessible infrastructure that customizes and executes a variety of peer-to-peer agreements (Werbach 2018). While traditional commercial contracts also offer this capacity, *the most important novel aspect of the smart contract concept is the ability for the agreements to execute automatically, thereby eliminating the possibility of renegotiation*.

A less novel but still notable aspect of the smart contract concept is the improved, and potentially more cost effective, monitoring of digitally codified contractual terms. Technologies that allow for better and cheaper monitoring of contractual terms have been developed and deployed for decades (Asif 2005). For example, in digital supply chains, contacting parties can use wireless readings from a GPS sensor and a digital thermometer to determine whether a container of produce reaches its destination without exceeding a pre-defined temperature. Adoption of the smart contract concept in practice further propels the use of digital sensors and other digital data inputs in contract monitoring because monitoring could be tied directly to contractual terms through automatic execution (Iansiti and Lakhani 2017).

Transaction Cost Economics Overview

Transaction cost economics (TCE) has posited that firms and markets are alternative modes of governing economic activity in the society (Williamson 1985). According to this theory, firms exist to economize on governance costs which arise when a market is used as a governance mechanism. Firms govern transactions by directing and controlling agents' actions through managerial hierarchies. Markets, on the other hand, govern transactions through contractual agreements, which can be enforced through a court system.

TCE assumes that agents are self-interested ("opportunity seeking with guile") and boundedly rational (Williamson 1985). Self-interest refers to a "condition of human nature with which the economic organizational studies should be actively concerned" (Knight 1941 as cited in Williamson 1985, p. 6). Agents are boundedly rational due to the limits imposed by biological, physical, and social factors (Simon 1957). Bounded rationality forestalls comprehensive contracting as it is impossible to specify how the parties will act in all possible contingencies (Williamson 1985). The incompleteness of a contract can give rise to opportunistic behavior *ex post* (Williamson 1971). Hierarchical governance mechanisms can resolve conflict by imposing order "from above" and allow firms to adapt to new conditions in situations when market contracts fail (Williamson 1985). Parties also should make efforts to select counterparties in terms of reputation and reliability and establish *ex post* transactions safeguard against the risk of opportunism (Williamson 1967; Williamson 2008).

Governance costs arise due to asset specificity in conditions of high uncertainty and transaction infrequency (Williamson 1973; Williamson 1985). As Williamson summarizes in his 2008 paper:

> The key attributes of transactions to which TCE calls attention are asset specificity, uncertainty and frequency. Although much of the explanatory power of the theory turns on asset specificity (Williamson 1971, 1975, 1985; Klein et al. 1978), which gives rise to bilateral dependency (or the absence thereof), bilateral dependency by itself would not pose a problem were it not for the need for the parties to an incomplete contract to adapt to disturbances. (Williamson, 2008, p. 8)

Asset specificity creates a condition of dependences on the owner of a certain asset because such an asset's value depends on another input to which the former is specific (Williamson 1985). In other words, it is hard to put transaction-specific assets to other uses if the relationship breaks down. Hayek argued that an uncertainty related economic problem is "mainly one of adaptation to change in particular circumstances of time and place (Hayek 1945, p. 524)." In the presence of a relationship-specific asset, once parties face the need for adaptation, the ease of contract enforcement vanishes and the costs associated with the use of courts or other adjustment mechanisms arise (Williamson 1985).

Both firms and markets face governance costs. Comparative governance costs impact the make-or-buy decision, and therefore, the boundary of the firm (Williamson 1985). In this view, inside the firm, governance costs are associated with running a bureaucracy. Such costs are higher than the costs of relying on a simple contract if asset specific and uncertainty are low, as they involve enabling numerous costly administrative controls invoked often excessively for small and large disputes. In the market, which operates within a public contract law regime, governance costs are associated with (1) finding vendors, (2) writing contracts, (3) monitoring vendors, and (4) enforcing contracts through courts if necessary (Dahlman 1979; Dyer 1997; North 1990; Williamson 1985). Contract writing costs include the costs of specifying, negotiating, and safeguarding agreements (Williamson 1985). Contract enforcement costs include contract monitoring as well as costs associated with dispute resolution. Even if such disputes are settled out of court there are significant costs associated with using arbitrage, renegotiating, or simply ignoring the conflict (Galanter 1981; Williamson 2002).

Williamson takes particular care, especially, in his later work to discuss that contract law regime that governs a particular transaction is context specific rather than general. He writes:

> Yet another organizational dimension that distinguishes alternative modes of governance is the regime of contract laws. Whereas economic orthodoxy often implicitly assumes that there is a single, all-purpose law of contract that is costlessly enforced by well-informed courts (Williamson, 2002, p. 177)

Therefore, when facing a make-or-buy decision, it is important to consider the relative costs of running the hierarchy internally that would enable a private contractual regime versus relying on the public contract law regime to enforce commercial contracts. Williamson (1985) argues that for transactions with high asset specificity, in conditions of high uncertainty and low frequency, the governance costs associated with running a hierarchy are lower than public contracting. In his later work, Williamson (2002, 2008) further nuances his initial binary choice by discussing complex contracts with multiple safeguards and hybrid organizations (or relational contacts) where both hierarchical and contractual mechanisms are used to govern economic exchanges.

The Role of New Information Technology on TCE Analysis

IS research has embraced TCE as one of its key theoretical bases. Generally, IS literature argues that Information Technology (IT) has been responsible for the shift of economic activity from firms to markets. Seminal paper by Malone (1987) argues that adoption of IT would reduce asset specificity by enabling flexible production processes relying on standardized components:

> Flexible manufacturing technology allows rapid changeover of production lines from one product to another. Thus, some physically asset-specific components that are similar to other, non-specific components may begin to be produced by more companies. Companies that in the past would not have tooled up for such a small market now may produce small numbers of these components without significant switch-over costs. (p. 489)

They also foresightedly predict the rise of electronic markets, which resemble modern digital platforms, which help enable contracting by reducing costs of finding and evaluating appropriate vendors (Malone et al. 1987 p. 488). They referred to this idea as "electronic brokerage effect" (ibid). Some nuance was introduced into this argument subsequently (Gurbaxani and Whang 1991) as IT could possibly shift economic activity in the opposite direction from markets to firms because the hierarchical governance form would also benefit from the new technology. Specifically, the costs of running a hierarchy associated with implementing uniform policies and monitoring employees would be reduced.

A series of empirical papers that followed investigated these propositions by investigating how the level of IT investment in a firm or industry influenced firm size or the degree of vertical integration. Most famously, Malone et al. (1994) conducted analyses of longitudinal, multi-industry, economy-wide data that indicated that IT investments are associated with a smaller firm size. Others have found that firms that are less vertically integrated have a higher level of IT investment (Dewan et al. 1998; Hitt 1999). Well-aligned with the TCE-based argument, other researchers found that IT is associated with a decrease in vertical integration when demand uncertainty is high or industry concentration is low (Ray et al. 2009). Contrary to Malone et al.'s (1987) general prediction, these same researchers found that IT is associated with an increase in vertical integration when industry concentration is high or demand uncertainty is low (ibid). Moreover, they argue that historically, vertical integration rates in US firms have increased suggesting that not only transaction cost-based consideration but other factors such as industry concentration and the nature of demand might play a role (Ray et al. 2009). Most recently, Forman and McElheran (2011), drawing directly on TCE, examine the impact of different types of IT investments – customer-facing IT and upstream supplier-focused IT – on intrafirm transfers. They find that investment in upstream supplier-focused IT indeed leads to decrease in intrafirm transfers (ibid).

A large body of research on IT outsourcing has turned to TCE as a key theory for explaining why IT is sourced internally or externally-based on asset specificity, uncertainty, and transaction frequency (e.g., Ang and Straub 1998). There is mixed, not to say weak, empirical support for the basic TCE-based hypotheses in IS outsourcing literature as most studies find that production-based, resource-based, or institutional influence arguments tend to outweigh contractual risk concerns (Levina and Ross 2003; Ang and Staub 1988). Most of the empirical evidence suggests that firms outsource even in the case of high asset-specificity and uncertainty. While on the surface TCE-based arguments are not sustained, a more detailed set of studies by Mani et al. (2012) argue that when outsourcing complex IT projects, firms rely on hybrid contracting structures and, thus, do not violate TCE principles.

Overall, IS literature broadly suggests that TCE offers us an insightful tool for understanding the implications of new technology on firm boundaries, but that it does not offer a comprehensive treatment of this question. IS economists highlight the importance of taking into account the nature of production processes, demand characteristics, and competitive environment in understanding the impact of IT on firm boundaries. Yet, when an emergent technology specifically promises to reduce the costs associated with enforcing contracts, which is the core of the organizing concept of smart contract, TCE is an attractive theory to focus on.

Smart Contracts as a new Option in the Public Contract Law Regime

An often-overlooked part of TCE is its emphasis on the presence of the "contract law regime" that underlies transaction governance. Specifically, Williamson argues for "legal pluralism" as opposed to the "legal centrism" perspective, which he claims is often assumed by economists, and observes "that many disputes between firms that could under current rules be brought to a court are resolved instead by avoidance, self-help, and the like" (2002, p. 177). Moreover, Williamson observes that many types of disputes cannot be brought to a public court at all as commercial contracts cannot be fully specified due to bounded rationality (Williamson 1985, p. 32, 220). This leads to an organization becoming their "own court and ultimate appeal" systems, in essence, creating their own private "contract law regime." (Williamson, 2002, p. 178).

Considering the potential impact of the smart contract concept on the private versus public contract law regimes, and following Gurbaxani and Whang's (1991) argument, we may imagine that smart contracts like other IT that reduces the costs of monitoring economic transactions may have ambiguous impact on the firm boundary. However, unlike general purpose monitoring IT, a key part of the conceptual idea behind smart contracts is the prevention of renegotiation due to their automatic execution. TCE's key postulate, however, is that private contract law regime exists in order to settle disputes that arise precisely when future states of the world are not possible to fully specify in commercial contracts. In these cases, the cost of a hierarchy is justified because it allows to resolve *ex post* disputes through managerial top-down authority. While some aspects of private contract law regime that rely on monitoring agents' actions can benefit from digital automation (Murray et al. 2019), the novelty of automatic contract enforcement between independent parties associated with the smart contract concept is best theorized as a transformation of public (rather than private) contract law regime.

We propose specifically that widespread adoption of sociomaterial practices associated with the concept of smart contract can transform existing public contract law regime into a ***smart contract-augmented contract law regime****. This augmented contract law regime will include a new option for executing market transactions. We will argue that adding this option may be particularly appealing for a limited set of transactions for which the costs of digitally codifying actions, states, and inputs involved in a contractual agreement is relatively low and asset specificity is relatively high. We will theorize how this new option fits with the general TCE framework and what set of tradeoffs arise.*

The adoption of well-designed smart contracts can reduce transaction costs in two ways: by lowering contract monitoring costs (Szabo 1997) and by preventing renegotiation of contractual terms (Raskin 2016; Werbach and Cornell 2017). An obvious, but perhaps less important, part of the smart contract concept is lowering contract monitoring costs. The digitization of codified triggers necessary for enabling the execution of smart contracts can lower monitoring costs by reducing ambiguity around what constitutes compliance with contractual terms, thereby preventing costly disputes, and by relying on software to perform monitoring (Szabo 1997).

Most importantly in terms of lowering transaction costs, the smart contract concept promises to prevent renegotiation. In the traditional public contract law regime, contracting parties often include legal and court fees associated with relying on a court system to resolve disputes even in well specified contracts (Savelyev 2017; Wright and De Filippi 2015). There could also be additional enforcement costs associated with incentivizing contract compliance such as provision of collateral assets and contract insurance (Savelyev 2017). Disputes among parties often arise due to holdup problems, which occur when in case of a multi-period relationship between transacting parties, one or both parties need to make relationship-specific investments while facing a possibility that the agreement will be renegotiated after the investment is made. Traditional contractual arrangements do not provide a cheap way for dealing with this problem because they can't prevent renegotiation (Williamson 2002). In contrast, with smart contracts, once the agreement is made, the contractual terms are inalterable, and the transactions are executed automatically based on encoded triggers. Thus, legal scholars have claimed that by preventing renegotiation the smart contracts may reduce the risk of the holdup problems in the market (Casey and Niblett 2017; Holden and Malani 2017).

The smart contract concept, however, may not be applicable to a wide range of transactions, as for many transactions (e.g., IS development contracts), it may be impossible or extremely costly to write a sensible smart contract. Specifically, to enable automatic monitoring and enforcement, parties to an agreement need to encode in digital, programmable terms (1) actions that each party is expected to take (e.g., make a payment) in (2) all relevant future states of the world (e.g., when full or partial service is performed) triggered by (3) certain inputs from sensors or information inflows (e.g., a container of fruit reaches a destination port without the container exceeding a pre-specified temperature). Moreover, a *well-defined smart contract* will specify these three aspects in a way that adequately captures each party' intent in the face of automatic execution. We introduce the notion of *smart contract specification costs* to capture the costs of digitally codifying an agreement into a well-designed smart contract.

Incurring smart contract specification costs may not be justified given the current public contract law regime. Bearing such costs becomes more attractive if parties can rely on smart-contract augmented contract law regime with lower contract monitoring and enforcement costs. In this new regime, economic actors would experience a new *tradeoff* which involves comparing (1) the increased costs of smart contract specification and (2) decreased costs associated with automatic monitoring and enforcement of smart contracts as compared to such costs in the old private (hierarchy) or public (courts) contract law regimes. The cost savings referred to in (2) are particularly salient for transactions with a high degree of asset specificity because they will benefit the most from preventing renegotiation. This tradeoff is depicted in Figure 1.

For example, food production firms such as Dole often own farms in order to gain a market premium attached to certain aspects of agricultural product quality (e.g., aesthetics and freshness) and agricultural production process (e.g., sustainability and fair trade) (Karst, 2019). In order to ensure that these value parameters are met, these firms exercise control over farming processes through their managerial hierarchies. Had farmers been operating independently, they would be forced to make a specific investment into some aspects of production that only a particular buyer (e.g., Dole) may be willing to pay a premium on. If Dole reneges on a contract, the farmer loses the investment. At the same time, it is costly for the buyer in this situation to verify that the product meets their specifications without exercising a great degree of control over the production process.

The adoption of smart contracts, however, may change the boundaries of such firms if the characteristics of the food quality and production that they put a premium on can be digitally codified and included in the contracts. For example, in order to purchase sustainable foods, an infrastructure equipped with sensors in the soil and a digital platform can be created to monitor what kind of water is used, whether fertilizers are applied, or whether the farmers rotate crops and periodically rest their land to increase the soil fertility.

When the breach of contract occurs, payment will not be processed. The attractiveness of a smart contract is higher compared to a traditional contract because automatic executive based on sensor data would offer lower contract enforcement costs as compared to invoking a court system or engaging in lengthy negotiations.

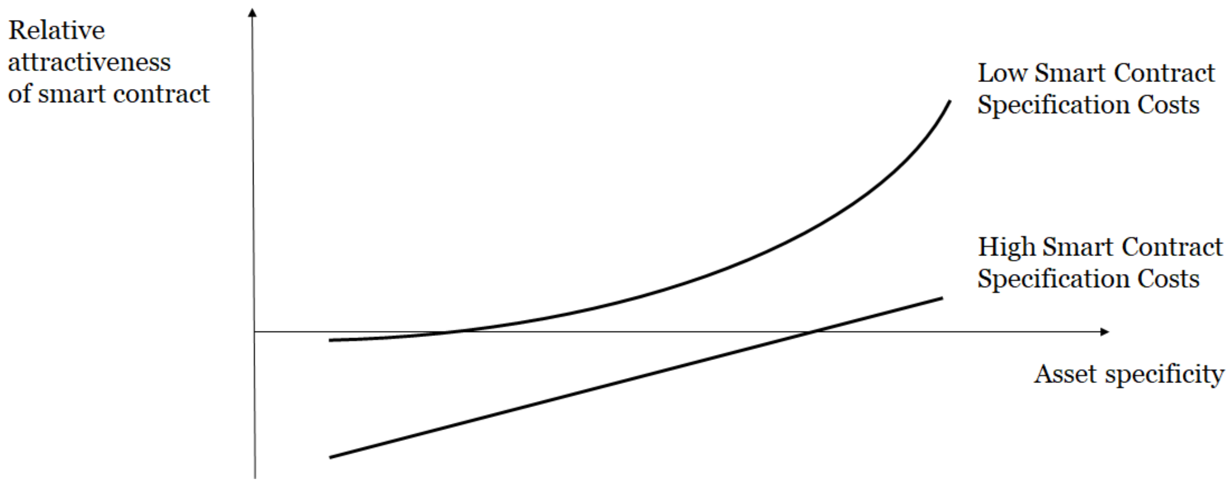

Figure 1. Relative Attractiveness of Smart Contract Concept

It may take a great degree of experimentation for firms to understand the tradeoffs captured in Figure 1 for different kinds of agreements, with different types of partners, and with diverse technological environments. Industries and governments may play a role in institutionalizing certain practices of smart contracting, but in certain areas, experimentation may be ongoing and firm boundaries may shift back and forth. IS outsourcing literature provides ample examples of such "unsettled" shifts. Within the 40+ year history of IS outsourcing even for services where contractual agreements can be fairly well specified such as the IT helpdesk service (e.g., Jaiswal and Levina 2012) we see a variety of unexpected factors arising that make it hard to optimize transaction costs for this service.

Moreover, as some activities are pushed towards a higher degree of codification, they may become more standardized (Malone et al. 1994; Argyres 1999, Levi et al. 2003). For example, the growing use of contractual work in an online labor marketplace has facilitated the creation of standard templates (Popiel 2017). We may see some of these fully codified activities become automatable. If the technology used to automate these activities presents a contractual hazard due to its uncertainty and asset specificity, "client" firms may try to bring its ownership inside. Hence it is possible that firm boundaries would shift yet again.

Smart Contract Concept Adoption Considerations

Beyond theoretical tradeoffs that may lead to a shift of firm boundary associated with the wide adoption of the concept of smart contracts, there are a number of considerations that may slow down such adoption. We will discuss several of these factors, specifically those pertaining to the economic forces that may affect such adoption.

Given their relational nature, adoption of smart contracts would offer benefits to its adopters only if others would also adopt, giving rise to network effects. A party adopting smart contracts needs to bear up-front costs of acquiring knowledge of the technology. These costs may be justified by the benefits of smart contracts. If, however, there are very few potential partners on the other side of the agreements that have already adopted the new technology, the benefit could be too small to justify the adoption costs. Every participant is willing to bear the cost of adoption only if sufficient mass of other participants have already adopted. This may create inefficient inertia in the market, where nobody adopts only because they don't see anybody else adopting. It is a well-known problem in environments with network effects (Katz and Shapiro 1994). Institutional, top-down coordination or setting a common standard typically helps to overcome this inertia (ibid).

Currently, for example, Ethereum platform provides ability to implement a wide variety of peer-to-peer smart contracts aiding adoption of this concept. However, Ethereum as a general purpose infrastructure, and as such does not alleviate the costs associated with adoption for many users who have specific needs. We are already witnessing and likely to continue seeing alternatives to Ethereum as well as special-purpose digital platforms being built to support special-purpose smart contracts ("A Deeper Look" 2018). Such platforms could provide additional services which would ease adoption and provide further transaction cost savings for firms considering moving additional transactions outside their boundaries. First, they could reduce various expenses such as contract drafting (including integrating sensor data) and negotiation costs through the provision of standardized smart contracts templates (Oranburg and Palagashvili 2018; Werbach and Cornell 2017). Furthermore, such platforms could decrease vendor search costs by providing cost-effective means to access information, reducing the burden of the parties to contact a huge number of alternative counterparties individually (Bakos 1998; Popiel 2017). For example, online platforms often screen out obviously inappropriate participants by defining platform participation criteria and building reputation systems (Bakos 1991; Malone et al. 1994). They can also reduce the problem of information asymmetry by helping optimize contractual terms through aggregation of historical data, thereby increasing the counterparty trust and accountability (Savelyev 2017). These benefits, however, arise from the use of particular digital platforms supporting smart contracts and not from the concept alone.

While the inefficient inertia in adoption is a typical problem for diffusion of any new technology with network effects, there is another problem that pertains specifically to smart contract adoption. Smart contracts by design refer to agreements that will need to be executed in the future. Also, smart contracts are software programs – they need infrastructure to run: a system and hardware. The promise of automatic monitoring and execution can only be fulfilled if the hosting infrastructure is expected to operate continuously all the time until the agreement will need to be executed. Imagine a will on a smart contract that would need to be executed say 50 years from now – will Ethereum be still around? If long-term existence of the smart contract infrastructure is not assured, appeal of this concept may be limited to only short-term agreements. Thus, the expectations about longevity of smart contract infrastructure may play a role in adoption of the technology.

Currently, the smart contract concept is stereotypically tied to blockchain technologies. Indeed, the enthusiasm surrounding the blockchain concept may drive further investments and adoption of smart contracts. Practitioners often expect a high number of benefits from adopting blockchain technologies including record security and decentralized governance with blockchain technologies (Du et al. 2019). The use of smart contracts, however, does not necessarily rely on all the promises associated with the adoption of blockchain technologies. Specifically, we can rely on a centralized platform for enabling peer-to-peer smart contracting without a blockchain. The owners of such platforms may invest and coordinate resources in promoting adoption, thereby, speeding up the establishment of the smart-contract-augmented contract law regime.

Potential Opportunities and Implications for Governments

In this section, we will discuss how smart contract concept can influence the functioning of the government as a hierarchical organization in its own right as well as the role of government in enabling the establishment of the smart-contract-augmented contract law regime. Many Western governments adopt the *trias politica* model, which was first proposed by 18th-century French political philosopher Montesquieu in his book *Spirit of the Laws* (De Montesquieu 1989). Specifically, he advocated for the separation of power of different branches of governments – legislative, executive, and judicial – to prevent concentration of authority in single hands (Möllers 2013; Vile 2012). The legislative branch writes and enacts the laws and appropriates the money needed for operating the government. The executive branch enforces the laws created by the legislative branch and is in charge of the implementation of policies funded and enacted by the legislative branch. The judicial branch interprets the meaning of laws and the constitution of the state and also resolves disputes.

A widespread adoption of the smart contract concept in our society may introduce some changes in the judicial and legislative parts of the government as well as changes in the functioning of the government as an organization that conducts economic activity (e.g., builds highways). First, smart contract platforms can serve as alternatives to some parts of the government by reducing reliance on court systems or judicial branch. Second, the adoption of smart contracts may increase the reliance on the legislative and judicial branches by creating a need for new laws and contractual templates. In this way, the government can serve as an enabler for advancing adoption of smart contracts. Third, utilizing smart contracts may improve the efficiency of the executive branch by, for example, lower enforcement costs for some government contracts.

Alternative to government

As far back as the writings of the 17th century philosopher Hobbs (1904), it was recognized that binding agreements among parties are more efficient in the presence of a top-down authority that enforces social contracts. Hobbs argued that peer-to-peer enforcement of agreements is too costly and ineffective often justifying citizens' willingness to give up some of their personal liberty to centralized authority. In a modern society, government-controlled legal and police systems are institutions that enforce social contracts by using courts to resolve disputes as well as by using police force to punish non-compliance (Werbach 2018).

In case of modern commercial contracts, contacting parties rely upon and assume a certain level of enforceability of a specific public contract law regime, such as US commercial law, when engaging in market transactions (Williamson 1985). Given the bounded rationality assumption in TCE, many commercial contracts cannot be fully specified as they cannot consider all possible scenarios, which may lead to disputes between parties (Williamson 1985). The courts may then be called upon to interpret the meaning of the signed contract in order to fill the gaps (Williamson 2002). A court may enforce contracts by awarding damages for loss derived from deficient performance or by legally ordering fulfillment of specific terms. Police force is instrumental in the enforcement of court orders. Legally enforceable contracts thus allow parties to believe that counterparty will fulfill their commitments (Bellia Jr 2002).

The envisioned wide accessibility of smart contracts leads to a speculation that smart contracts might obviate the need for contract law and attorneys and, thus, will become an alternative to the whole legal system when it comes to contracting (Wright and De Filippi 2015; Szabo 1997). Recently, this radical opinion was articulated by a legal scholar who argued that "smart contracts don't need a legal system to exist: they may operate without any overarching legal framework. De facto, they represent a technological alternative to the whole legal system" (Savelyev 2017, p. 132). Smart contracts would provide, not only cheaper, but also superior alternative to the legal system as relying on legal enforcement of the contracts may be prone to human errors, subject to human biases and corruption, and time-consuming.

Holden and Malani (2017) claimed that the need for centralized authority, especially courts, will be eliminated for those contracts for which contractual terms can be properly programmed as there will be no possibility of renegotiation through formal authority. Contract misinterpretation risks can also be mitigated through the use of smart contracts (Holden and Malani 2017). Human languages often have multiple interpretations and meanings. The ambiguities in meanings of terms have often been resolved by a court in the traditional contracts. The demand for interpretation of the contract by a court, however, may decrease as software language compilers, which have little tolerance for ambiguity, serve as interpreters and ban the variations in interpretation. Wright and De Filippi (2015) claimed that programming language for scripting smart contracts could be easier to use over time, and thus, people may rely more on this programming language to manage their affairs without hiring lawyers. This will affect the legal professions as they do not need to draft legal provisions and rather concentrate on higher order work while leaving high codifiable details to a machine.

Lastly, the use of smart contracts may reduce the effort required to monitor the behavior of parties (Oranburg and Palagashvili 2018). Once the smart contracts are properly designed and tested their execution would not require additional human monitoring typical of traditional contracts.

However, replacing legal enforcement of contracts with program running on the computer may have practical limitations. As we discussed earlier, most contracts are incomplete due to bounded rationality of agents. Often times, it would be also impossible to express some contractual terms through formal logic (Werbach and Cornell 2017). For example, computer programs are unable to measure whether a counterparty used best efforts. Thus, smart contracts can substitute only for those traditional contracts where terms can be readily specified and unambiguously monitored.

Government as an enabler

Scholars who acknowledge that smart contracts cannot be a full substitute for commercial law (Werbach and Cornell 2017) have argued that contract law and smart contracts serve fundamentally different goals.

Smart contracts function is to ensure actions ex-ante, while contract law is a remedial institution that recognizes and remedy grievances that may arise ex-post (Werbach 2017). Smart contracts promise to atomize the contractual process by stripping away the act of remediation, admitting no possibility of a breach. Werbach (2017) argues, however, that the idea that smart contracts will eliminate the possibility of all legal disputes is overly optimistic. The legal system should remain available if parties are unsatisfied with the outcomes of automated contracts.

The outcome of smart contracts may diverge from the intent of parties if they do not or cannot specify all possible results. In other words, it is quite likely that in practice some smart contracts will not be well-designed even if each party puts their best effort into designing it. For example, the algorithmic enforcements are not perfect as the smart contracts do not always operate according to the plan as illustrated in DAO's failure (Werbach and Cornell 2017). Even the sophisticated systems based on software can have errors and bugs. It is estimated that Ethereum smart contract platform, within itself, have 100 errors per 1000 lines of codes (Vessenes 2016). Because smart contracts involve real people in real relationships, it is impossible to avoid some of the ambiguity common in traditional contracts.

When such issues give rise to the smart contract-related disputes, the litigation would take the form of seeking to undo or reverse the executed transactions rather than seeking fulfillment of promised obligations (Werbach and Cornell 2017). One of the consequences of this trend would be a redefinition of how laws and regulations are designed, implemented, and enforced (Wright and De Filippi 2015). Thus, it is expected that the judicial system would develop a new way to deal with these challenges treating smart contracts as part of traditional legal contracts with a reference to smart contract as a software implementation.[1] In this way, the government potentially reinforces current contract law regime.

The government, the legislative branch in particular, can also serve as an enabler of new technologies by establishing proper legal foundations (Werbach 2018). When innovative technologies are expected to bring significant potential benefits to firms and markets, it is desirable for governments to create a favorable environment for using such technologies to realize their full potential. Legal systems which have the technology-friendly regulations may offer a competitive advantage in nurturing innovative business models and firms which are willing to use them in legal ways (Savelyev 2017). In the early stage of innovation, the creation of new laws can support companies that are trying to build a legitimate business with the new technologies. Werbach (2018) argued that innovators can benefit from the certainty that regulation can provide. Overall, well-designed laws will encourage technology-based innovation while protecting against abuses.

Indeed, attempts have been made by various state and national governments to establish legal foundations for using smart contracts (Sulkowski 2018; Werbach and Cornell 2017). For example, some states within the United States have passed legislation that allows for the utilization of smart contracts in commercial contexts (Adcock 2018). Arizona was the first mover that passed the legislation in 2017 allowing firms to use smart contracts in their businesses and preventing a contract from being denied legal effect. In Vermont, a bill was signed enabling the creation of limited liability companies for the "purpose of operating a business that utilizes blockchain technology for a material portion of its business activities" to elect to become a "blockchain-based limited liability company (BBLLC)" in May 2018. Under this bill, BBLLCs can use smart contracts to administer the BBLLC's voting procedures. Wyoming also passed a suite of bills that bestow companies with the authority to transact digital assets utilizing smart contracts (Long 2019).

Governments can also take on the role in regulating smart contract platforms by intervening in the enforcement of unconscionable contracts that go against public interests (Raskin 2016). For example, governments can put pressure on smart contract platforms to prevent financial crimes like money laundering even if it means stopping automatic contract execution. Werbach et al. (2017) also expect that

[1] This idea is similar to the way of utilizing Ricardian contracts in the current contract law regime. The notion of Ricardian contract invented in an effort to digitize a contract (Grigg 2004). A Recardian contract is defined as a method to register legally valid documents which contain all information in digitally connected texts with hash functions. These documents are machine readable and thus can be executed in software. A Ricardian contract states the intentions of a contract and related actions before the executions of terms whereas a smart contract refers to a contract which has been agreed and can be executed automatically. While the legal framework for smart contracts is lagging behind, a Ricardian contract is already accepted in the existing legislative framework.

regulators would try to regulate the platforms rather than the parties involved in smart contracts carrying criminal activity. Similar regulations were passed targeting the platform, rather than its users, in the early days of P2P file-sharing systems like Napster, which result in widespread copyright infringement. In a similar vein, we also expect that governments may want to restrict the use of smart contracts as part of reducing public risks associated with poorly designed contracts in some situations. Following Szabo's example of a smart contract for a car lease payment that would result in a car stopping to operate if the lease payment was missed, such a contract is potentially dangerous if its specification does not consider the case of a car being stopped in the middle of a highly or in other dangerous conditions that may not be fully predictable or easily codifiable.

The government can shape how contracts should be written by supporting the creation of standard smart contract templates which embody best practices. A template refers to electronically represented legal documents created by a standard body. The famous example can be a template created by the International Swaps and Derivatives Association (ISDA) (Clack et al. 2016). Some private organizations already have started involved in the creation of smart contracts templates for drafting legal documents (Werbach and Cornell 2017). The standard smart contract templates can be used to support the writing of complex legal documents and the subsequent use of these documents. The templates can also enable parties to avoid repeating mistakes from previous smart contracts and tap into the expertise of industry players carefully contemplating on potential pitfalls. Governments can also guide lawyers on the subsequent use of the templates in agreement of contracts and the negotiation with the counterparties. Technically savvy lawyers and legal engineers would be critical in aiding the government in the development of standard templates, creating and institutionalizing best practices for writing smart contacts, and for auditing platforms for compliance with the law (Clack et al. 2016; Sulkowski 2018).

The creation of legal foundations and templates may result in the increased number of implemented smart contracts (Raskin 2016; Savelyev 2017; Sulkowski 2018). In that case, more disputes will arise from these contracts if contracting parties are unsatisfied with the results of automated systems and start relying more on the legal system to resolve disputes (Werbach and Cornell 2017). Both smart-contract based infrastructure and the revised commercial law that supports it and delineates its scope would constitute the smart-contract-augmented contract law regime.

Improvement in the functioning of governance

Government outsourcing has become a well-established mechanism for public service provision in most industrialized nations (Barton 2006). The executive branch which is responsible for the policy implementation and administration of government, often relies on external vendors by writing contracts (Lavery 1999). For example, cities pay private firms that collect trash. By contracting out the provision of public services to the private companies, governments aim to achieve higher efficiency in their operations and tap into specialized expertise available in the private firms (Jensen and Stonecash 2004). The proponents of government outsourcing have claimed that contracting with private vendors would lead to efficient resource allocation and reduction in fiscal pressure on the government as well as taxpayers. However, there can be a risk that private firms – with the intention to maximize profit - may try to hold up the government when the contractual terms are renegotiated. Scholars have exposed the potential risk of such situations as private firms "ratchet up" price gradually, and thus, the cost savings from outsourcing can be eroded over time. Krugman (2002) argued that:

> "...it's common for private contractors to bid low to get the business, then push their prices up once the government work force has been disbanded. Projections of a 20 or 30 percent cost saving across the board are silly — and one suspects that the officials making those projections know that (p.31)."

The adoption of smart contracts can enhance the functioning of the executive branch by enabling greater efficiency in certain types of government contracts. The use of smart contracts in outsourcing the provision of public services may be a way to reduce holdup problem at least for those services for which well-designed smart contracts can be created. Adopting smart contracts for the activities that are already outsourced may also further reduce the transaction costs and increase the efficiency of the government functioning (Cardeira 2015). For example, in building a new highway, government agents can rely on smart contracts to ensure contract monitoring and fulfillment based on triggers codifying certain aspects of the processes (e.g., workers show up on location) and outcomes (e.g., a piece of road competed). Moreover, smart contracts may make it easier to govern predictable contract cost increases by putting budgets for potential cost increases into contractual terms and codifying under which circumstances such pay would be released. Table 1 summarizes our conceptualization of the diverse roles of the government in enabling and using smart-contract-augmented contract law regime.

	Potential Impact	Example	Citations
Alternative to government Judicial branch, Executive branch	Reducing reliance on courts for certain types of contracts	A dispute over not receiving payment on insurance leading to insurance cancellation would not be brought to courts if smart contract infrastructure that was set up for such payments is reliable and provides verifiable data.	Holden & Malani 2017; Savelyev 2017
Government as an enabler Legislative branch	Relying on the government to create laws enabling smart contracting and defining their scope in governing economic transactions	A state government would write a new set of laws on how smart contracts ought to be used for purchasing financial assets (e.g. ICOs) (e.g., Vermont law on ICOs)	Werbach & Cornell 2017; Raskin 2016; Sulkowski 2018
Improvement in government's functioning Executive branch	Enabling greater efficiency for certain types of government business	In constructing a new highway, government agents would rely on smart contracts to ensure contract fulfillment	Cardeira 2015

Table 1: Roles of Government in Enabling and Using Smart Contract-Augmented Contract Law Regime

Limitation of the Theory

In this paper we adopt the TCE perspective to understand the potential impact of the wide adoption of smart concept on firm boundaries. TCE theory, however, in spite of its significant following and Noble prize distinction, has received a great degree of criticism in organizational theory, economics, and IS. Organization theorists have argued that TCE's singular focus on incentives -- preventing opportunistic behavior -- and its insistence that production costs advantages and control over valuable resources are not directly salient to explaining firm boundaries makes this theory rather limited (Kogut & Zander 1992). This limitation is particularly apparent when one acknowledges that modern firms are the sites for technological innovation and other knowledge-related activities (Kogut & Zander 1992). Economist, for their part, have also challenged TCE because of its embracing of the bounded rationality assumption, which leads to the impossibility of translating contractual incompleteness into a cost function – something that incomplete contract theory paradigm provides (Hart & More 1988). This impossibility makes mathematical modeling difficult and limits possibilities of formal theorizing. Strategy scholars have argued that variables like asset specificity are not an endogenous property of a given transaction, but rather an organizational design variable that firms may or may not want to reduce to tap into external opportunities for competitive advantage (e.g., Lakhani et al. 2013). Finally, organizational scholars that emphasize interpretive and emergent views of organizing, suggest that variables that TCE considers endogenous (e.g., asset specificity and uncertainty) are actually subjectively constituted by organizational actors and management scholars (Srikanth & Puranam 2011). With all these limitations, it is not surprising that TCE has received mixed empirical support, especially in IS literature where the threat of contractual hazards is often less salient to a decision maker than knowledge-based considerations (e.g., Levina & Ross 2003).

We have justified our focus on TCE as our theoretical base, in-spite of its limitations, by arguing that it is the only theory of the firm that we are aware of that directly theorizes the role of contract law regime. We have argued for smart contract concept, by definition, has direct implications to changes in such regimes.

This does not mean, however, that the smart contract concept has no implications within other views of the firm. Resource-based view of the firm holds that some firms can be better than others in performing particular activities (constituting firm's core capabilities). For such core activities, a firm may decide to keep these activities in house even if smart contract make outsourcing them attractive from contractual hazard standpoint. Following the same logic, there may be no vendors offering a particular service even if well-designed smart contracts can support procuring such services if high quality delivery of a given certain requires hard to obtain resources. Finally, some firms may be particularly apt at adopting smart contracts due, for example, to their ownership of technological resources and knowhow that eases smart contract adoption. All of these possibilities would present a different empirical picture than the one we have envisioned based on TCE considerations alone.

Diverse views of the firm, and their extensions, tend to pay special attention to the notion of *codification*. We have used this notion to talk about costs of specifying a well-designed smart contract arguing that such contracts require investing in digital codification of contractual terms including states of the world, actions of each party, and inputs that trigger various actions. We have not unpacked this concept ignoring its rich history in IS and organizational research. IS economics literature has drawn on TCE to discuss how different degrees of codifiability of products and services can enable the movement from firms to electronic supply chains and B2B markets (e.g., Levi et al. 2003). IS outsourcing literature has drawn on agency theory and emphasized the critical role of codifiability of the outsourced processes in improving contract performance (Aron and Liu 2014). Within the knowledge-based view of the firm perspective, scholars have argued that digital codification of work eases knowledge transfer across firms (Kogut & Zander 1992; Vaast and Levina 2006) and across global locations (Mithas and Whitaker 2007; Srikanth and Puranam 2011). These diverse literature streams use the term codification differently sometimes referring to codifiability as an intrinsic property of a particular activity (Levi et al. 2003), sometimes referring to codifiability of work interfaces (Srikanth & Puranam 2011), and other times referring to codification rather than codifiability (Vaast and Levina 2006). Our theoretical framework would benefit from a deeper dive into these issues.

Future Research Directions

In light of the theoretical tradeoffs developed in our conceptualization, future researchers can explore questions such as (1) Which transactions are worth codifying further so as to justify the tradeoff involved in smart contracting? (2) How do different types and degrees of asset specificity influence the attractiveness of smart contracts? As smart contract adoption grows, researchers can also investigate whether some smart contracts supporting highly codified transactions actually facilitate the movement of these transactions back to the firm by means of full automation. What conditions would facilitate this?

Our discussion of a number of considerations that may slow down the adoption of smart contracts concept can also open up new avenues for research including: (1) How do different implementations of the smart contract concept enable or inhibit the adoption (e.g., providing templates, offering legal services, etc.)? (2) What will be the dynamics of competition within online platforms supporting smart contracts? Also, what would be the impact of the ownership structure, level of decentralization, and other factors on these dynamics? In addition, qualitative research may enhance our theoretical understanding of the adoption process in a more nuanced way. It can help develop answers to questions such as how people perceive and use smart contracts, what their benefits and costs are, and what public discourse around blockchain plays in driving adoption?

To explore how a smart-contract-augmented contract law regime can affect diverse roles of government, for example, by lessening the reliance on the existing court system, researchers can investigate: (1) Which technological implementations of smart contract systems reduce legal disputes? (2) What types of legal situations are worth codifying further? (3) How do court systems adjust to this new option? (4) In which conditions does the government decide to regulate smart contracts and how does this influence adoption? (5) Does the use of smart contracts for some categories of government procurement lead to cost reduction?

Conclusion and Discussions

To conclude, this paper uses TCE to identify key considerations and tradeoffs involved in understanding how the adoption of the smart contract concept can enable a shift in firm boundaries. It also categorizes the potential impact of smart contracts concept on government, focusing on the role of each of the three branches in enabling and using smart-contract-augmented contract law regime.

There are several considerations that may cause variations in the adoption of the new contract law regime. First, the adoption of smart contract as a substitute for firm-based transactions assumes that contractual terms adequately reflect the intended agreement reached between contracting parties. The misinterpretation of contractual terms, especially when there is a cultural gap between contracting parties, is a familiar phenomenon even in a traditional contract law regime. Encoding contractual terms in a digital form may be perceived as a way of reducing ambiguity associated with the use of natural languages. Yet, codifying certain aspects of the agreement necessarily leaves out the complexity and richness associated with other aspects, which may have previously been documented in a traditional contract. In this way, a smart contract-augmented contract law regime may increase the risk associated with public contracting (in the market). Assuming that the firm still relies on human (rather than algorithmic) managerial hierarchies, such cultural misunderstandings can be mitigated by a manager as they arise.

Second, we have focused our paper explicitly on a particular institutional context -- a democratic society typical of Western countries. In a different institutional environment, such as an autocratic systems where the optimization of social welfare is not a priority, the adoption of smart contract concept can meet resistance for reasons other than those implied by the TCE theory. . In such environments, various branches of government depending on their political interests may engage in a battle over adopting or resisting this new option.

Last but not least, adoption of smart contract-augmented contract law regime and associated practices necessitates the transformation of existing institutions, which invariably leads to pushback. If smart contracts are to be adopted as part of a legal environment in a given country, they may meet resistance from a number of institutional stakeholders such as members of the legal profession, from firms that may fear disintermediation and partial loss of profits, and current members of the judicial court system. These resistance may be powerful enough to prevent smart contract adoption as envisioned in this paper altogether. Nonetheless, even if the smart contract is implemented merely as part of the current legal law regime, the ability to digitally codify some aspects of public contracting to allow for automatic execution is likely to reshape firm boundaries as we discussed.

References

Adcock, S. H. K. a. C. 2018. "The State of Smart Contract Legislation." Retrieved April 15, 2019, from https://www.blockchainlegalresource.com/2018/09/state-smart-contract-legislation/

"A Deeper Look at Different Smart Contract Platforms." *Blockgeeks*, Retrieved 1 May, 2019, from https://blockgeeks.com/guides/different-smart-contract-platforms/.

Ang, S. and Straub, D.W., 1998. Production and transaction economies and IS outsourcing: a study of the US banking industry. *MIS quarterly*, pp.535-552.

Argyres, N. S. (1999). The impact of information technology on coordination: Evidence from the B-2 "Stealth" bomber. *Organization Science*, *10*(2), 162-180.

Asif, Z. (2005). Integrating the supply chain with RFID: A technical and business analysis. *Communications of the Association for Information Systems*, *15*(1), 24.

Bakos, J. Y. (1991). A strategic analysis of electronic marketplaces. MIS quarterly, 15(3).

Bakos, Y. 1998. "The Emerging Role of Electronic Marketplaces on the Internet," *Communications of the ACM*.

Barton, A. D. 2006. "Public Sector Accountability and Commercial-in-Confidence Outsourcing Contracts," *Accounting, Auditing & Accountability Journal* (19:2), pp. 256-271.

Bellia Jr, A. J. 2002. "Promises, Trust, and Contract Law," *Am J Juris* (47), p. 25 at 32.

Brown, R. G., Carlyle, J., Grigg, I., and Hearn, M. 2016. "Corda: An Introduction," in: *R3 CEV, August*.

Buterin, V. 2014. "A Next-Generation Smart Contract and Decentralized Application Platform," in: *white paper*.

Cardeira, H. (2015). Smart contracts and their applications in the construction industry.Casey, A. J., and Niblett, A. 2017. "Self-Driving Contracts," *J. Corp. L.* (43), p. 1.

Clack, C. D., Bakshi, V. A., and Braine, L. 2016. "Smart Contract Templates: Foundations, Design Landscape and Research Directions," in: *arXiv preprint arXiv:1608.00771*.

Dahlman, C. J. 1979. "The Problem of Externality," *The journal of law and economics* (22:1), pp. 141-162.

De Montesquieu, C. 1989. *Montesquieu: The Spirit of the Laws*. Cambridge University Press.
Dewan, S., Michael, S. C., and Min, C.-K. 1998. "Firm Characteristics and Investments in Information Technology: Scale and Scope Effects," *Information Systems Research* (9:3), pp. 219-232.
Du, W. D., Pan, S. L., Leidner, D. E., & Ying, W. (2019). Affordances, experimentation and actualization of FinTech: A blockchain implementation study. The Journal of Strategic Information Systems, 28(1), 50-65.
Dyer, J. H. 1997. "Effective Interim Collaboration: How Firms Minimize Transaction Costs and Maximise Transaction Value," *Strategic management journal* (18:7), pp. 535-556.
Epstein. 2015. " Here Comes Ethereum, an Information Technology Dreamed up by a Wunderkind 19-Year-Old That Could One Day Transform Law, Finance, and Civil Society." Retrieved April 15, 2019, from http://reason.com/blog/2015/03/19/here-comes-ethereum-an-information-techn
Fenu, G., Marchesi, L., Marchesi, M., and Tonelli, R. 2018. "The Ico Phenomenon and Its Relationships with Ethereum Smart Contract Environment," *2018 International Workshop on Blockchain Oriented Software Engineering (IWBOSE)*: IEEE, pp. 26-32.
Forman, C., and McElheran, K. S. 2011. *Information Technology and Boundary of the Firm: Evidence from Plant-Level Data*. Harvard Business School.
Galanter, M. 1981. "Justice in Many Rooms: Courts, Private Ordering, and Indigenous Law," *The Journal of Legal Pluralism and Unofficial Law* (13:19), pp. 1-47.
Grigg, I., 2004, July. "The ricardian contract" In *Proceedings. First IEEE International Workshop on Electronic Contracting, 2004.* (pp. 25-31). IEEE.
Gurbaxani, V., and Whang, S. 1991. "The Impact of Information Systems on Organizations and Markets," *Communications of the ACM* (34:1), pp. 59-73.
Halaburda, H. 2018. "Blockchain Revolution without the Blockchain," *Bank of Canada Staff Analytical Note* (5).
Halaburda, H., and Sarvary, M. 2016. *Beyond Bitcoin*. The Economics of Digital Currencies.
Hart, O., and Moore, J. 1999. "Foundations of Incomplete Contracts," *The Review of Economic Studies* (66:1), pp. 115-138.
Hayek, F. A. 1945. "The Use of Knowledge in Society," *The American economic review* (35:4), pp. 519-530.
Hitt, L. M. 1999. "Information Technology and Firm Boundaries: Evidence from Panel Data," *Information Systems Research* (10:2), pp. 134-149.
Hobbs, W. H. 1904. "Lineaments of the Atlantic Border Region," *Bulletin of the Geological Society of America* (15:1), pp. 483-506.
Holden, R., and Malani, A. 2017. "Can Blockchain Solve the Holdup Problem in Contracts?," in: *University of Chicago Coase-Sandor Institute for Law & Economics Research Paper*.
HÜTTEN, M. 2018. "The Soft Spot of Hard Code: Blockchain Technology, Network Governance and Pitfalls of Technological Utopianism," *Global Networks*.
Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. *Harvard Business Review*, *95*(1), 118-127.
Jaiswal, V., & Levina, N. (2012). J-TRADING: Full Circle Outsourcing. Journal of Information Technology Teaching Cases, 2(2), 61–70. https://doi.org/10.1057/jittc.2012.11
Jensen, P. H., and Stonecash, R. E. 2004. "The Efficiency of Public Sector Outsourcing Contracts: A Literature Review."
Karst, T. 2019. "Banana companies invest in sustainability, efficiencies." *The Packer*. Retrieved 5 September, 2019, from https://www.thepacker.com/article/banana-companies-invest-sustainability-efficiencies
Katz, M. L., and Shapiro, C. (1994). Systems competition and network effects. *Journal of economic perspectives*, *8*(2), 93-115.
Klein, B., Crawford, R. G., & Alchian, A. A. (1978). Vertical integration, appropriable rents, and the competitive contracting process. The journal of Law and Economics, 21(2), 297-326.
Knight, F. H. 1941. "Review of Melville J. Herskovits'‘Economic Anthropology’," *Journal of Political Economy* (49:1), pp. 247-268.
Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization science*, *3*(3), 383-397.
Krugman, P. 2002. "Victors and Spoils," *New York Times* (19), p. 31.
Lakhani, K. R., Lifshitz-Assaf, H., & Tushman, M. (2013). Open innovation and organizational boundaries: task decomposition, knowledge distribution and the locus of innovation. *Handbook of economic organization: Integrating economic and organizational theory*, 355-382.

Lavery, K. 1999. *Smart Contracting for Local Government Services: Processes and Experience*. Greenwood Publishing Group.

Levi, M., Kleindorfer, P. R., and Wu, D. J. (2003). Codifiability, relationship-specific information technology investment, and optimal contracting. *Journal of Management Information Systems*, *20*(2), 77-98.

Levina, N., and Ross, J. W. 2003. "From the Vendor's Perspective: Exploring the Value Proposition in Information Technology Outsourcing," *MIS quarterly* (Sep 1), pp. 331-364.

Liu, Y., and Aron, R. 2014. "Organizational Control, Incentive Contracts, and Knowledge Transfer in Offshore Business Process Outsourcing," *Information Systems Research* (26:1), pp. 81-99.

Long, C. 2019. "What Do Wyoming's 13 New Blockchain Laws Mean?" *Forbes*, Retrieved September 4, 2019, from https://www.forbes.com/sites/caitlinlong/2019/03/04/what-do-wyomings-new-blockchain-laws-mean/#e89f0165fde6

Malone, T. W. 1987. "Modeling Coordination in Organizations and Markets," *Management science* (33:10), pp. 1317-1332.

Malone, T. W., Yates, J., & Benjamin, R. I. (1994). Electronic markets and electronic hierarchies (pp. 61-83). New York: Oxford University Press.

Mani, D., Barua, A., & Whinston, A. B. (2012). An empirical analysis of the contractual and information structures of business process outsourcing relationships. Information Systems Research, 23(3-part-1), 618-634.

Möllers, C. 2013. *The Three Branches: A Comparative Model of Separation of Powers*. Oxford University Press.

Murray, A., Kuban, S., Josefy, M. and Anderson, J. (2019), Contracting in the Smart Era: The Implications of Blockchain and Decentralized Autonomous Organizations for Contracting and Corporate Governance. *Academy of Management Perspectives*.

Nakamoto, S. 2008. "Bitcoin: A Peer-to-Peer Electronic Cash System."

North, D. C. 1990. "A Transaction Cost Theory of Politics," *Journal of theoretical politics* (2:4), pp. 355-367.

Oranburg, S., and Palagashvili, L. 2018. "The Gig Economy, Smart Contracts, and Disruption of Traditional Work Arrangements," *Smart Contracts, and Disruption of Traditional Work Arrangements (October 22, 2018)*).

Popiel, P. 2017. "“Boundaryless” in the Creative Economy: Assessing Freelancing on Upwork," *Critical Studies in Media Communication* (34:3), pp. 220-233.

Raskin, M. 2016. "The Law and Legality of Smart Contracts."

Ray, G., Wu, D., and Konana, P. 2009. "Competitive Environment and the Relationship between It and Vertical Integration," *Information Systems Research* (20:4), pp. 585-603.

Savelyev, A. 2017. "Contract Law 2.0:‘Smart’contracts as the Beginning of the End of Classic Contract Law," *Information & Communications Technology Law* (26:2), pp. 116-134.

Schneider. 2015. "After the Bitcoin Gold Rush." Retrieved April, 2019, from https://newrepublic.com/article/121089/how-small-bitcoin-miners-lose-crypto-currency-boom-bust-cycle

Simon, H. A. 1957. *Models of Man; Social and Rational*.

Sulkowski, A. J. 2018. "Blockchain, Law, and Business Supply Chains: The Need for Governance and Legal Frameworks to Achieve Sustainability."

Szabo, N. 1997. "Formalizing and Securing Relationships on Public Networks," *First Monday* (2:9).

Vessenes, P. 2016. "Deconstructing the Dao Attack: A Brief Code Tour."

Vile, M. J. C. 2012. *Constitutionalism and the Separation of Powers*. Liberty Fund.

Werbach, K. 2018. *The Blockchain and the New Architecture of Trust*. Mit Press.

Werbach, K., and Cornell, N. 2017. "Contracts Ex Machina," *Duke LJ* (67), p. 313.

Williamson, O. E. 1967. "The Economics of Defense Contracting: Incentives and Performance," in *Issues in Defense Economics*. NBER, pp. 217-278.

Williamson, O. E. 1971. "The Vertical Integration of Production: Market Failure Considerations," *1971*).

Williamson, O. E. 1973. "Markets and Hierarchies: Some Elementary Considerations," *The American economic review* (63:2), pp. 316-325.

Williamson, O. E. 1985. *The economic institutions of capitalism: Firms, markets, relational contracting*. New York: Free Press.

Williamson, O. E. 2002. "The Theory of the Firm as Governance Structure: From Choice to Contract," *Journal of economic perspectives* (16:3), pp. 171-195.

Williamson, O. E. 2008. "Outsourcing: Transaction Cost Economics and Supply Chain Management," *Journal of supply chain management* (44:2), pp. 5-16.

Wright, A., and De Filippi, P. 2015. "Decentralized Blockchain Technology and the Rise of Lex Cryptographia," in: *Available at SSRN 2580664*.