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Would Ronald Coase love Bitcoin? How Blockchain Lowers Transaction Costs and Changes the Coasian Firm

Bachelor's Thesis

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I hereby declare that I am the sole author of this thesis, and that I duly marked out all quotations. The used literature and sources are attached in the list of references.

Amira Kaid

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Abstract

The rising popularity of blockchain technology, otherwise known as the technology that underlies the Bitcoin protocol has been the subject of a lot of investigation and enthusiasm among financial organizations for its potentially revolutionary properties that will likely change how the economy works in the future. The blockchain is a decentralized, open source ledger that records bitcoin transactions and is maintained by a distributed network of miners. Blockchain technology, however, has many applications beyond currency and can be applied in various areas including the firm's organizational structure and law.This thesis examines how blockchain technology would lower the transaction costs involved in organizing the firm and how it would thus change the role of the firm. Coase (1937) in his article "The Nature of the Firm" explained that firms exist and continue to operate in a hierarchal manner because of the transaction costs that are involved in using the market mechanism. This paper also examines how the blockchain would lower the transaction costs of resolving disputes through carrying out market transactions that were mentioned by Coase (1960) in "The Problem of Social Cost". In order to achieve this aim Coase' s framework is used to theoretically model a future firm and legal system which are blockchain-based and that use bitcoin in their transactions. The results indicate that blockchain technology would reduce the transaction costs pointed out by Coase in such a way that it would cause the firm to become less hierarchal in nature and would allow it to adopt a more inclusive and distributed management system. Similarly, in the case of law, the transaction costs would fall, making it easier for parties to resolve their disputes using the market mechanism instead of having to rely on a central authority.

Keywords: Blockchain, bitcoin, firm, law, transaction costs, smart contracts, decentralized
JEL Classification: E14, H32, L22, L24, L25

Introduction

Economic advancement can be thought to have been directly linked to technological advancement throughout history. Technological progress has led to organizations changing for the better, saving us from having to incur the costs that our ancestors have had to face. Firms can now operate more efficiently and produce at a larger scale, faster pace and at lower costs than they could a century ago. The invention of the Internet has allowed individuals and organizations to trade information more easily and at less cost than was previously possible. As technological advancements and innovations continue to evolve and grow, economic organizations and legal institutions will have to adapt to these advancements (Morabito, 2017, p. 3). Blockchain technology (the technology underlying Bitcoin) is thought to be a disruptive technology that could profoundly change many aspects of human life including economics and law in the future (Swan, 2015, p. vii). The blockchain is the technology that underlies the Bitcoin protocol and facilitates the fast and frictionless exchange of bitcoins. In addition, the blockchain unlike the traditional ledger systems of banks and other financial intermediaries has the properties of being open source, tamper-proof, decentralized and distributed, so it offers more transparency, does not necessitate the involvement of a third party to establish trust because it is maintained by a network of miners through a proof-of-work consensus mechanism rather than a central authority. All of these properties would likely have a significant impact on some of the other spheres in which this technology could be applied, some of which include companies' organizational structures and the resolution of legal affairs. Most importantly, this technology would reduce transaction costs significantly which would lead to a change in how firms are managed and how legal systems operate in the future.

This topic has become of increasing relevance recently because of its possible economic implications. As such The subject has been studied in various pieces of literature. In the case of the economics and the firm (Coase, 1937), (Williamson, 1981). With regard to blockchain technology (Swan, 2015), (Tapscott & Tapscott, 2016), and (Morabito, 2017) provide a cursory and brief introduction of how the blockchain could lower the transaction costs across a wide range of economic, social and governing spheres. In the case of law (Szabo, 1997) provides an

explanation of the workings of smart contracts and smart property, whereas (Wright & De Filippi, 2015a) and (Abramowicz, 2015) discuss how the blockchain could affect law and governance in the future .

The hypothesis in this thesis is that blockchain technology will reduce the role of the firm and the role of law in the Coasean framework. The aim of this thesis is to examine in more detail how blockchain technology might reduce the transaction costs involved in organizing the firm and enforcing legal rights, using Coase's framework from his articles "The Nature of the Firm" and "The Problem of Social Cost" to model theoretically, a future firm and a future legal system that are blockchain-based and use the blockchain to carry out their operations and use bitcoins in their transactions. From that analysis, a conclusion is drawn as to how the roles of the firm and law as we know them today, will change in the future.

As a starting point, the first chapter provides an explanation as to how this technology works by first examining the historical and theoretical origins of Bitcoin's blockchain, followed by an overview of the inner workings of the blockchain and its various applications beyond currency, such as smart contracting and transforming property into smart property and finally the initiatives and organizations that are currently using it in their operations. In the second chapter, the future firm is examined by applying the analysis of the properties of the blockchain to Coase's theory of the firm to find out how the blockchain will reduce transaction costs, and how it will subsequently change the firm. In particular, the dynamics of a firm's organizational choices relative to the transaction costs pointed out by Coase are analyzed, followed by an analysis of the various functions that make up the firm's structure, including the role of the entrepreneur in coordinating the operations of the firm, and the hiring of labor and the procurement of the firm's resources. In addition, the chapter includes an analysis of how the blockchain would affect the transaction costs involved in managing and organizing the firm as described by Coase including the coordination, search, contract and trust establishment costs. The third chapter provides an analysis of how the blockchain would change the legal system with regards to the areas of law highlighted by Coase which include dispute resolution, the judicial system and externality internalization. Thus, a smart contracting and peer-to-peer dispute resolution system is introduced, followed by an analysis of a decentralized judicial enforcement system and finally an analysis of how the blockchain could be used to incentivize firms to pollute less.

1 How Blockchain Technology Could Revolutionize Economic and Legal Systems

The invention and subsequently mainstream adoption of the Internet in the 1990s brought about a wave of change that revolutionized the way that individuals and organizations were able to communicate, access and share information. Blockchain technology has the potential to change society in a similar way. While the Internet facilitated the movement of information within and between organizations, it was not designed to transfer actual value from person to person, because while files for example, can be exchanged easily through email, the exchange of money (something of value) would still have to go through some financial intermediary. Intermediaries such as governments, banks and large corporations are used to maintain integrity and to establish a sense of trust. Using intermediaries has some notable shortcomings, some of which include the use of servers that are vulnerable to crashing, hacking and fraudulent activities, the charging of fees by these intermediaries and the exclusion of those who cannot afford a bank account. Since anyone can create a Bitcoin account free of charge and without having to be subject to rigorous monitoring or centralized vetting procedures, Bitcoin offers a more private and flexible way to carry out transactions. Blockchain technology will make it possible for individuals and organizations to store and exchange value without the need for intermediaries thereby, doing away with some of the inefficiencies brought about by these institutions (Tapscott & Tapscott, 2017, p. 10).

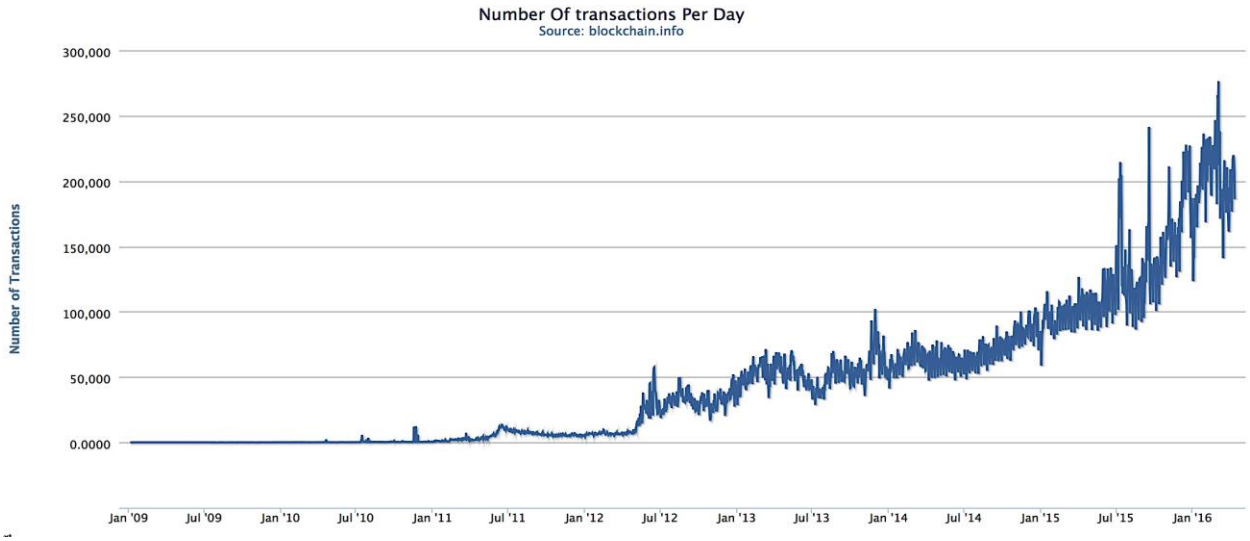

Figure 1: Number of transactions per day (BTC)

Source: Blockchain.info (2016)

Bitcoin usage has increased significantly over the years. Figure 1 shows the number of daily bitcoin transactions that took placefrom January 2009 to January 2016. The graph in figure 1 shows an upward trend in terms of the number of daily bitcoin transactions being undertaken.

Blockchain is the technology underpinning Bitcoin and it has many applications beyond just facilitating the creation of decentralized currencies, it also allows for the creation of smart property (assets that will be controlled over the Internet, and smart contracts (digital contracts that are self-executing), (Wright & De Filippi, 2015b, p. 1). Blockchain technology is sometimes compared to the Internet because it has many potential applications across various spheres ranging from economics and finance to law and governance (Swan, 2015, p. ix).The nature the blockchain makes it suitable for applications in industries beyond the financial service industry. Blockchain technology has the potential to be used to settle legal affairs where instead of a regular contract a blockchain based smart contract could be used. Smart contracts can be thought be thought of as software that functions in a similar way to regular contracts and can be used by organizations to execute and enforce certain conditions, individuals and corporations could decide on how to automate the terms of their contracts and agreements (Collomb & Sok, 2016a, p. 98). Blockchain can also be adapted to provide decentralized governance service such as ID systems that verify reputation, voting capabilities and dispute resolution. It can also serve as a

registry for all kinds of legal documents such as corporate contracts, marriage contracts, contracts concerning childcare, wills and land deeds. Most importantly, blockchain technology can have important implications for society as a whole and it has the potential to advance certain aspects of the economy and to facilitate the forward progress of society. Used as a public record the blockchain provides a record that is accessible to everyone in society, and has the capacity to hold a wide variety of information such as registers of various assets, identities, events and documents (Swan, 2015, p. 45).

Class	Examples
General	Escrow transactions, bonded contracts, third-party arbitration, multiparty signature transactions
Financial transactions	Stock, private equity, crowdfunding, bonds, mutual funds, derivatives, annuities, pensions
Public records	Land and property titles, vehicle registrations, business licenses, marriage certificates, death certificates
Identification	Driver's licenses, identity cards, passports, voter registrations
Private records	IOUs, loans, contracts, bets, signatures, wills, trusts, escrows
Attestation	Proof of insurance, proof of ownership, notarized documents
Physical asset keys	Home, hotel rooms, rental cars, automobile access
Intangible assets	Patents, trademarks, copyrights, reservations, domain names

Table 1: Blockchain applications beyond currency

Source: Adapted from Swan (2015)

Table 1 shows the various classes and examples of contracts and property that could potentially be reinvented on blockchain. Starting generally with things like bonded contracts, escrow transactions and third-party arbitration, all of the financial assets, like crowdfunding and land and property titles as well as public and private records. Things like identification records, physical asset keys can also be reinvented into the blockchain. Attestation can be carried out through the blockchain to obtain things like proof of ownership, proof of insurance as well as notorized documents. Blockchain can also be programmed to protect intangible assets such as patents, copyrights and trademarks.

1.1 The History of Money and The Development of Crypto-currencies

The story of the development of the blockchain and crypto-currencies begins with peoples' need for money, and a convenient system of exchange and record keeping (Ferguson, 2008, p. 23). Humans first began exchanging goods and services in a direct manner through a barter system. Parities would meet by coincidence, and notice that they each had an item that the other might want and if the trade benefited both of them they made the exchange. The problem with that system was that it required that the parties involved have a double coincidence of wants, which was in practice quite rare. The barter system also was also prone to a lot of risk, especially in situations where perishable and seasonal goods had to be traded (Jevons, 1875, p. 4). This is because in some cases one party would give up some items and would then have to wait for the other party to fulfill their end of the deal. In some cases, the risks involved with bartering would make trading not worthwhile, so the need for a better system arose (Halaburda, 2016, p. 79). Then hunter-gather groups started to use the collective memory of their group to keep track of exchanges. So members of the group could get goods and services from other members, as long as they had made a contribution to the group that they could benefit from at some point in time. The group's collective memory was used as a ledger that kept a record of the contributions that the members made to the group and they put in place penalties to lessen the chances that free-riding would occur. This system was efficient in smaller groups but not so much when larger communities were involved. As groups grew larger, it became more difficult to keep a record of every member's consumption from the group's resources and their contributions to it.

Furthermore, as the number of groups increased, it became difficult to ensure that a member from a certain group would repay the person from the other group from whom he may have received a good or a service, because the trading parties would not know each other. There was also the chance that different hunter-gatherer groups would resort to violence and start fighting over scarce resources (Ferguson, 2008, p. 19). Hence, the exchange system had to evolve further, and over time, the collective memory system gave way to the institution of money as we know it today where money started to be used as a medium of exchange (Kiyotaki & Wright, 1989, p. 950). Money made trading even easier and similarly to the previous systems, it served as a ledger that kept a record of the contributions made by everyone. The difference in this ledger was that instead of it being virtual and having to be stored in the group's memory, it now became more material and decentralized as a result of the development of money. When someone contributed to other peoples' needs, in terms of goods or services, his account balance increased. People have historically used various objects as money like shells and similar objects, then, over time coins started being used and continue to be used today (Halaburda, 2016, p. 81). Then banks where developed, which recorded the amount of funds that people have deposited and withdrawn from their accounts. Technological advancements and inventions such as the Internet made the world more digitalized, so there was a need for money to evolve again, this time it had to have the capacity to be used for transactions that took place in the digital market place. Hence, digital currencies were invented. Although, people could still transact online using their credit cards or other traditional forms of payment, digital currency offered them the chance to do so without having to reveal their personal data to whomever they were buying from. But digital currency is vulnerable to counterfeit because it could be easily copied and used in transactions that could then become accepted by sellers, so it was still prone to the double spending problem. In order to prevent the copying of the digital currency, a ledger would need to be used to keep a record of every unit of that digital currency as well as information showing if a user had spent a unit of the currency. The ledger could be maintained by a third party institution, which would be tasked with ensuring that the ledger is safe-guarded and that the transactions on it have been recorded accurately. Another solution would be to make that ledger distributed, in this case, no single party would be in control of the ledger and it would become decentralized and maintained by a network of participants rather than a single party (Vigna & Casey, 2015, p. 5). That is how the blockchain came to be, along with bitcoin as a crypto-currency.

1.2 Bitcoin's Origins and Theoretical Foundations

Bitcoin actually finds its theoretical foundations in the Austrian school of economics, which criticized the fiat money system. According to the Austrian school view, the fiat money system is open to government intervention that could potentially cause inflation and disrupt the business cycles (Hayek, 1976, p. 28). Also relevant in the case of Bitcoin is the Austrian school's view on monetary theory, and how governments' intervention when it comes to the issuing of money.

1.2.1 Business Cycles

Based on the Austrian theory, business cycles result because of monetary interventions in the market, and when bank credit is expanded excessively (ECB, 2012b, p. 22). Austrian economists are also particularly critical of the fractional reserve banking system. There is a distinction between central banks and the government in fractional reserve banking. This is because although both the governments and the central banks are united in the issuing of a sovereign currency, the central banks are the ones who influence how much money is created based on the interest rate and their inflation targets. In most countries central banks are considered independent because they do not have to get approval from a president to or any official in the legislative or executive branches of government to be able to carry out their monetary policy decisions (Bheemaiah, 2017, p. 5). In a system of fractional reserve banking, the money supply increases in the process of money creation. This then results in the onset of an artificially low interest rate, to which entrepreneurs react by undertaking overly ambitious investments in response to the now distorted interest rate signals. This creates an imbalance in the market since the entrepreneurs' investments do not match their consumers' preferences at the designated time related to their inter-temporal consumption patterns (their decisions with regards to their near-term and future consumption). This imbalance then eventually results in the onset of a recession. Overtime, firms end up having to liquidate their failing investment projects and having to restructure their production structures in a way that better matches the inter-temporal preferences of their consumer. On that basis, Austrian economists are in favor of using money

that is based on the gold standard as opposed to the fractional reserve banking system, in order to avoid having the money be manipulated by the government (ECB, 2012b, p. 22)..

1.2.2 Monetary Theory

Monetary theory is another area that was highlighted by the Austrian school of economics. In his (1976) publication, Denationalization of Money. Hayek argued that the government should not have a monopoly over the issuing of money. He suggested that it would instead be better if the private banks (possessing their own registered trademarks) issued currencies in the form of non-interest bearing certificates. These currencies should be left open to competition and should have the capacity to be traded at varying exchange rates. This would result in the elimination of the less stable currencies, thereby, only leaving the currencies that would have a stable purchasing power in the market. Allowing for this process of profit maximization and competition to take place results in a more efficient monetary system which only supports currencies that are stable (ECB, 2012b, p. 22).

1.2.3 Bitcoin in Relation to the Austrian Theory

Bitcoin can be seen as a currency that embodies the ideas outlined by the Austrian school of economics related to the business cycle and monetary theory for several reasons. Firstly, Bitcoin provides a good starting point for the movement towards the ending of the monopoly that central banks have over the issuing of money. Secondly, the Bitcoin scheme is inspired by the gold standard (ECB, 2012a, p. 22). Although some argue that Bitcoins do not have an intrinsic value unlike gold and that they are just bits that stored in computers, Bitcoin's supply is limited and once 21 million Bitcoins have been created no additional Bitcoins will be issued. This renders Bitcoin's supply even more inelastic than that of gold. In addition, the supply of Bitcoin is more transparent than that of gold due to the open source nature of the Blockchain (the platform upon which Bitcoin runs). Another similarity that Bitcoin shares with gold is that it does not decay or deteriorate,it is a global currency because it has no particular country of origin or issuing authority, therefore, it has the capacity to be the medium of exchange between two parties wherever they may be in the world Furthermore, it serves as both a payment system as well as a monetary raw material, it does not need to be stored and does not require the use of a

third party intermediary (Rose, 2015, p. 620). Although some argue that Bitcoin does not satisfy the Misean Regression Theorem, which states that money becomes accepted because it is rooted in a commodity that has some purchasing power, not because of government decree or social acceptance. Bitcoin is still, however, a medium of exchange because it is not the product of a pure barter exchange system. It therefore, does not have to have a direct-use value in order to be considered a medium of exchange, so it does not violate the Mises's regression theorem (Davidson & Block, 2015, p. 333).

1.3 Blockchain Applications: Currency, Contracts and Legal Affairs

Blockchain technology has a variety of different potential applications according to Swan (2015, p. ix) ranging from the financial sphere to the political and legal spheres. The current and potential applications of the blockchain can be distilled into three main catagories: *Currency*, the use of cryptocurrncies such as Bitcoin as a digital payment system to carry out transactions, in simple cases related to cash. *Contracts*, the class of economic and financial applications that are more complicated than simple cash transactions, including items such as stocks, bonds, mortgages, loans, smart property and smart contracts. *Legal Affairs*, the areas that go beyond finance and market based transactions including areas such as the governance and legal system.

1.3.1 Currency

The first application of blockchain is in the areas of currency and payments. Bitcoin could be thought of as referring to three layers in the technology stack of Bitcoin's blockchain. The first layer is the *blockchain*, the technology underlying Bitcoin. The blockchain represents the decentralized open source ledger that has the transactions recorded on it and is shared by the nodes that connect the network. The blockchain is not owned by any particular entity and is constantly being updated and maintained by the miners, and it is transparent, since it can be seen by anyone. It also records the history of the bitcoin as it circulates, so when the ownership of a bitcoin is transferred from one party to another, it is recorded on the blockchain. The middle layer is the *protocol*, the software program through which money is transferred over the

blockchain. The top layer is *Bitcoin*, as in the currency itself (as in the bitcoin coins) (Swan, 2015, p. 1). Together these three layers make up the foundational structure of a crypto-currency. Transactions carried out with bitcoin allow users to maintain some degree of anonymity while keeping the system highly transparent at the same time. It only shows users' digital wallets but not their names. However, since the wallet is tied to a user's name, the whole record of that user is available publicly for anyone to see (Pagliery, 2014, p. 32).

1.3.2 How Bitcoin's blockchain Works

Bitcoin is the digital currency created by Satoshi Nakamoto which he described as "A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution." (2008, p. 1). Bitcoin is a digital currency and an online payment system that employs encryption techniques, in order to control the units of currency that are generated and to verify the transactions that take place. Since Bitcoin operates independently of central banks, it is a decentralized currency. In fact, it is the world's first ever decentralized peer-to-peer digital currency to have originated (Chowdhury & Mendelson, 2013, p. 2). The Bitcoin network is made up of a network of computers that keep the system maintained and receive bitcoins as a reward for doing so. Bitcoins are traded between different parties using a digital wallet. Every hour a fixed amount of bitcoins is mined and that amount is slowly reduced over the years until the production of bitcoins reaches its peak at 21 million bitcoins, at which point no more bitcoins will be produced (Pagliery, 2014, p. 29). There are roughly 16 milllion bitcoins in circulation currently.

Payments using bitcoin are recorded on the blockchain, which is the public ledger upon which all bitcoin transactions that have ever occurred are recorded. The blockchain is stored on all of the computers of all Bitcoin users, and is open source and can be viewed by anyone on the Internet. Users known as miners use their computing power to process, verify and then record payments into the blockchain in exchange for rewards in the form of newly created bitcoins. As miners continue to add new blocks to the blockchain it continues to grow in size. Each computer that is connected to the Bitcoin network used by a client who validates and transactions represents a full node in the blockchain. Each node has a copy of the blockchain downloaded automatically as soon as the miner joins the network. The blockchain holds information about

the balances and addresses of users from the genesis block to the latest block added (Swan, 2015, p. x). The blockchain provides a decentralized, trustless proof mechanism where instead of relying on a third party intermediary or a transaction counterparty, users can trust the blockchain system which is stored on a large number of decentralized nodes that are maintained by miners. In addition, beyond its capacity to be used to process transactions, the blockchain could also be used as an inventory system or registry that records any type of asset including tangible assets (any type of physical property) and intangible assets such as votes and rights to intellectual property. As such, the blockchain could be thought of as a large spreadsheet for registering assets, as well as an accounting system that foresees the processing of the transaction of these assets on a global scale (Morabito, 2017, p. 10).

1.3.2.1 The Creation, Storage and Transfer of Bitcoins

The creation of a bitcoin starts with miners (participating computers also known as nodes) trying to solve a complicated mathematical puzzle, the miner who first solves the puzzle gets rewarded with a bitcoin, so there is always an incentive for more miners with higher processing power to join the network and participate in maintaining it (Caetano, 2015, p. 129). In addition to attempting to solve a puzzle to create more bitcoins, miners have to group proposed transactions into a block and then send them to the others in the network. They also have to check all of the blocks to verify if all of the transactions are legitimate. The block is then added to the official blockchain upon approval (Böhme, Brenner, Moore, & Smith, 2014, p. 439). The system controls the supply of bitcoins so that it does not increase sharply. As more miners join the network and become more advanced at mining the bitcoins, there is the risk of miners solving the puzzles too quickly, which would cause the bitcoin supply to rise too fast. In order to address this risk Satoshi Nakimoto built into the software a speed limit at which every two weeks the mathematical puzzles required to be solved increase in difficulty, so that one block is added to the blockchain roughly within a 10 minute time interval (Antonopoulos, 2014, p. 26). According to Stevenson there is a certain value attached to the hash of a block, there is a target value that is presented by the bitcoin protocol, the miners' task is to produce a hash with a value that is lower

than the target value. This process requires miners to generate a series of hashes until it finally produces the hash with the right composition for the block. When a computer successfully generates an appropriate hash for the block, it broadcasts it to the other computers that are in the network, the other computers then proceed to verify if the hash is in fact the right one by checking for the fulfillment of certain conditions (2013, p. 8). In particular, the proposed block has to have been built over the real blockchain it has to have the right hash for the latest block that had been finalized on the blockchain. The time stamps need to be recent and the block has to contain only transactions that are valid. When another miner's computer approves the block, it goes about working on the next block and relies on the just approved block as the hash of the previous block (Karame & Androulaki, 2016, p. 45).

Bitcoins are stored in digital wallets that work similarly to a bank account. The wallet can be kept locked and inaccessible to others or it could be left open for others to access depending on whether the owner of the account chooses to share their private key. A known address can have funds deposited into it but it cannot be accessed and withdrawn from, unless the user has the permission required to access the account. The wallet functions as an encrypted computer file and it interacts with other wallets using public key cryptography (asymmetric key encryption). When someone creates a digital wallet, their wallet is assigned a public key, which functions as the lock, and a private key, which is the key to that lock. The public key also serves as the user's address and can be shared in order to have another party deposit funds into the account, for example. The private key authorizes the movement of funds out of the wallet in transactions where the user transfers bitcoins to another party or when they buy something using bitcoins. It is important to note that the blockchain is absolutely central to the existence of bitcoin, because bitcoin does not exist in and of itself as a string of codes, for example, its existence is tied to its presence as a record on the blockchain. This quality protects it from being copied and counterfeited, which could easily happen if it was just a computer file or a string of codes (Sammons, 2015, p. 8).

To transfer bitcoins to another party the sender needs to know the receiver's public key, the sender then uses his private key and links it to his public key, this signals to the Bitcoin network that the sender has the authority to make the transaction. Also within this process, the sender is signing digitally, a shorter code of the preceding transaction called a hash (Gimigliano, 2016, p. 39). A hash function is a code that coverts data into a number within a certain interval.

Hashing takes place when a mathematical algorithm applied to a set of information like a concept or a word for example, the application of that algorithm causes that information to then be translated into a code that has a certain fixed length. If any part of the information changes the hash will also change, every individual item has its own special hash. Hashing is a very important part of the process because it compresses the information in the blockchain so that it is not inundated with too much information. This is because every block is placed on top of the block that preceded it and if every block had to scan all of the text of the preceding block, the data would expand inconveniently across the blockchain. Additionally, hashing makes the system more secure because each hash is created using the hash of the previous block. if anyone tries to tamper with the any of the hashes, all of the hashes that are subsequently added will be changed, and will be tagged as false. This makes it more difficult for any inaccurate data to enter the blockchain, because even the smallest change in the letters of the data would automatically trigger a change in the hash which and the would then cause the system to reject that data (Pagliery, 2014, p. 44). Once all of that takes effect, the proposed transaction is broadcasted all over the bitcoin network, and the transaction waits for the miners to verify if it is legitimate and if it is, it becomes official and gets recorded on the blockchain (Caetano, 2015, p. 91). The nodes in the network also ensure that a user is not spending bitcoins twice. The proposed transaction is then issued a time stamp and joins the other transactions. Next, all of these transactions are grouped together as a group of transactions known as a block. The system then proceeds to check if these transactions are valid and if there was no double spending that occurred, if the transactions prove to be valid they are approved and become a part of the blockchain. A transaction is officially verified when all of the transactions on the block have been verified and the block finally joins the chain (Kelly, 2014, p. 79). The whole verification process takes roughly 10 minutes per block, which is shorter than the time it takes for a transaction to go through the conventional banking system.

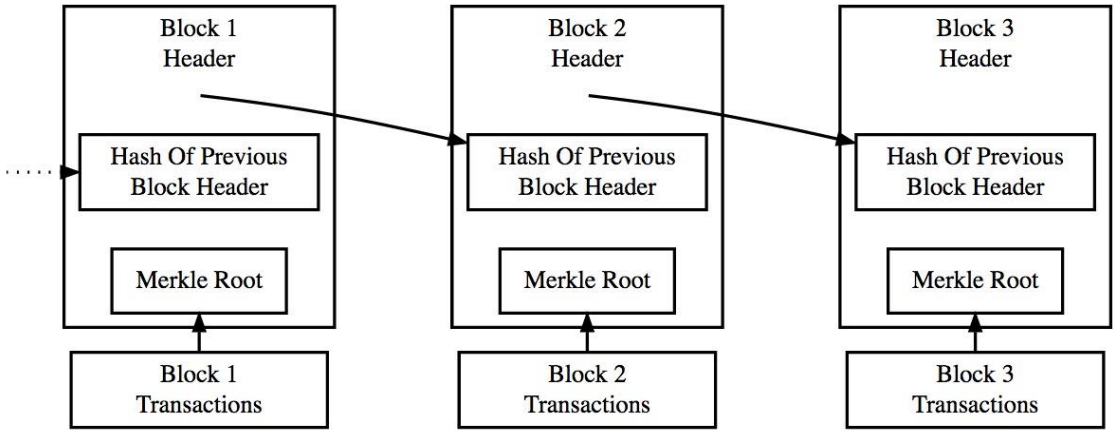

Figure 2: Bitcoin blockchain

Source: Adapted from bitcoin.org (2009)

Figure 2 shows a simplified version of Bitcoin's blockchain, it shows how blocks of new transactions are collected into the part of the block designated for new transactions, transaction copies hashed and then paired and continue to be hashed and paired over and over until just one hash remains.

1.3.2.2 Summary: Bitcoin's Blockchain

In summary, the Bitcoin network works to process payments are facilitated by the blockchain in the following way: The person sending bitcoins creates a transaction message, which is then transmitted to the network. The details included in the transaction message are the value of the transaction, the public address of the person who will be receiving the bitcoins and a cryptographic digital signature, which serves as proof that the transaction is authentic. The nodes in the network then receive the message and decrypt the digital signature in order to show that the message is valid and authentic, this transaction is then placed in a pool full of other pending transactions (Bandelj, Wherry, & Zelizer, 2017, p. 220). Next, one of the nodes in the network places the pending transactions on a block (an updated version of the ledger), the node then proceeds to broadcast the block to the network for validation within a certain time interval. The validating nodes receive the block and start working on the validation of the transaction, which involves a process requiring that the majority of the network reach a consensus as to the validity of the transaction. In order for any transaction to be validated a majority of the nodes in the

network have to have reached a consensus, and if they do then the transaction is considered valid. Different networks use different methods to check if the transactions are valid, Bitcoin's blockchain uses "proof-of-work" to ensure the validity of transactions. When all of the transactions are considered valid the block upon which they are recorded is added or "chained" into the blockchain, and it becomes visible in the network as part of the ledger (Prypto, 2016, p. 137). One of the most obvious advantages of using Bitcoin is that it allows funds to be transferred immediately and saves users from having to wait days for the transfers to occur. There is no need for third party intermediaries, so two individuals can source and complete the transaction directly without any intervention by a third party, this means that users can avoid the transaction fees that are charged by financial intermediaries such as banks for example. The problem of double spending is also avoided, and the system is open source and transparent. The blockchain's currency application serves to decentralize and dis-intermediate the processing of payments and money (Swan, 2015, p. 2).

1.3.3 Contracts and Legal Applications

In addition to currency, the blockchain technology could be applied to design and enforce contracts. When Bitcoin was invented, it was set up in such a way that its protocol could have contracts and money programmed into it. This is possible because of the extensible nature of the structure that it was developed for. Bitcoin's blockchain application in contracts is for the decentralization of markets in general, and can encompass the transfer of other types of assets that go beyond currency. The blockchain is essentially a decentralized transaction ledger, it can be used for the purposes of confirming, registering and transferring different types of property and contracts (Prypto, 2016, p. 106).

1.3.3.1 Smart Contracts

Smart contracts make it easier to establish new organizational forms, such as that of the Distributed Autonomous Organization (DAO), which is similar to Hayek's spontaneous order theory (Collomb & Sok, 2016a, p. 98). Smart contracts entail blockchain transactions that involve more than just buying and selling transactions, such contracts might need to have more

complex instructions embedded into them. In this sense, a contract would be a method by which Bitcoin is used to create agreements with others through the blockchain. A traditional legal contract is an agreement between two or more individuals to either do something or to avoid doing it in exchange for something in return. A contract whether it is smart or otherwise is meant to establish trust between parties. What makes a smart contract different from a traditional one is that rather than relying on a single party to establish that trust, it relies on a distributed network that is secured by the hashing and cryptography that is carried out by the miners in the network. Smart contracts consist of the same kind of agreement as a traditional contract, except that the smart contracts eliminate the need for one kind of trust between the parties, because smart contracts are both defined and automatically enforced by the code (Mougayar, 2016, p. 44) . The key qualities of smart contracts that distinguish them from traditional ones is that they are autonomous, self-sufficient and decentralized (Sundararajan, 2016, p. 93). A smart contract is a computer software that enables the exchange of things of value such as money, property and content. The smart contract is run on the blockchain and then becomes a self-executing computer program that automatically executes operations under certain conditions. Since they run on the blockchain smart contracts are protected from any form of fraud or censorship, and they do not require any intervention by a third party. To set up a smart contract between parties, an option contract with coded terms would be encoded into the blockchain, the contract would enter the blockchain but the users would continue to be anonymous. Next, the contract would be triggered by a certain event such as the expiration of a specific date or the meeting of a certain target and the contract would execute itself in response to the triggering event (Morabito, 2017, p. 31) (Swan, 2015, p. 16) .

1.3.3.2 Smart Property

According to Kelly, smart property is any digitally identifiable property (2014, p. 150). The ownership of smart property is controlled through the blockchain using contracts that are subject to existing laws. Any property can then be turned into smart property by encoding the assets to the blockchain using a unique identifier that enables the asset to be tracked and exchanged when it is sold and bought on the blockchain. Any type of asset can be registered and transacted on the blockchain and that includes tangible assets such as vehicles and buildings as well as digital assets. It can also be used to register and protect intellectual property, thereby,

supplementing or replacing, in some cases, the intellectual property management systems that are currently in place (Swan, 2015, p. 16). A smart contract is designed with special security protocols that embed the contractual terms of a property, into that property. Based on the contract, these protocols give the rightful owner of the property control over the cryptographic keys that are used to operate that property. If the owner wanted to sell this property to another party, a contract could be created that would transfer the ownership of the property's cryptographic key from the seller to the buyer, once the terms of the contract have been fulfilled (Szabo, 1997, p. 4).

1.4 Organizations and Initiatives Currently Using Blockchain Technology

Blockchain technology has been growing in popularity in recent years. Numerous organizations (mainly in the financial service industry) are attempting to explore the potential applications of this revolutionary technology. Blockchain is currently being investigated by the R3 partnership (consortium of 45 of the largest financial institutions) in an attempt to bring this technology to the financial system (Guo & Liang, 2016, p. 2). Aside from the R3 consortium, four of the largest global banks that are led by the Swiss bank UBS, have come up with a digital counterpart of all of the major currencies that are backed by the central banks, known as the "Utility Settlement Coin" (USC). They intended to develop a settlement system that could process transactions a lot faster almost in real time rather than it having to take days for transactions to be settled through the traditional financial institutions (Gibson & Kirk, 2016, p. 4).

Ethereum is one of the best applications of a smart contract platform. Ethereum offers flexibility in creating a smart contract code because it allows users to create different operations based on their preferences and needs. The Ethereum blockchain was designed to have the capacity to allow for the creation and execution of smart contracts that are more complicated in nature (Franco, 2014, p. 199). Two types of accounts can be created in Ethereum, the first type being the externally owned account, which works like a bitcoin account. Just like bitcoin transactions between two walllets, Ethereum allows for transactions to take place between two

externally owned accounts in a similar fashion. The second type of account that can be created is a contract account. The contract account has its own data storage and stores the codes of the contracts. Whereas transactions between two externally owned accounts result in the movement of a certain amount of ether from one account to the other, transactions on contract accounts run the contracts' codes. Contract codes are able to read the codes and the amounts of ether and can store the information (Karame & Androulaki, 2016, p. 182).

There are also initiatives aimed at facilitating finance where business–to-business commerce is involved. B2B commerce currently entails a lot of paper work in the form of letters of credit and other documents that have to be faxed to the other party. Skuchain Brackets for example, is an initiative that uses the blockchain as a platform to build products that facilitate the trade between enterprises, and allows trade partners to interact in a smoother and more efficient manner. It uses the concept of BRACKETS which stands for Blockchain based Release of funds, that Are Conditionally Key-signed, and E Triggered by Signals, to help alleviate some of the complications inherent in the trade between businesses today. Skuchain aims to develop a smart contract solution that will "govern all phases of trade agreements" from ordering, invoicing, shipping all the way through to final payments. Skuchain also enables trade partners to gain a deeper insight into their supply chains thereby, saving them from having to adhere to cash flow constraints and the costs and complications that they may encounter to their inventories. Today's supply chains rely on direct relationships between banks and buyers and sellers. Banks have relations with each other, and sellers and buyers have relationships with their banks as well as with each other. Blockchain would change the supply chain by increasing the transparency and trust involved in the flow of funds and goods while at the same time preserving the direct relationships between the banks, the buyers and sellers, and the banks and their clients (skuchain.com, 2017).

2 The Future of the Firm

The firm has historically been explained using different approaches and theories. First there was the neoclassical view according to which the firm was "a set of feasible production plans. A manager presides over this production set, buying and selling inputs and outputs in a spot market and choosing the plan that maximizes owners' welfare. Welfare is usually represented by profit, or, if profit is uncertain so that profit-maximization is not well defined, by expected net present value of future profit (possibly discounted for risk) or by market value". Then the theory of the firm went through another development with the principle-agent theory. The principle agent theory, modified the neoclassical paradigm, and showed that there is a conflict of interest between different economic agents, and included the idea of information asymmetry into the analysis of the firm. Finally, Coase introduced transaction cost economics in his article (Hart, 1989, p. 1760). Transaction costs economics views the existence of the firm as the result of the costs that go into thinking, planning and contracting that come with any transaction, the cost component was not given as much attention in the neoclassical paradigm. Coase presented a framework that explained in theory, why firms might emerge, and why an entrepreneur might choose to organize within the firm instead of using the price mechanism and trading by means of contracts through the market. In some cases, transaction costs will be lower if the transaction is carried out internally, within the firm instead of in the market. Coase identified a major cost of transacting through the market, the cost of trying to learn about and bargain over the terms of trade. Based on Coase's theory, there are certain conditions that determine the size of the firm, the most important of which is the cost of using the price mechanism as opposed to the cost of organizing within the firm.

Blockchain technology is set to transform the operational structure of the firm. It will change the way that they are managed, financed and their production process. It also has the potential to be applied to a company's accounting, marketing and human resource departments to make to make them operate more efficiently. In addition, the blockchain software will help lower some of the transaction costs that are associated with the overall management of the firm and offers a safe way to create and exchange value. These benefits would be made possible because of blockchain's three special properties: that it is open source and can be viewed by anyone, that

it is distributed across computers worldwide and that it is encrypted to ensure maximum security. The firm will also be able to take on more diverse transactions, which would otherwise have been too risky to undertake, this is because it would free the firm from having to bear the costs of establishing trust. It will also increase transparency within the firm thereby, minimizing the chances of corruption or otherwise unethical behavior occurring at the hands of managers or executives. The firm would be able to specify on the blockchain details of the goals and outcomes that it expects to achieve and every employee's responsibility towards meeting those goals. Through smart contracts shareholders would be able to enforce the commitments that were made by managers. The firm would departure from its traditional hierarchal organization, to one that is more decentralized, efficient and less costly (Tapscott & Tapscott, 2017, p. 10).

2.1 The Emergence of the Firm

Coase began his famous article by posing an interesting question as to why firms tend to emerge in a specialized exchange economy, and why entrepreneurs replace the price mechanism in production organization (1937, p. 390). When a firm is established and an entrepreneur becomes in charge of organizing internally within the firm, in a competitive system, he in effect takes the place of the price mechanism in the direction of resources. As a starting point, Coase quotes Sir Arthur Salter and points out that the economic system works itself, and that economists tend to view the economic system as being coordinated by the price mechanism. Individuals still engage in planning though, because they have to use foresight and choose between different alternatives. Since production can be regulated through price movements, it could therefore be argued that production can be carried out without the establishment of an organization. While economists see the price mechanism as the coordinating instrument they also acknowledge the coordinating function of the entrepreneur.

The main reason firms emerge is because there is a cost to organizing through the price mechanism, firms are established because, an entrepreneur can organize production internally in such a way that the cost of organizing internally is less than the cost of using the price mechanism. One of the costs of organizing production through the price mechanism is that of having to discover what prices are relevant. This cost could be reduced if specialists who sell the information were to emerge. Negotiating agreements' costs are another obvious cost of

organizing production through the price mechanism, because it is costly for firms to negotiate and conclude separate contracts for every exchange transaction that is carried out on the market. Firms also come to exist because of uncertainty, because individuals have to forecast future demand and this leads to the appearance of a "special class" who is deemed to have better judgment and knowledge and whose job is to direct other peoples' activities to whom they then give guaranteed wages (Coase, 1937, p. 400).

Williamson builds on Coase's concept of the firm, but he examines the firm through the lens of the contract, and as such depicts the firm not as a production function as it is assumed to be in choice theory but as a governance structure. According to this contract approach the firm is a governance structure that exists mainly to economize on transaction costs. The firm is always compared with other forms of governance rather than being seen as a stand-alone entity. Coase pointed out that the establishment of firms is profitable because there are costs to using the price mechanism especially the cost of having to discover relevant prices, Williamson agrees with this view but proceeds to ask "How is it that internal procurement by the firm avoids the cost of price discovery?" Answering his own question he explains that sole-source internal supply makes it unnecessary to consult the market about prices, this is because internal accounting prices, (cost-plus, for example) can be used to move goods and services from one internal stage to another (Williamson, 2002, p. 180). Combining these two approaches provides a deeper and more accurate understanding of why internal organization within firms might replace the use of the price mechanism. The firm emerges because there are transaction costs involved in using the price mechanism, and internal organization within the firm facilitates the economization on transaction costs.

2.2 The Transaction Costs Involved in Organizing the Firm

The transaction costs of operating a firm really began to diminish with the onset of the Internet. Firms were suddenly able to use the Internet to send email, conduct searches and market their products online faster and at a much lower cost. Enterprise resource planning applications and cloud computing lowered the costs associated with coordination. Coase points out that positive transaction costs are the reason why firms exist and continue to be successful at organizing internally "The main reason why it is profitable to establish a firm would seem to be

that there is a cost of using the price mechanism. The most obvious cost of "organizing" production through the price mechanism is that of discovering what the relevant prices are. This cost may be reduced but it will not be eliminated by the emergence of specialists who will sell this information. The costs of negotiating and concluding a separate contract for each exchange transaction that takes place on the market must also be taken into account. Again, in certain markets, e.g., produce ex-changes, a technique is devised for minimizing these contract costs; but they are not eliminated. It is true that contracts are not eliminated when there is a firm but they are greatly reduced." (Coase, 1937, p. 4). Coase emphasized two major costs of using the price mechanism, the first one has to do with the need to find out relevant prices and the second one has to do with the contracting costs that a producer would have to incur if they were to carry out every exchange transaction on the market. It therefore, becomes cheaper for the producer to organize internally and to have the entrepreneur coordinate production instead of the price mechanism. If the entrepreneur is not able to organize internally at a lower cost than that of using the price mechanism, he is replaced by the price mechanism. In order to find out how blockchain technology will affect the firm, its role and its size we first take a closer look at the marketing costs (the costs of using the price mechanism) involved in operating a firm that will influence whether or not organization expands internally within the firm. Blockchain technology should lower the costs of using the price mechanism in relation to the costs of internally organizing within the firm.

The price mechanism has several functions including the allocation of scarce resources, the rationing of resources when market demand is greater than supply, allows for the forecasting of demand influencing producer and consumer incentives and signaling and showing where resources may be required the most. Hayek made mention of the importance of the price mechanism as an efficient information communicating system, he wrote that the main function of the price system is to serve as an information communication mechanism "The forces which would operate through changes in price still operate to a considerable extent through changes in the other terms of the contract" (Hayek, 1945, p. 526). He then goes on to explain that: "Only the most essential information is passed on, and passed on only to those concerned. It is more than a metaphor to describe the price system as a kind of machinery for registering change, or a system of telecommunications which enables individual producers to watch merely the movement of a few pointers, as an engineer might watch the hands of a few dials, in order to adjust their

activities to changes of which they may never know more than is reflected in the price movement." (Hayek, 1945, p. 527). Therefore, the price system is seen here as the mechanism conveying relevant prices among other things. If the transaction costs within the firm are at the same level as the transaction costs in the market, the market will outperform the firm and the management coordination done by the entrepreneur. This is because an entrepreneur cannot carry out all of the functions of the price mechanism mentioned above on his own, for such functions are the result of a set of complex and broad chain of events involving many people and circumstances that are beyond the control of a central authority. The knowledge brought about by market prices cannot be entirely gathered by a central authority because of its complexity. The free market transmits this knowledge, which is otherwise dispersed among millions of people. (Hayek, 1945, p. 521).

It is already known that according to Coase, within the firm, the owner does not need to make a series of contracts with the factors that he is cooperating with, he just makes one contract, but if this cooperation was carried out through the market mechanism the producer would have to negotiate and create a separate contract for every transaction that is undertaken through the market (Coase, 1937, p. 391). There is another shortcoming of the price mechanism, and it is that because in an attempt to avoid the cost of making several short-term contracts the owner of the firm ends up making one contract but for a longer period of time. The likelihood of the emergence of the firm, therefore, increases where a short-term-contract is undesirable from the firm owner's standpoint (Coase, 1937, p. 392).

Standard	MODEL	Blockchain
Trusted third-party / central coordinator	Paradigm	Trustless system / pseudonymous participants
Centralized server / many clients	Architecture	Peer-to-peer network
Single copy	Database	Multiple copies
Controlled access / firewalls	Security	Cryptography
Intermediation	Price / Cost	Consensus / proof-of-work
PRIVATE	⟷	PUBLIC

Table 2: Standard transactional model versus blockchain-based transactional model

Source: Adapted from Collomb & Sok (2016)

In comparing the traditional transactional model with the decentralized model, it appears that the centralized traditional model has some deficiencies that make the decentralized model appear more efficient and secure. First, in the centralized model, ledgers are under the control of a trusted third party, who may be vulnerable to bribery and corruption and may therefore not be trustworthy. Second, the data on a centralized ledger is not immutable, so the third-party controller can alter the data or discriminate against some market participants whereas the blockchain is immutable so data on it cannot be altered in any way. Third, centralized ledgers are vulnerable to the loss of data. The blockchain can address all of these issues because of its open source nature and its decentralized consensus reaching mechanism, so everyone can have access to a copy of the information stored on the blockchain (Collomb & Sok, 2016b, p. 96). Table 2 summarizes the differences between transactions that take place in the traditional transactional model versus the decentralized model.

2.3 The Dynamics of Vertical Integration and Outsourcing

According to supply chain analysis, a firm's management should aim to keep transaction costs at a minimum while actively pursuing the coordination of the chain in which the firm is located. The firm's managers should ensure that production flows smoothly and that value is being obtained along the chain. On the other hand, according to network analysis literature, collaborations taking place within the firm are of a more autonomous nature. Based on this perspective the firm's management try to develop social connections where activities are adjusted mutually as opposed to being planned. The management should aim to flexibly position the firm in networks that provide value to the firm in terms of access to diverse knowledge and new information (Lazzarini, Chaddad, & Cook, 2001, p. 19). Although price theory does not provide much of an explanation as to why firms have come to exist, it does provide some insight as to why a firm may choose to integrate vertically into production, supply or distribution, by deciding to perform tasks within the boundaries of the firm as opposed to outsourcing. Price theorists point to two possible motives (one beneficial, the other harmful) for firms to integrate vertically. The beneficial motive has to do with the technological efficiencies that would be created as a result of gathering the separate components that go into the production process in one place. The harmful motive, according to economists, is that vertical integration could result in market power being seized by a particular firm, and the protection of this power by, for example, restricting the firm's rivals from accessing certain inputs (Meese, 2014, p. 956).

There are different types of transactions that require different coordinating mechanisms or various degrees of coordination from both the market and the firm. The simplest type of transaction is the so-called arms-length transaction, like for example directly buying a good. Here there is no need for internal organization within the firm. The contract is more complex and requires that something is set up before, during and after a simple transaction. Vertical integration is the most complex of the three and becomes necessary when there is a synchronization of upstream and downstream activity. As the type of transaction becomes more complex it becomes cheaper for the firm to organize internally (Patrick, 2015). It is important to note that technology can influence what type of coordinating mechanism will be at play or if it will be some mixture of the two (firm and Market).

Transaction Type	Complexity	Coordinating Mechanism
Arms-length transaction	Simple, low cost	Market
Contract	More complex	Market and Firm
Vertical integration	Highly complex	Firm

Table 3: Transaction types, their complexity and the coordinating mechanisms.
Source: Adapted from Patrick (2015)

Table 3 summarizes the various types of transactions, their complexities and the coordinating mechanisms that facilitate them.

Blockchain has properties that can lower the costs of transacting through the market, thereby, causing a shift from a centralized internal organization within the firm to a more decentralized setting whereby the costs of carrying out business transactions through the market are reduced, and this will in turn lessen the role of the firm. In relation to the first cost that of buying a good or a service on the market, we know from Coase that such costs are positive otherwise there would be no need for the firm. The bitcoin platform offers a less costly way of transacting because it allows for a direct and quicker way of making payments, but its implications go beyond money "Bitcoin is a decentralized way of recording and transferring ownership rights (not just of money) in the presence of untrustworthy parties, without the need for a trusted intermediary" (Savalle, 2014).

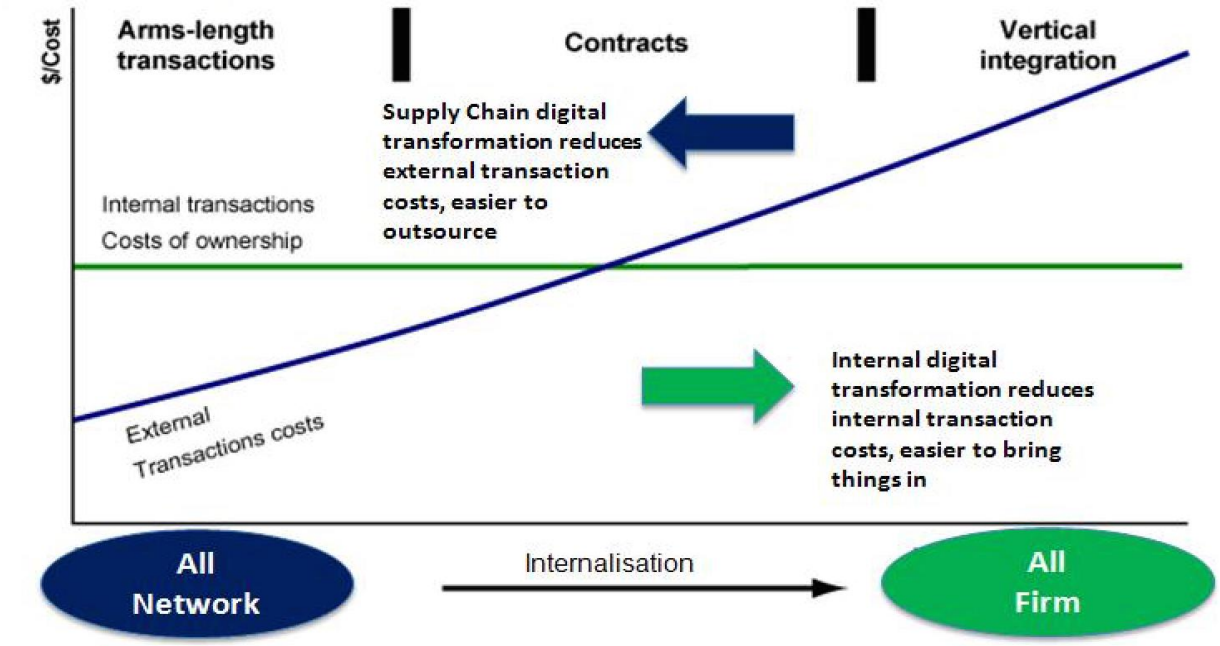

Figure 3: Transaction Cost Model

Source: Adapted from Patrick (2015)

In the figure 3, the upward sloping blue line depicts the increasing transaction costs as the transaction increases in complexity from the left hand side to the right. We can see the types of transactions ranging from the simple arms-length transaction to the contract to vertical integration. The horizontal green line represents the cost of undertaking transactions within the firm it is a fixed cost so any transaction costs incurred within the firm are the same. In economics, fixed costs (overhead costs) are the business expenses incurred by the firm that do not depend on the amount of goods and services that the firm produced. They are usually time-related like, for example, the rents and salaries that a firm has to pay on a monthly basis According to Coase's reasoning, the firm will want to organize internally at the point where the green line is below the blue one, because it is less costly to do so at that point. So the firm in effect, the firm will take up the organization of the more complex transaction internally. The main transaction costs involved in using the market mechanism include: 1) The cost of acquiring a good or a service through the market. 2) Information and search costs. 3) Bargaining costs. 4) Enforcement costs (Patrick, 2015). Next, we consider the impacts of technology, specifically

Bitcoin's blockchain technology on each of the costs mentioned above.

2.4 Managing and Organizing the Firm with the Blockchain

Having established the transaction costs involved in organizing the firm, and the different types of transaction complexities and coordinating mechanisms, we now turn to the different components of the firm, including the entrepreneur, the employee, and the organization related to the finance, advertising, and legal areas of the firm. The emphasis will be on applying the analysis of the blockchain technology to the Coasean framework of the firm to see if it reduces the overall transaction costs of organizing the firm, relative to the traditional way that the firm is managed as highlighted by Coase. Blockchain should change the way that the firm is organized, making outsourcing just as easy for the firm as insourcing is, while at the same time reducing transaction costs. The following analysis will be carried out keeping in mind the assumption that individuals and organizations in this future model will have their personal data stored online in the blockain so that the blockchain would be able to refer to this data for various purposes.

2.4.1 Firm Coordination and the Role of the Entrepreneur

Among the costs mentioned by Coase was the cost of coordinating, which is the cost involved in ensuring that all of the workers in the firm are working together in efficient manner. Coase added to the theory of the firm a clearer explanation of the role of the entrepreneur which was previously not addressed in the neoclassical theory of the firm (Hart, 1989, p. 1760). According to Coase's theory the entrepreneur has a central role in the organization within the firm. Following from the assumption that the firm exists because there are positive transaction costs involved in production, like those of price discovery and contract execution, comes the entrepreneur's task of coordinating production within the firm. The entrepreneur's main purpose is to reduce the above mentioned production costs, by obtaining factors of production for a lower price than that available through market transactions outside of the boundaries of the firm, and he has the incentive to do so because he knows that if he fails to do so properly, he could always be replaced by the open market. In addition, the entrepreneur has to ensure that the firm's functions

are performed at a lower cost than would be the cost of carrying out the same functions but by another firm. The entrepreneur can choose to either contract with suppliers of different goods or to hire employees, which will be working under his direction. This view of the firm and entrepreneurial management can be thought of as a good approximation of firms existing these days, but in the future as the firm changes in response to technological advancement this view can be adapted to fit the features of the future firm. According to Tapscott (2016, p. 105), the problem with the hierarchical management of the firm is that it makes the firm less productive. Pursuing networking and decentralization in the firm's management would enable the firm to operate more efficiently.

In applying the information of how blockchain technology works when applied to Coase's (1937) theory, we can gain a clearer idea of how this future firm might operate with the help of such technology. The hypothesis being that blockchain technology will reduce the costs of using the price mechanism thereby, freeing the entrepreneur from the burden of having to organize and coordinate within the firm so heavily, and this can also increase the efficiency of the firm by preventing the entrepreneur from making mistakes due to him being over-exhausted theoretically speaking. It is important here to note two key assumptions made by Coase the first being that the entrepreneur function may yield decreasing returns as the firm grows, and second, that as the number of transactions that have to be organized by the entrepreneur increases, so does the chance that he will make a mistake in his placement of the factors of production into their appropriate uses (where the most can be made of their value). The firm is more likely to emerge when there is a need for long-term contracts because in the case of goods, a contract is set up with the supplier of the good, specifying just the limit to the extent of what is expected of the supplier to do, the details of which are worked out later by the buyer (the entrepreneur). In the case of labor however, things get more complicated because the longer the contract's period is the less favorable it will be for the buyer specify what he expects of the employee in case conditions change in the future.

In relation to the entrepreneur's first problem with the costs of finding out relative prices the Internet today has helped reduce information costs significantly and has made such information widely available. The the blockchain would enable smoother networking within the firm, so rather than assuming a top-down management, the firm would assume a more distributed and decentralized style of management. It would allow the different workers in the firm to work

persistently and harmoniously without having to be managed in a hierarchal manner. In addition, shareholders will have more insight into how managers conduct themselves, because of the transparency that the network provides (Tapscott & Tapscott, 2016, p. 106). There are even some service markets that have already emerged such as Uber where apps serve as a replacement for managers. What once required the establishment of large corporations can now be performed by smaller firms (Kilpi, 2015, p. 1). So there is already a movement toward a more decentralized structure of some firms. As for the costs associated with having to execute contracts separately for all of the transactions that are involved in production, smart property and smart contracts will make it much easier for contracts to be executed at a much lower cost, and at a faster pace because there would be more digital transparency and less reliance on intermediaries to execute contracts (Nicoletti, 2017, p. 130). Supposing that in the future peoples' assets and actions will be activated cryptographically, both the physical and intellectual properties will be registered in the blockchain as smart property and the transaction of such property will occur through the blockchain. Similarly, contractual agreements will also be recorded in the blockchain as smart contracts, which will be based on codes that would be encoded into the blockchain.

The blockchain has the capacity to register and exchange assets and to keep track of inventories, this includes hard assets like a house, a computer or a car, and intangible assets such as stock shares, information, intention, and copy rights on books and music, for example. The property becomes encoded in the blockchain and can thereby be transacted through smart contracts. The ownership of such assets is controlled by whoever owns the private key, the assets can be sold by giving the private key to another individual. The ownership of smart property is controlled through the blockchain, and the contracts in place are in accordance with the existing laws (S & S, 2017, p. 51).With smart property, property rights are defined through cryptography and it is self-enforced by a code that has to operate on the basis of an underlying code and it cannot deviate from what was encoded. So if a property transfer is encoded the property transfer will have to occur without deviation from the code. Turning property into smart property makes it easier for that property to be traded without much trust, and this has a variety of advantages including the lowering of mediation and fraud fees, it also serves to increase the potential for trade to occur, because trading parties would not need to know or trust each other anymore for the transactions to occur safely (Swan, 2015, p. 16). Parties can easily lend money to each other because the lending party could always take the creditors smart property as collateral for

example.

Following from the knowledge of the nature of smart property and how it is linked to the blockchain network, smart contracts can be thought of as contracts that are more sophisticated than a simple buying and selling transaction, in the sense that they contain more instructions embedded within them. In other words, an agreement is formed through the blockchain between people using Bitcoin. The contract is by definition an agreement between two or more individuals to do or to avoid doing something in exchange for getting something else, and every party must be able to trust the other to fulfill its part of the deal. Similarly, the smart contracts have a similar dynamic involving action or inaction, except that they eliminate the need for trust between the contracting parties, and this is because a smart contract would be defined by the code as well as automatically enforced by it. Furthermore, there are three special elements that distinguish a smart contract from a regular one and these are that smart contracts are autonomous, self-sufficient and decentralized. Autonomy refers to the fact that once an agent initiates a contract he/she does not need to be in contact with that contract after it has been launched. The smart contract is self-sufficient because it would have the capacity to organize resources efficiently, it would have the ability to raise funds by issuing equity for example, and then it would be able to use that money where it is most needed like to buy storage or processing power. The decentralized nature of smart contracts stems from the fact that they do not exist in a single centralized server but are instead dispersed across a network and are self-executing. A smart contract executes the pre-specified code without deviation (Swan, 2015, p. 17).

In the context of the Coasian firm, this means that blockchain through applications such as smart property and smart contracts, can reduce the transaction costs involved in executing contracts, thereby, making it much cheaper for the entrepreneur to choose to contract out to various suppliers and contractors. In addition, this firm will have a decentralized management structure, where the role of the entrepreneur will be smaller because the firm will be managed by a network of workers rather than just the entrepreneur as the case was made by Coase (Tapscott & Tapscott, 2016, p. 106). The firm's coordination will therefore, shift from a more centralized kind of coordination, which is heavily dependent on the entrepreneur, to a more decentralized type of coordination with a larger network of contractors and suppliers involved, and a relatively smaller role of the entrepreneur. In this case, the transaction costs mentioned by Coase would have been significantly reduced in such a way that carrying out the organization using the market

mechanism would have become less expensive compared to organizing within the firm. This would serve to shrink the size of the firm while also making it operate more efficiently, as Coase pointed out the firm grows as more exchange transactions are organized by the entrepreneur, and becomes smaller when he does not have to coordinate all of those transactions.

2.4.2 Hiring Labor and Procuring Resources

Coase (1937) also mentioned that the legal relationship between "employee and employer" was an important constituent of the firm. He established two conditions with where he specified the nature of the contractual relationship between the employer and his worker, referring to them as master and servant respectively. First, the servant must be willing to provide the master with services or to others (on the behalf of the master). Second, the master has to have the right to have control over the servant's labor either personally or through another agent. Based on the conditions mentioned above, there is a clear distinction between two kinds of labor, that of a servant (completely under the control of the master) and that of the independent contractor who enjoys more freedom. The difference between the two is that the servant's employer controls the servant by telling them when to work and what to do and how to work, whereas the independent contractor is not under the employer's control in doing his work or providing services, he simply has to make sure that he manages his work to reach the result that he has contractually promised to achieve. The independent contractor would have more freedom in terms of his employment, and it is possible that in the future with firms becoming smaller and more decentralized because of the blockchain, employment will shift from what it looks like now (vertical integration), to a less controlled type of employment where workers will be able to work with more freedom, perhaps as independent contractors. Based on Coase's theory, the firm faces information, coordination and contracting costs, if these costs are significantly reduced, the firm will end up being smaller in size. In this section, we examine how the blockchain would reduce the costs of searching for specialized labor, contractors and suppliers that a firm would need to connect with to carry out its operations, as well as costs in the context of hiring workers, paying their salaries using Bitcoin and using blockchain-based smart contracts, to see how these costs could be lowered.

2.4.2.1 Searching for Specialized Labor, Contractors and Suppliers on the Blockchain

Also related to the firm's searching costs are the costs of having to search for skilled labor, contractors and suppliers. In the conventional procurement processes there is room for asymmetric information that might potentially result in the employer making a less than optimal decision in terms of who they decide to employ and that might prove to be costly to the firm. Blockchain will allow firms to have better access to information about potential recruits with specific skill sets and qualifications, and potential partners and contractors, because it allows for multidimensional searching. According to Tapscott (2016, p. 97) the Internet enables us to carry out two-dimensional searches, horizontal (wide searches over the Internet) and vertical (deep searches of individual Web sites). Blockchain adds the third dimension of time to the search process, it allows searchers to see the sequence of the information that they are searching for in the order in which it was uploaded over time. The employer will be able to access a collection of reliable information (upon the prospective employee's agreement) related to the prospective employee's skills, educational attainment and any other qualifications. That information would be accurate and would be uploaded and stored on the blockchain, which is a secure, distributed and immutable network. Schools and training institutions would enter the information of their graduates on the blockchain and from there on out the information would be rendered tamper-proof on the blockchain. This would make it impossible for a prospective recruit to lie about or otherwise manipulate any of the information pertaining to their education and training. While individuals do still own their identity today, because of the internet people now have virtual identities but the data that comes from their interaction with the world is not owned by them and is instead owned by intermediaries including banks, credit card companies and social media companies (Sondergaard, 2013). So companies could use the Internet to gather a collection of information about a prospective employee, some of the information they find, may not even be relevant to the recruitment process. But with the blockchain people would have full ownership of all of their personal data. People would have a personalized avatar that resides in a black box of their identities. They would be able to upload their personal information such as their educational attainment, citizenship and financial information into the black box on the blockchain, and they would have full control and ownership of this information rather than it being owned by a third party. Special software would only release information from the black box that is relevant to the

situation at hand, thereby, protecting the individual's privacy (Tapscott & Tapscott, 2016, p. 15). An employer would not have access to information that is not relevant to the job he is offering such as gender, ethnicity or age and would, therefore, have to rely on information that is only pertinent to the skills he is looking for in a prospective employee. This will eliminate the biases inherent in the recruitment processes and would also end the need for executive recruitment fees. Employers could view the information that people have made accessible on the blockchain and would be able to use the blockchain to set up questionnaires that are specifically tailored to the qualities that they are looking for in their prospective recruits. Applicants would then have the opportunity to respond to the questions by programing their black boxes to reveal their responses, or they could decline to respond. Based on their responses, employers would be able to find out easily which applicants meet their standards. Employers would be able to find prospective recruits with more precision, but the downside is that this would reduce the likelihood of serendipity occurring, because of this precision they might miss out on finding an unskilled applicant who might have otherwise been exceptionally capable of learning and making good connections, which are asset to the firm (Tapscott & Tapscott, 2016, p. 97). Individuals would be able to retain more privacy than they do today and employers would enjoy a higher level of transparency at the same time. In the case of contractors and suppliers, a firm would be able to more easily find, partners and suppliers that meet their standards, because the blockchain would record the details as to the goods that they supply, their experience in providing these goods and they would be able to find reviews on them, so it will be easier to distinguish the good ones from the bad. The firm will be able to use the blockchain to find different suppliers and contractors at a lower cost and it would have insight into their experience and ability to meet budget and time constraints as well as their capability to fulfill the terms of their smart contracts (Tapscott & Tapscott, 2016, p. 96). This would lower the search costs related to finding employees and suppliers so firms could hire workers and contract with suppliers more easily and reliably and this will provide more of an incentive for the firm to open its boundaries to outsourcing from the market. This solves the problem posed by Coase regarding the search and information costs that are incurred by the firm.

2.4.2.2 Searching for Potential Customers on the Blockchain

The firm would also be able to find individuals and corporations who could potentially become its customers according to Tapscott (2016, p. 97). The company will not be able to track customers' consumption patterns over the Internet, so it will not be able to profile customers, because people will be in control of their own information, which will be stored in their virtual black boxes. The blockchain would, however, enable the firm to interact with customers on an individual and peer-to-peer basis. So rather than capturing potential customers' attention through marketing links, information about firms and the products or services that they provide will be recorded on the blockchain and the firms will be ranked based on reviews and reputation scores. Firms might have to pay potential customers for the right to access their data, to find out which customers are within the firm's target audience. While this may seem like an additional cost that would have to be borne by the firm, it would enable firms to pinpoint their target audience more precisely. The firm will prepare questionnaires and will pay prospective customers for the right to present these questionnaires to their virtual black boxes for responses, the black boxes would provide only responses that are relevant to the questions being asked. Then, based on the information gathered from the prospective customers' black boxes, the company would be able to make an inference as to which of the customers are in their target audience. The firm could then use social media and e-mail, where communication costs are zero, to advertise to its precisely defined target audience. Furthermore, the firm could easily target individuals who may choose to provide information that is pertinent to their interests voluntarily and freely (Tapscott & Tapscott, 2016, p. 97). Just as in the case of searching for employees, the additional precision that firms would have in finding their target audience comes at the price of them possibly missing out on being able to capture the attention of people who are not initially in their target audience but might have become part of the target group because they were persuaded by the marketing. Firms will benefit by being able to reach their target audiences more effectively and customers would also benefit from being able to retain their privacy and to make financial gains from their personal data(Tapscott & Tapscott, 2017, p. 12). In this case, although the firm might have to compensate prospective customers in some way, to be able to gain access to their information, it will have the benefit of having a more precise audience to target, so it will be able to avoid wasting time and resources unnecessarily.

2.4.3 Contracting with Employees and Suppliers with Smart Contracts

Contracting costs, according to Coase (1937) are the costs that involve price negotiations, and decisions about the specific details like the specific amounts and types of goods or services that will be provided by the supplier. Also included as contracting costs are the costs of monitoring and enforcing the terms and conditions of the contract, as well as the clauses that specify the remedial actions that would have to take place, should one of the parties fail to deliver as was stated in the contract. Coase also pointed out that companies are like vehicles that create long-term contracts when short-term contracts become too costly in terms of negotitation and enforcement. A contract's main functions are to define each party's obligations and to establish expectations and trust among the parties that are involved in the agreement. Coase posited that contracting costs are higher on the market and that they are lower within the firm. He argued that a firm is, therefore, an organization that creates long-term contracts when short-term contracts would otherwise be too costly, in terms of time and effort, to carry out. Paper contracts today serve merely the purpose of documenting an agreement between two or more parties. Contracts in the form of software, on the other hand, such as the blockchain- based smart contracts could have further benefits to simply documenting agreements, they could make it easier for a firm to outsource resources from the market and could make it easier to set up both short-term and long-term contracts (Tapscott & Tapscott, 2016, p. 105). Because blockchain would lower contracting costs, it would make it easier and less costly for firms to foster relationships with entities outside of their boundaries, because these relationships would be maintained through smart contracts instead of managers. Smart contracts take the form of computer protocols that self-execute a transaction once certain pre-specified conditions have been met (Swanson, 2015, p. 15). Smart contracts could be used in place of traditional contracts to specify and enforce certain terms related to payments or legal claims, for example. Once a smart contract self-executes, the outcome it triggered cannot be reversed, so parties will need to spend more time negotiating its terms beforehand to ensure a mutually satisfactory agreement is reached (Christidis & Devetsikiotis, 2016, p. 2301). A smart contract could also be used to establish trust without the need for an intermediary (Morabito, 2017, p. 12). Smart contracts have the added benefit of being more dynamic than conventional contracts because they can self-execute decisions and transmit information, whereas, conventional contracts cannot. Smart

contracts also have the capacity to capture and store a wider range of information compared to traditional contracts, smart contracts could hold different types of data even nonlinguistic data (Tapscott & Tapscott, 2016, p. 101). Additionally, smart contracts would lower enforcement and arbitration costs as well as the costs arising from fraudulent activities (Tasca, Aste, Pelizzon, & Perony, 2016, p. 234). Blocokchain would thus greatly reduce the costs and friction involved in contracting, and this would make it so that firms would find it easier to outsource. Although it may at first seem that this need for a more thorough negotiation process would be burdensome and time consuming to the parties involved, the benefits of opening the firm's boundaries would far outweigh this cost. This is because, if the parties spend more time negotiating the terms of their contract, the costs of monitoring, enforcing, and settling the agreement could fall dramatically, even to zero (Tapscott & Tapscott, 2016, p. 103). This would lower the contracting costs pointed out by Coase significantly enough to allow the firm to enter into shorter term contracts without having to fear incurring higher costs. So rather than the firm having only the long-term contract as a lower cost option, with blockchain technology and smart contracting it will be easier for the firm to enter into short-term contracts.

2.4.4 Making Payments in Bitcoin and Establishing Trust

The blockchain has a lot of potential where financial applications are concerned. It can be applied to areas such as payments, corporate finance and financial reporting and accounting. Bitcoin's blockchain makes it easier and cheaper to transact internationally and to pay remittances at a faster pace and at lower transaction costs relative to the conventional banking system that involves higher transaction costs in terms of banking fees and a longer transaction settlement period. It takes a few days for an international transfer to be settled through a bank, whereas, it takes roughly 10 minutes for a Bitcoin transaction to be settled on the blockchain wherever in the world the transacting parties might be (Miller, 2014, p. 44). Furthermore, in relation to the trust establishment costs highlighted by Coase, bitcoin allows for more transparency and openness in transactions and saves users from the costs of having to rely on a single trusted third party because of the distributed nature of its maintenance process. Sellers would no longer have to bear the costs of having to establish trust with their customers, they would be able to take on more transactions, some of which would otherwise be considered to be

too risky to undertake through the traditional banking system (Böhme et al., 2014, p. 34). In the context of the firm, the blockchain could be used to trace the firm's ownership. Because it could sometimes be difficult to trace the ownership of a particular firm, while companies that are traded publicly likely do know who their major shareholders are and regulations could sometimes force the shareholders to reveal their ownership, minority shareholders are usually harder to trace. In some cases, it so difficult to trace these minority shareholders to the point that if the firm were to undergo a takeover, the firm's management would have a hard time trying to find these shareholders. The blockchain could fill this gap where the firm's management sometimes fails to produce an efficient outcome, in this case, the management's inability to discern which shareholders own which stock. It could also help in the area of corporate governance, making it easier to consult shareholders annually, at general meetings through secure and tamper-proof electronic voting. Since the blockcahin would make it easier to trace shareholders, it would also make it easier to make dividend payouts to these shareholders, and to make payment coupons to bondholders. In effect, corporate governance would become a lot more inclusive (Collomb & Sok, 2016b, p. 100). All of the firm's financial transactions would potentially be recorded on the blockchain, this could do wonders for the firm's management. In addition, individuals employed in chief positions such as the chief financial officers, chief accountants, treasurers, sales managers and legal counselors would also benefit from the blockchain. Blockcahin would also allow for higher precision where financial management and accounting are concerned because it would facilitate the quick updating in almost real time of the firm's financial statements such as the firm's cash flow and income statements and its balance sheet. All of these use cases showcase how blockchain would increase the efficiency of the financial processes of the firm, while at the same time reducing some of the costs associated with organizing the firm. Because of its capacity to trace ownership in an open source, distributed and tamper-proof manner blockchain could also be used to strengthen financial reporting and the enforcement of compliance procedures by automating financial reports and changing how reporting channels are designed. Since it offers a complete record of all of the transactions that were ever undertaken by the firm, it could make it easier for regulator's to monitor the company's business activities, it could also make auditors jobs easier because they would have a clearer overall picture of all of the activities that were undertaken by the firm. Another area where the blockchain could be helpful in a financial setting is in peer-to-peer lending and crowd

funding (Collomb & Sok, 2016b, p. 102). All of these use cases showcase how blockchain would increase the efficiency of the financial processes of the firm, while at the same time reducing some of the costs associated with organizing the firm. When put into the context of Coase's analysis of the firm we see that the use of blockchain technology would reduce some of the financial transaction costs involved in running a firm as well as the costs of having to establish trust through a third party intermediary when transferring funds.

2.5 Summary

The firm starts off as described by Coase in his (1937) paper, as an organization that is rather centralized. In this firm, the entrepreneur is in charge of directing the firm's production resources in way that ensures that transaction costs remain lower than they would otherwise be if the price mechanism were left to direct production. In organizing production, the firm faces search costs, coordination costs, contracting costs and the costs that come with trying to establish trust. Long-term contracts are more convenient for such a firm as opposed to short-term contracts. The firm then ends up assuming vertical integration by seizing control over more steps in its production process to save on some of these costs, and it expands because these costs make it difficult for the firm to outsource. This results in the firm adopting a hierarchical organizational structure. If these costs were to be sufficiently reduced, the firm would find it easier to outsource and integrate horizontally instead. Applying the blockchain's operational framework to Coase's analysis of the firm, we find that blockchain would reduce these transaction costs considerably. Coordination costs would drop because the entrepreneur would be relieved of the pressure of having to organize heavily, instead networking would be adopted and management will no longer be from the top down. Smart contracts would reduce contracting costs and the costs of establishing trust would also fall. Smart contracts would make it easier to set up both short-term long-term contracts, and would reduce the costs of having to monitor and maintain the smart contract because the contract would self-execute so it would not have to be monitored and maintained after it has been run on the blockchain. Contracting parties would have to spend more time agreeing on the terms of their smart contracts because smart contracts are irreversible upon execution, but in doing so the firm will save on enforcement and arbitration costs. The costs of searching for skilled employees, suppliers and contractors would also drop,

because blockchain would allow the firm to carry out more precise searches that would yield precise results. Similarly, companies would be able to find their target customers with more precision. The precision of the system, however, lessens the likelihood of serendipity occurring in the situations where employers are searching for prospective recruits, and similarly, in situations where companies are trying to find their target audience. However, the cost saving advantages of being able to carry out more precise searches would outweigh any costs associated with the loss of serendipity, because the firm would be subject to lower search costs. In addition, the future firm's potential use of Bitcoins to transact would allow it to save on the transaction costs that come with the use of conventional financial intermediaries to transfer funds. The result is a smaller, decentralized and more efficiently operating firm with a more inclusive management system, and boundaries that are more open to outsourcing.

3 Blockchain Technology and the Future of Legal Affairs

Coase addressed some of the problems inherent in the legal system, and how despite the importance of the establishment of the delimitation of rights, the courts' decisions might sometimes lead to less than optimal results (1960, p. 9). He sought to explain why some externalities are internalized and why the initial delimitation of legal property rights, although necessary, does not affect the ultimate result, provided that the pricing mechanism is operating smoothly and without cost. Given the reciprocal nature of the problem of social cost, Coase argued that economists and courts should attempt to understand the economic implications of the courts' decisions.

In the cases where legal rights need to be allocated, people end up going to court because of the transaction costs that they would face if they were to try to carry out market transactions privately. These transaction costs, according to Coase include the costs of having to search for someone to make the deal with, having to inform people of the deal that would be made and on what terms it would be made, having to make negotiations before a bargain can be struck, having to set up a contract and having to inspect it to ensure that the terms of the contract are understood

and so on. Due to the transaction costs involved in market transactions, the firm becomes an alternative to these market transactions in organizing production. The firm does away with the negotiations between the cooperating factors of production and administrative decisions substitute market transactions. Production is rearranged without the need for negotiations between the owners of the factors of production. In cases where negative externalities are involved, drawing up contracts becomes more complicated and costly, long-term contracts might therefore be a desirable solution. In this case, either a firm would emerge to deal with these harmful effects, or an already existing firm would expand to be able to address the problems that come with negative externalities (Coase, 1960, p. 17). This solution would be adopted as long as the costs of undertaking market transactions would exceed the firm's administrative costs and as long as the gains that result from the firm's administrative actions outweigh the costs associated with organizing them. However, in more complicated cases that involve a large number of people as in the cases of smoke nuisances, for example, the administrative costs of organizing such transactions within the firm may become so high that they necessitate the involvement of the government and this is where law becomes a desirable solution to these larger social problems. So rather than instituting a legal system that defines rights which can be modified by market transactions, the government passes regulations that restrict peoples' or firms' activities, such as prohibitions and zoning regulations, some of which might lead to inefficient economic outcomes. The issue that arises with government intervention is that it is not subject to the competitive check that a firm is subject to. The firm has to adjust its operations in a way that ensures its survival given the competition of the other firms and this keeps the firm operating efficiently, whereas the government can avoid the market altogether, if it wanted to, because it has at its disposal authoritarian power in the form of control over law enforcement agencies and the police. The lack of a competitive check over the government's actions means that some of the regulations brought about by the state might not necessarily be efficient (Coase, 1960, p. 18). Coase thus summarizes the problem by emphasizing that with transaction costs present, the courts would have to be used to enforce parties' rights, as transaction costs continue to rise the solution necessitates the use of more centralized institutions. In the absence of transaction costs, however, externalities will be internalized regardless of the initial assignment of property rights. Parties would be able to bargain with one another until they reach a mutually beneficial agreement, they could renegotiate the property rights, since there would be no transaction costs

involved, and the externality could be priced and dealt with in a decentralized way that leads to a more efficient allocation of resources. The hypothesis in this section is that blockchain technology would lower transaction costs sufficiently enough to allow for a more decentralized legal system that relies more on market transactions than it does on the traditional centralized arbitrators. For the purposes of this paper we focus on the areas of law that involve only cases of dispute resolution, and externality internalization excluding criminal law from the analysis.

The following analysis would be carried out assuming that in this future model, individuals and organizations would have their information such as their bank account and the prices of the commodities that they offer stored in data fields on the blockchain (Tapscott & Tapscott, 2017, p. 12), so smart contracts would be able to refer to those fields, to for example, automatically transfer funds from one person's account to another's once the terms of a sale have been met and to carry out other similar transactions.

3.1 Blockchain and Decentralized Peer-to-Peer Law

Laws are put in place for various reasons: to establish individuals' rights over one another and over their governments, to maintain social order by encouraging good behavior and punishing bad behavior. As such, laws represent a society's values and provide a framework of the structure of markets, organizations and governments (Wright & De Filippi, 2015a, p. 50). The blockchain could add more transparency to the judicial processes, facilitate the crowdsourcing of law, and make it easier for citizens to participate in the legal process (Swan, 2015, p. 48). In the same way that it facilitates peer-to-peer transactions between parties without the need for a central authority, the blockchain could also have a similar effect in legal cases, where two parties could reach an agreement and then decide to enforce it using a smart contract. The blockchain would allow people to assume the role of a collective middleman and would thus reduce the need for centralized authorities. It would allow Internet users to use a shared and decentralized database and smart contracts to resolve their own affairs. Property, data and any kind of content would be registered on the blockchain and would be encrypted which would allow people to carry out transaction directly on a peer-to-peer basis and more quickly while allowing them to maintain a high degree of privacy at the same time. As such, the blockchain would provide a space for people to interact with one another more fairly and would result in the

transfer of functions from centralized organizations to more decentralized entities (Wright & De Filippi, 2015a, p. 19). In the following sections, we explore how the blockchain would apply to the different areas of law that were highlighted by Coase to see how it could reduce the transaction costs that arise in legal situations and make it hard for the parties involved to use market transactions to resolve their disputes and to help internalize negative externalities.

3.1.1 Smart Contracts and Collaborative Peer-to-Peer Dispute Resolution

Judicial dispute resolution becomes necessary when disputes arise between parties that involve the establishment of perceived legal rights, or some kind of perceived wrongdoing by one of the parties. According to Coase in the absence of transaction costs, the parties would negotiate with one another without cost, until they arrive at a mutually beneficial resolution and that resolution would result in an economically efficient outcome. Disputants, however, face positive transaction costs in trying to resolve their disputes, so they end up going to court over their disputes. Aside from decentralizing the judiciary, blockchain technology could also help make dispute resolutions between parties more collaborative and it could make it easier for parties to enter into contractual agreements on a peer-to-peer basis without needing to rely on a central authority to establish and enforce their rights (Blockchain technology, 2017). In applying Coase's theory to this logic it becomes apparent that the blockchain would help move law in the direction of Coase's ideal because it would lower transaction costs in such a way that would allow parties to negotiate directly almost without cost and would therefore make it easier for parties to use market transactions and resolve their disputes on their own instead of having to rely on a third party such as a judge who might resolve their disputes inefficiently.

A peer-to-peer dispute resolution would differ in several ways from the kind of dispute resolution that exists in conventional litigation systems. In a peer-to-peer arbitration system arbitrators do not need to be selected, legal enforcement can be avoided and formalized rules related to presenting and considering arguments and evidence are not required. Smart contracts would essentially enable parties to engage in peer-to-peer dispute resolution without the need for an arbitrator because of their ability to self-execute after they have been run on the blockchain,

rather than needing a third party to enforce the contract it would simply enforce itself according to the conditions that were agreed upon by the parties involved. Peer-to-peer law could help reduce transaction costs when corporate decision making or litigation impose unnecessarily high costs on simple decisions (Abramowicz, 2015, p. 7). Smart contracts would allow users more flexibility in defining the terms of their agreements, users will be able to require multiple signatures made possible by multi-sig technology and set a specific time for a transaction contract to execute, then once all the conditions have been met and the appointed time comes to pass, the contract would enforce its own terms (Wright & De Filippi, 2015a, p. 16). Arbitration would shift from the traditional court systems to private law firms, which would act as smart contract mediators. Lawyers would have to learn to code the terms and conditions of the smart contracts into the blockchain and to ensure that the contracts are consistent with what both parties would be agreeing to (Tasca et al., 2016, p. 227). To enter into a contractual agreement, parties would enlist the help of a smart contract mediator who would draft an arbitration clause that would include the terms and conditions of the smart contract that would be coded into the blockchain, upon the agreement of the parties involved. Once the clause has been coded into the blockchain, and the conditions specific to it have been met, it will self-execute (Jacob, Schindler, & Strathausen, 2016, p. 101). This would reduce the costs in the form of the legal fees, time and opportunity costs inherent in the traditional legal system which would be incurred by the parties in the event that a dispute were to arise. This would especially be relevant in cases where, for example, one party would have signed an agreement to pay the other party a certain amount of money in exchange for something but would then only partially pay the amount, knowing that the other party would have to incur high costs to be able to extract the rest of the payment through the conventional legal system. In such a case the smart contract would self-enforce without the need for third party arbitration, and given the assumption made earlier that smart contracts will be able to refer to data fields on the blockchain and transfer funds from one party to another once the contract terms have been met and the smart contract has self-executed, the funds will be transferred based on the agreements in the contract for sure, and parties will not be able to reverse or deviate from the terms of their smart contract. Moreover, carrying out arbitration over the blockchain could lead to more collaborative dispute resolutions (Blockchain technology, 2017), because the traditional legal system leaves parties vulnerable to being taken advantage of in cases where the parties would like to maintain a relationship after their dispute

has been resolved, business partnerships and divorces can be thought of as examples of such cases. In such cases, the parties would agree to certain terms and enforce them on the blockchain through smart contracts and depending on the terms that were agreed upon, this would prevent any of the parties from trying exploit the legal system to take financial advantage of one another. These transaction cost reductions would move arbitration closer to Coase's ideal where parties would be able to carry out market transactions and negotiate and bargain without cost and would therefore, be able to reach a mutually beneficial outcome that would be economically efficient at the same time.

3.1.2 Decentralized Judicial Enforcement on the Blockchain

Smart contracts cannot process notions of justice and fairness, and are not able to settle cases where conflicting information exists, however, in such complicated cases the blockchain can be used as a platform to resolve the disputes in a decentralized judicial system (Tapscott & Tapscott, 2016, p. 219). In the event that parties should require their contracts to be enforced by some third party, they could have a judiciary make these enforcements in a decentralized judicial system. The judicial enforcement of law could take place over the blockchain. Using a system of decentralized contracts and smart contracts, the blockchain can be used to establish the structural framework and the laws that individuals and organizations would abide by. The blockchain would be made to reflect societal values and norms through a self-executing code that would be run on it. Smart contracts could be programmed to re-write some aspects of constitutional rights and property law in such a way that would turn these laws into a subset of contractual law. A smart contract can be encoded into the blockchain and could be made to rely on a certain level of human judgment at some point during the execution of this smart contract (Wright & De Filippi, 2015a, p. 50). For example, in order to verify if certain contractual conditions were fulfilled, a judiciary, jury or a panel of arbitrators could be selected from all around the Internet based on past experience in resolving disputes. The system would operate with a higher level of transparency and the chances of a jury being potentially biased with regard to a certain case would be significantly reduced because jurors would be chosen randomly. Information regarding the jurors' backgrounds, experience and reputation will be made publicly available online, this would provide more transparency and will incentivize jurors to try to maintain a good reputation

(Tapscott & Tapscott, 2016, p. 223). This would impose upon the jurors a competitive check which could in turn increase the economic efficiency of the system because as Coase pointed out governmental administrative decisions can sometimes be very costly and without a competitive check the decisions of a central authority might not always lead to efficient outcomes (1960, p. 18). These decentralized judiciaries could continue to take on dispute resolution procedures and expand upon them and this would reduce the role of centralized judiciaries (Wright & De Filippi, 2015a, p. 51).

In the case of a dispute arising between two parties, the judicial processes would be moved online and the blockchain as well as crowdsourcing would be used to process legal complaints and charges. The process would start with someone filing a complaint or a charge of some sort online, witnesses would then be summoned to provide evidence in addition to the information that would be collected from other sources. The complaint that was filed would be stored on the blockchain and would be secured using cryptography to ensure that it is not tampered with. A jury would be selected randomly based on their reputation, experience and expertise in resolving disputes, so as to reduce the chances of the jurors being biased in any of the cases. The jury would be in charge of examining the facts and deciding if the case should go to trial. If the case necessitates a trial, then a trial ensues during which the defendant is presented with two options, to plead guilty and make an offer of restoration, which the jury would consider and would either accept or reject, alternatively, the case could proceed to another trial online in the presence of a larger jury. The trial would be broadcasted online along with the evidence, and a verdict would be issued after members of the jury vote for a verdict online (Tapscott & Tapscott, 2016, p. 220). The downside is that such a system may raise privacy concerns because of the open source nature of the trial process. On the other hand, it would increase transparency and would reduce the likelihood of corruption and judicial misconduct leading to more efficient outcomes.

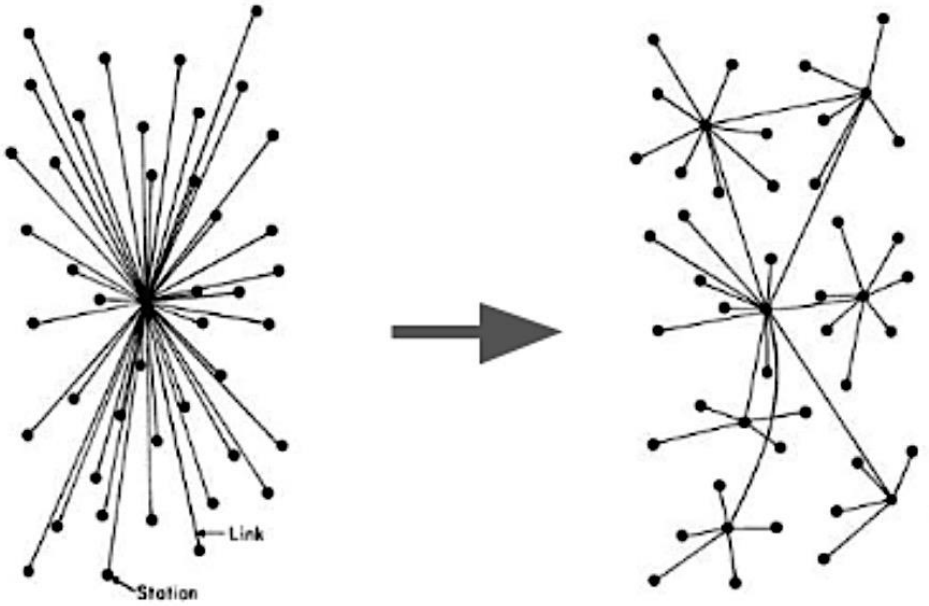

Figure 4: The shift from centralization to decentralization
Source: Adapted from Wright & De Filippi (2015a)

Figure 4 illustrates how blockchain technology will decentralize organizations in the future including the currently highly centralized legal system.

3.1.3 Automating Pollution Control on the Blockchain

In cases that involve a negative externality, like for example, when a firm's production results in carbon emissions which affect a large group of people, it is often difficult and costly as Coase pointed out, for the firm to enter into contractual agreements with every person that is being affected by the negative externality, so such cases end up being left to the government to deal with. Several groups all around the world, including governments and non-governmental organizations, have been undertaking various efforts to try and reduce carbon emissions. One of the best policies that help reduce greenhouse gas emissions is the cap-and-trade policy has proved to be an economically practical method of reducing carbon emissions and has thus been effective in lessening environmental pollution (Tvinnereim, 2014, p. 453). The way this takes effect in the current conventional setting is that in order to incentivize companies to pollute less, a regulatory body sets a limit on the amount of carbon emissions that can be produced and it keeps lowering that limit over time in order to reduce the overall amount of carbon emissions

being released. The government then issues these allowances to companies, which they can then trade with one another. This could also take place over the blockchain where the cap-and-trade system would be maintained. Reputation systems could be set on the blockchain that would use the standards of greenhouse gas reduction as a baseline to rate the energy being transmitted in kilowatt-hours from companies' production. The system would then assign higher cap debits to energy that would be sourced from coal and credits would be assigned to renewable energy sources such as solar energy, this would incentivize firms to use renewable energy sources (Tapscott & Tapscott, 2016, p. 222). This would help automate the pollution control, and would decentralize it and make it operate at a lower cost and with less reliance on central authority.

3.2 Summary

Legal affairs are usually dealt with through the legal system because of the high transaction costs involved trying to resolve them privately. The court's decisions may sometimes lead to inefficient outcomes since the court system is not subject to the competitive forces of the market. Furthermore, the judges might not be aware of the reciprocal nature of problems in deciding whom to allocate property rights to. Legal affairs can be resolved using blockchain technology and doing so would move the process of delimitating rights closer to Coase's ideal. It would lower the costs of carrying out market transactions and would allow the parties to negotiate and have their agreements be enforced on a peer-to-peer basis through self-enforcing smart contracts without having to keep referring to a third party arbitrator which would entail additional costs. Smart contracts' self-executing feature saves users the cost of having to go through the legal system to be able to claim outstanding amounts of money from a party who might not be willing to fulfill the terms that they have agreed to in the contract. So rather than having to enlist the help of their lawyers and having to go to court to seek restitution or a dispute resolution from the courts and having to incur higher costs along the way, parties would be able to reach a resolution privately. In the event that the parties decide to have an arbitrator review their case, they would be able to do so in a decentralized court system, the members of which would be subject to the competitive forces of the market which means that they would have to adhere to higher standards of conduct due to the open source nature of the technology. Lawyers'

profession will be transformed by the technology as well, because rather than having to prepare lengthy contracts for their clients, they would have set up smart contracts by coding the terms and conditions of the agreement into the blockchain. The parties will have to spend more time negotiating the terms of their contracts in advance because of the irreversible nature of smart contracts. Pollution control would be automated and managed on the blockchain in a more decentralized way, rather than government having to issue allowances as it does in the cap-and-trade system, pollution levels will be recorded and tracked on the blockchain, and companies would be incentivized to pollute less through a debit and credit system where polluting companies would be assigned higher cap debits and firms using renewable energy sources would be given credits. Blockchain technology will result in a shift in the litigation processes from being mostly under the control of centralized authorities to more decentralized entities. Additionally, the transaction costs associated with litigation would be reduced significantly due to the blockchain's capacity to enable direct and instantaneous transactions between parties on a peer-to-peer basis, thereby saving the parties involved from having to incur financial costs, trust establishment costs, time costs and opportunity costs.

Conclusion

The blockchain evolved as a result of humans' need for money and a ledger system that would allow them to make exchanges and keep track of them more effectively. The origin of the concept of Bitcoin as a currency can be traced to the Austrian school of economics that supported the idea of a currency that cannot be manipulated by central authority. Blockchain technology has applications beyond just being a platform for cryptocurrencies, other than currency, it has applications in financial and legal spheres to name a few. Smart contracts are protocols that are coded into the blockchain and that have the terms and conditions of an agreement embedded in them and work like regular contracts except that they are self-executing. Smart property is property that is encoded into the blockchain with a special identifier that allows the asset to be monitored and exchanged. The Bitcoin network operates in an open source,

decentralized and distributed fashion and is maintained by a proof-of-work consensus mechanism that serves to ensure the validity of the transactions and that double spending does not occur. There are already initiatives and organizations that are using the blockchain to help lower transaction costs across various spheres. Some examples include, the R3 consortium and UBS's Utility Settlement Coin, that aim to reduce the transaction costs that financial transaction costs. Etherium that could reduce contracting costs, and Skuchain which was designed to facilitate B2B trade between firms.

Blockchain technology would lead to a reduction in the transaction costs that come with organizing the firm and with resolving legal disputes as described by Coase (1937), and that would subsequently lead to a change in the role of these organizations in the future. We have established that from Coase's perspective, the reason a firm grows and becomes more centralized in nature, is because of the transaction costs involved in outsourcing from the market, and that such costs include the costs of having to coordinate the firm, the costs of having to search for resources and for labor, as well as the costs of contracting and having to establish trust. In an effort to avoid these costs the firm expands and assumes a vertically integrated hierarchal organizational structure, where the entrepreneur plays a central role in the organization of the firm and long-term contracts are more desirable relative to short-term contracts. In a future firm that is blockchain-based these costs will be reduced and the firm will have its borders more open to outsourcing from the market. Coordination costs would be reduced because the blockchain would facilitate networking within the firm so there will be less of a burden on the entrepreneur in organizing the firm and management would become more distributed in nature and less hierarchal. Search costs would be reduced because the firm would be able to carry out more precise and targeted searches on the blockchain, when searching for skilled employees to hire or for reputable contractors and suppliers to contract with. In addition, the firm would be able to find its group of target customers more precisely. However, because the system would be so precise it would lessen the chance that serendipity would occur in cases where employers would be searching for prospective employees and where the firm would be searching for its target audience, but the advantages of having access to more precise searches would outweigh the costs of the reduced likelihood of serendipity occurring because the firm would save on search costs. Contracting and trust establishment costs would be reduced because of the adoption of smart contracts, which would allow parties to contract with one another on a peer-to-peer basis without

the need for a third party arbitrator, and would thus, make it easier for the firm to enter into not only long-term contracts, but short-term contracts as well, which were previously undesirable according to Coase, because it would reduce the costs of maintaining and monitoring contracts because after the smart contract protocol is run on the blockchain it would simply self-execute upon the fulfillment of certain conditions and the passing of certain deadlines. Parties would need to dedicate more time to negotiating the terms of their smart contracts due to the irreversible nature of smart contracts upon their execution, but the firm will be able to save on arbitration and enforcement costs as a result of these negotiations being carried out early on. Finally, because the firm would carry out its transactions using bitcoins it would be able to save on the transaction costs that involved in using traditional financial intermediaries to transfer funds. This would result in the firm becoming smaller, decentralized in structure, more efficient and more open to outsourcing from the market. The firm's management will become more distributed and inclusive as opposed to being hierarchal.

In the case of the issues arising from the transaction costs that come from the legal disputes pointed out by Coase (1960), legal affairs are left to the legal system to resolve, because of the high transaction costs that the disputants would have to incur if they were to try to resolve their disputes privately. Coase also highlighted some of the problems that result from the centralization of legal systems, including the fact that, in deciding to whom they would allocate the rights judges may be unaware of the reciprocal nature of the problems that they are presented with. Furthermore, judicial decisions may result in outcomes that would not be economically efficient given that the court system is not subject to the competitive forces of the market. Blockchain technology would lower the transaction costs that individuals and organizations face in trying to resolve their disputes thereby making it easier for them to use market transactions to resolve their disputes. Parties would be able to negotiate the terms of and conditions of their agreements on a peer-to-peer basis, and would have them be enforced through self-executing smart contracts that would be enforced on the blockchain, this would allow them to save on arbitration and enforcement costs. If the parties were to decide at some point that they would like to have an arbitrator review their case, they would have the option of seeking arbitration from a decentralized court system, whose members would be subject to the market's competitive forces because they would be chosen randomly and based on their experience and reputation the records of which would be publicly available so they would have an incentive to maintain good conduct.

In addition, they would have to operate under higher standards of transparency due to the open source nature of the blockchain. Lawyers would be tasked with coding smart contract protocols into the blockchain rather than having to draft long contract documents. In cases that involve negative externalities that would affect a larger number of people such as when a firm's production results in pollution affecting people living in a certain area, it would, according to Coase, be difficult to resolve such a case privately due to the large number of people involved. Blockchain technology would automate and decentralize the process of pollution control, the most notable example of which is the cap-and-trade system, so instead of the governments having to issue these allowances to the firms as it currently does, pollution levels would be recorded and monitored on the blockchain. A debit and credit system would be used to incentivize firms to pollute less because they would receive credits whereas, polluting firms would receive cap debits. Blockchain technology would cause the control of litigation processes to shift from being in the hands of mostly centralized authorities to the hands of more decentralized entities. Furthermore, blockchain can reduce the transaction costs that come with having to undergo litigation processes such as the financial costs, time, trust establishment and other opportunity costs, this because it has the capacity to facilitate peer-to-peer instant and direct transactions between parties.

In conclusion, blockchain technology will reduce the transaction costs that a firm has to take into account in its organizational decisions, in particular, it would lead to a reduction in the coordination, search, contract and trust establishment costs. The firm's role would change from being a highly centralized, hierarchal and vertically integrated organization where the entrepreneur would be in charge of overseeing the management of the firm mostly himself, into a smaller and more decentralized firm where networking will make management of the firm become more inclusive and distributed among the workers in the firm. Given the reduction in transaction costs resulting from the use of blockchain technology, the firm will find it easier to outsource from the market and will be able to enter into short-term contracts with more ease. Blockchain technology would also reduce the transaction costs of having to carry out market transactions to resolve disputes privately and would thus, shift the power and control of the litigation and dispute resolution processes from central authority to entities that operate in a distributed and decentralized way. Parties would be able to carry out market transactions and to resolve their disputes privately since there would be no transaction costs involved in doing so.

Hence, in both of these cases, we see a shift from more hierarchal organizational structures to more decentralized and market-based structures that are closer to Coase's ideal, where transaction costs would be low enough and the market mechanism would have a bigger role than the entrepreneur and central authorities when it comes to firm organization and litigation processes.

Although this technology is still in its infancy in terms of its development, there are efforts being currently undertaken by several initiatives and organizations which have already begun researching the various possibilities in which it can be used to lower transaction costs and the friction involved in carrying out financial transactions and to increase the transparency and efficiency with which organizations operate. Future research can improve and expand upon the research done in this thesis by perhaps examining the changes empirically. In the context of the firm and the legal system, blockchain technology presents an interesting glimpse into what the world might look like in the future in terms of how companies will operate and how laws will be enforced. It is almost as if Coase might have predicted that such a technology might someday emerge.

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