Universitat Autònoma de Barcelona

Four Essays on Distributed Ledger Technology (DLT) and Its Uptake by Firms

Loha Hashimy

Doctoral Dissertation

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Author

Emili Grifell-Tatjé

Thesis Supervisor

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Acknowledgements

Doing an industrial Ph.D. is not easy. It comes with a full-time industry job and academic research. The last four years have been a long and at times daunting journey that I would not have been able to do it without the support and help I received from many companies, communities, and individuals.

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Abstract

The purpose of this dissertation is to investigate the adoption of distributed ledger technologies (DLTs), namely blockchain, by firms. It assembles four essays on various topics ranging from the basics of the technology to its adoption and the regulatory hurdles that DLT businesses confront.

The first essay serves as an introductory chapter and answers questions such as What is DLT? What is Blockchain? What are the advantages and challenges associated with the technology? What are its applications in some specific sectors? When can it be used? The chapter aims to fill a knowledge gap and provide a foundation for the readers, specifically company managers, to gain an understanding of the technology through a detailed explanation of the Bitcoin Blockchain, including the benefits and drawbacks of this type of Blockchain that spawned other types of Blockchains. An extensive literature analysis is conducted to identify Blockchain use cases in both the financial and non-financial industries, which can assist managers in better understanding the technology's applicability. In addition, towards the end of the chapter, a decision tree is proposed which can be used to analyze the suitability of using Blockchain.

The second essay employs an exploratory approach to examine the hurdles small and medium enterprises (SMEs) confront in adopting open innovation and the role of DLTs as a potential solution to some of these constraints. These difficulties are classified as search and management obstacles. The findings of semi-structured interviews with both academics and practitioners indicate that DLTS can alleviate some barriers such as contract-related issues, a lack of trust, a lack of capital, legacy systems, supply chain-related challenges such as raw materials, limited information about the supplier of the innovation, IP rights, market-related barriers such as access to domestic and international markets, and regulatory barriers. However, the same as any other information technology system, DLTs cannot address many other issues in the adoption of open innovation by SMEs, both at the search and management stages, such as network and collaboration management, administrative and control barriers, and cultural and human nature barriers and challenges in dealing with customer demand. The findings also indicate that SEMs may encounter integration issues, complicated transition periods, high setup costs, and issues attracting and keeping skilled people when implementing DLTs to boost open innovation processes.

The third essay looks at the elements that influence firms' adoption of Blockchain technology. Some variables, as competence, competitive pressure, and top management support, have a positive effect on adoption of Blockchain technology. While relative advantage, complexity and competence have no significant impact on adoption. The study adds to the small pool of quantitative publications on the acceptability and adoption of Blockchain technology by investigating the factors that influence its use in the European context The findings have theoretical as well as managerial implications.

The fourth essay focuses on regulation, which is one of the most critical challenges that DLT businesses confront. The goal of this chapter is to better explain how financial regulations affect the development of token-based DLT companies. Twenty DLT businesses in Europe were interviewed using in-depth semi-structured open-ended interviews. The findings demonstrate that financial regulation can have an unclear influence, as it can both facilitate and limit the development of a DLT business. It is recommended that a minimal regulatory framework be established within which firms may lawfully function, but policymakers should be cautious of not surpassing the regulations and stifling innovation.

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Introduction

Industrial Ph.D., a Generalitat de Catalunya-funded initiative, aims to bridge the gap between industry and academia by transferring knowledge and fostering cooperation between universities, research centers, and firms. One of the main components of this program is to enable companies to conduct research projects in collaboration with universities and research centers as guiding institutions, allowing the researcher to meet academic standards and obtain a Ph.D. while solving or investigating an industry or market problem or gap.

Motivation and Research Questions

The impetus for this thesis stems from my attendance at a conference on new technologies and their influence on enterprises. As a newly hired full-time innovation consultant through the industrial Ph.D. program at Knowledge Innovation Market (KIM), I was tasked with performing technology watch to assist the company and its clients in capturing, analyzing, and implementing the latest technologies that can help them differentiate and position themselves in the market.

While I had started reading the literature on innovation and technology transfer, the more I was reading the more I was realizing that it is a broad topic and I need to find a gap in the literature that attracts my attention and sparks my curiosity. One of the areas that interested the company the most was the engagement of Small Medium Enterprises (SMEs) in the open innovation process. I started investigating the hurdles SMEs are faced with in implementing open innovation. Among many conferences I attended, in one of them, "Eurecat Mobile Forum,"[1] I got to know about Blockchain. Many speakers in that conference were talking about the emergence of a "revolutionary" technology called "Blockchain" that will change the "whole economy." Blockchain was called the "internet of value" and was claimed to be the technology that will "shape the 5th Industrial Revolution." Immediately after the conference, I started searching and reading more about Blockchain. Reading article in Forbes on how Blockchain will change the world (Marlin, 2017) rose my curiosity even more and created questions as What is Blockchain?

[1] Rangel, N. (2017). *8va edición del Eurecat Mobile Forum estará centrada en blockchain, FinTech y ciberseguridad*. Criptonoticia. https://www.criptonoticias.com/comunidad/eventos/8va-edicion-eurecat-mobile-forum-estara-centrada-blockchain-fintech-ciberseguridad/

What are its applications? What are the factors that impact its adoption by firms? What are the challenges DLT companies are faced with? I started searching google scholars for some academic papers about Blockchain and found few technical papers, but almost no paper that answer these questions. I read the Bitcoin paper (Nakamoto, 2008) and I believe that it is one of the most complex, nevertheless one of the most impactful papers I have ever read. It raises questions about the role of central entities as banks, firms, and institutions. I had found a gap in the literature that had captured my interest and I had already started investigating. This thesis addresses some of the questions rose before and aims to investigate the uptake of DLTs such as Blockchain by firms. The results will contribute to this nascent research area.

Methodology

Depending on the type of research questions, both qualitative and quantitative approaches are used as underlying methodologies of the four essays. Chapter one uses desk research and literature review to explain the fundamentals of Blockchain technology, its advantages and associated challenges, its types, and applications. The second and fourth chapters use in-depth expert interviews to gather insights on the use of DLTs for tackling some open innovation barriers in SMEs and understand the impact of financial regulations on DLT companies. The use of qualitative methods matched the exploratory nature of these chapters and helped us delve into details in answering the research questions, understand better the concepts, and know both academics and practitioners' opinion on the topic which can be used to build theoretical frameworks and hypothesis. The third chapter uses the technology-organization-environment (TOE) framework as the underlying theory to study the impact of relative advantage, competitive pressure, complexity, compatibility, top management support, and capability on the adoption Blockchain in Spanish firms. Quantitative data is gathered for the statistical analysis and testing the hypothesis using partial least square structural equation model.

The Chapters

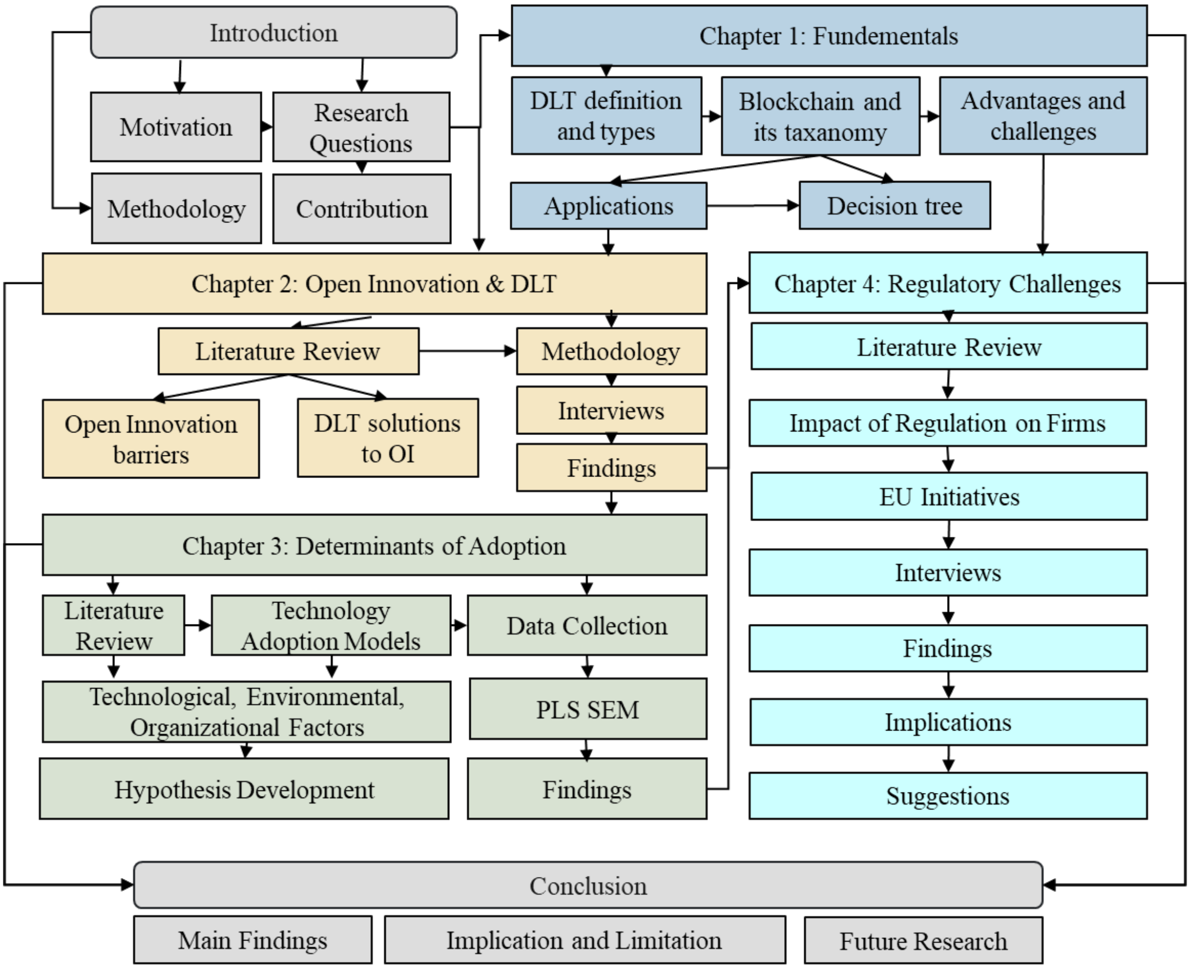
Figure 1 demonstrates the structure of the dissertation and the relationship among chapters. The first chapter lays down the fundamentals that form the basis for this thesis. It defines the main concepts and contributes to the knowledge gap in the industry on the use of Blockchains. During the first year of investigation, it was found out that lack of a credible and clearly accessible scholarly source, along with the hype around the technology, has led in confusion and misunderstanding of the technology's uses and advantages, leading to its misuse by certain company executives. Thus, the first chapter aims the reader and company managers in better understanding of the technology, its benefits, and applications. It also provides a decision tree diagram that can be used by company managers to evaluate the use of DLTs.

Openness is essential for innovation, and technology may occasionally assist firms in becoming more open. Trust is crucial when it comes to open innovation or any form of collaborative initiative. DLTs, like Blockchain, have proved to give birth to what is called trust-less networks, where members of the network do not need to trust each other to perform a transaction. In the prior investigation I had done on the adoption of open innovation by SMEs, I realized that there are no studies on the use of new technologies as DLTs to tackle the adoption barriers to open innovation. While investigating the applications of Blockchain (Chapter 1), some studies were found on the use of Blockchain for management of intellectual property and improving open innovation. Thus, chapter 2 aims to systematically investigate the potential of DLT to tackle SMEs' difficulties related to open innovation adoption. The results of this chapter show that indeed DLTs can facilitate a more open and collaborative innovation process, but as the adoption of any other technology, there are different factors that impact the use of DLTs by SMEs. This chapter is published at the Journal of High Technology Management Research in 2021.

The results of the second chapter in addition to the slow uptake of the technology by Spanish firms, despite the technological readiness level, embarked our curiosity about the determinants of DLT adoption by firms. Thus, the third chapter of the thesis aims to answer the research question What are the key factors impacting Blockchain adoption among Spanish companies? The TOE framework is used to investigate some technological, organizational, and environmental constructs that influence the Blockchain adoption. The results show that variables as competence, competitive pressure, and top management support impact adoption positively while complexity relative advantage and compatibility do not have significant impact on adoption of Blockchain. This chapter contributes to the limited empirical quantitative papers that investigate the adoption of Blockchain in the European context. The model used for this study is simple with few constructs that provide some first insights on the Blockchain adoption determinants. It opens room for further research on the impact of some other variables that are not included in the model as cost, regulation, and standardization. A version of this article is published at Industrial Management & Data Systems in 2022.

The results of the first, second and the third chapter show that complying with regulation, mainly the financial regulations, can be one of the challenges that DLT firms are faced with as these regulations are designed for the centralized entities not taking into consideration decentralized and peer to peer systems. Thus, the fourth chapter investigates the impact of financial regulations on development and growth of DLT firms. The results of in-depth interviews with DLT company owners and technology experts show that un-updated and old regulations moreover to lack of unification, clarity, and guidelines at the EU are the main challenges of DLT companies. It is detected that there is no framework under which decentralized and peer to peer initiatives can operate and complying with regulations as anti-money laundering (AML) and know your customer (KYC) for a system that uses a public registry with anonymous transactions. Moreover, complying with the general data protection regulation (GDPR) for a company that uses an immutable ledger is challenging. Not to mention the slow and costly registration, audit, and certification process for these companies. Although adhering to current rules might be difficult and impede a DLT firm's development, once the business has done so, it can provide users with peace of mind and confidence, as well as a better, more trustworthy, and high-quality service, offering extra credibility to the company. The chapter ends with some policy recommendations and practical implications. This chapter is published at Frontiers in Blockchain in 2020.

***Figure 1** Dissertation Structure and the Relationship Among Chapters*



Chapter 1: Fundamental Advantages, Challenges, and Applications of Blockchain

Abstract

Distributed ledger technology (DLT) represents a decentralized system that allows for the real-time sharing of datasets with the aim of improving efficiency, reducing costs, and guaranteeing immutability, traceability, security, and transparency. Blockchain, which is one specific type of DLT, has been the subject of considerable attention on the part of both practitioners and researchers since the appearance of its first application, that is, Bitcoin, in 2008. As an emerging technology, blockchain is associated with both benefits and drawbacks, which is why its use is only recommended in certain circumstances. This chapter explains the fundamentals of blockchain by providing a comprehensive example of how the technology works. The chapter then goes on to detail the benefits and challenges of blockchain, in addition to reviewing both the academic literature and industry use cases in order to identify its applications in different sectors. The overall aim of this chapter is to fill the current knowledge gap concerning blockchain and provide a foundation for managers to better understand the technology, gain insights into its different applications, and assess the suitability of applying it using the proposed decision tree framework.

1.1 Introduction

Blockchain was listed among the top ten strategic technology trends of 2020 by Gartner (Cearley et al., 2020). This is unsurprising given that while the hype surrounding blockchain, as the technology that underpins Bitcoin, is mostly related to its applications in the financial sector, it has already impacted many other sectors and has the potential to further disrupt and challenge many existing centralized business activities and models. As a consequence, blockchain has attracted the attention of scholars and practitioners alike in recent years. In 2010, a search for the term "blockchain" using Google Scholar would have yielded only 654 results. Yet, in 2020, the same search would have yielded 282,000 results. This exponential increase in the number of publications concerning blockchain indicates the significant and growing interest in the technology in both industry and academia.

While much information is available on the internet regarding blockchain and its applications in different sectors, it remains difficult to find academic sources that explain how the technology works in a simple and non-technical way that can be easily understood by industry practitioners, managers, researchers, policymakers, and the general public. This lack of reliable and easily understandable sources, as well as the hype surrounding the technology, has resulted in widespread confusion and misunderstandings concerning the applications and benefits of blockchain, which has led to the technology's misuse by some company managers. This chapter aims to fill the knowledge gap related to blockchain by answering the following fundamental questions facing company leaders and decision makers: What is DLT? What is blockchain? What are the advantages and disadvantages of blockchain technology? What are its applications? When should it be used by firms?

More specifically, this chapter will fill the gap identified in the existing literature in five key ways. First, it will provide a detailed explanation of blockchain's architecture and technical characteristics through a simple and easily understandable example as well as a comprehensive explanation of the Bitcoin system presented in non-technical language in order to enhance understanding of the technology. Second, it will provide a detailed analysis of the advantages and disadvantages of blockchain so as to elucidate the benefits and challenges associated with the technology. Third, it will offer a systematic review of use cases and applications of blockchain in the financial, supply chain, healthcare, and energy sectors to highlight the real value of the technology to firms.

Fourth, it will provide a categorization of the applications of blockchain in these four sectors in an effort to clarify the usability of the technology. Fifth, it will present a series of managerial recommendations concerning the use of blockchain using a decision tree diagram in order to highlight the technology's practical value.

In light of the above, the present chapter makes two significant contributions to this dissertation as a whole. First, it forms the basis for subsequent chapters by gathering information about different aspects of the technology in one place and providing a holistic overview of the preliminary concepts and terminology related to blockchain in a simple and comprehensible manner for those with non-technical backgrounds. Second, it presents an updated and comprehensive decision tree featuring additional action points to assist company managers in evaluating the applicability of blockchain in various scenarios.

The remainder of this chapter is organized as follows. In Section 1.2, detailed background information will be presented concerning the concepts of decentralization and DLT, the different types of DLTs, and blockchain as a specific type of DLT through a comprehensible example. Then, in Section 1.3, a discussion will be offered regarding the potential advantages and challenges associated with the use of blockchain. In doing so, an assessment will be made of the applications of blockchain in the financial, supply chain and logistics, healthcare, and energy sectors. In Section 1.4, the use cases will be divided into different categories based on the relevant blockchain applications. Next, a series of managerial implications will be provided in the form of a decision tree diagram in Section 1.5. Finally, the conclusions that can be drawn based on the information presented in this chapter will be set out in Section 1.6 along with some suggestions for future research in this area.

1.2 Background

1.2.1 Distributed Ledger Technologies

In the wake of technological advancements, real-world problems require modern solutions. A "ledger" is a set of records or data held in common by several participants within a network.[2] During the early days of ledger usage, the communities involved were

[2] There are three types of systems: a) centralized systems where everything is controlled by a central authority or node that has sole power to verify, make decisions or rules, give access to the system, and make changes to the system; b) decentralized systems where anyone can join and gain access and where any changes to the system require consensus on the part of the majority, meaning that there is no single

small, meaning that people knew each other and could keep track of what was owned by whom. As a result, authentication was not a problem. The transactions were validated by the people executing them and verified by those witnessing the actions performed by people they knew. However, as the communities involved grew and people lost track of who owned what, due diligence and authentication with regard to the transactions had to be performed and verified by a trusted intermediary such as a bank. Thus, banks served as the entities that controlled the general transaction ledgers, which meant that only banks could modify and add transaction entries to those ledgers.

Ledgers were digitized and partially automated during the 20th century, although most ledgers were still controlled by central entities. Centralization, despite offering a number of advantages, is both prone to having a single point of failure and vulnerable to malicious actions such as hacking, corruption, and alteration (Catalini & Gans, 2020). In addition, centralization can have negative consequences such as increased market power on the part of the intermediaries[3] and censorship (Catalini & Gans, 2020; Davidson et al., 2016).

Over the years, individuals have sought to identify ways of decentralizing some or all of the power centralized in the hands of governments, banks, and corporate entities through the decentralization of ledgers. Innovations and technologies designed to ensure the distribution of ledgers are known as DLTs. According to the European Central Bank (2016), a distributed ledger is "A record of information, or database, that is shared across the network" (p. 1). Among the different types of DLTs are blockchain, directed acyclic graph (DAG), hashgraph, and holochain. Table 1 provides a summary of the differences among these different types of DLTs.

As can be seen in Table 1, the two main differences among the various types of DLTs concern the data structure and the consensus mechanism. In the case of blockchain, the transactions are recorded in blocks that are connected to each other in such a way as to form a chain. This is why the technology is known as blockchain. There are also other ways to record transactions, including DAGs. To explain this technology simply, it is useful to decompose the whole term. An acyclic graph lacks complete circuits or cycles,

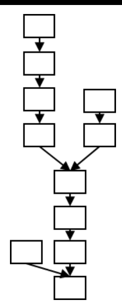
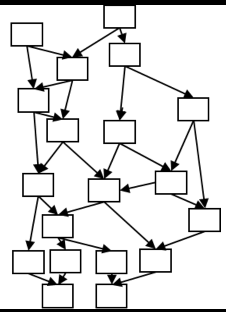
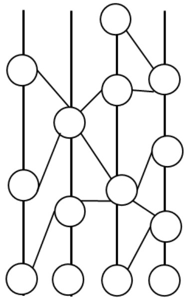
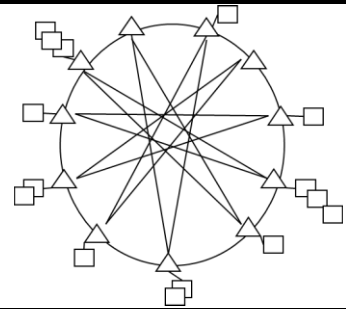
entity in control of the system; and c) distributed systems where a copy of the system is distributed to each node within the system, meaning that each node can modify its version of the system, which can be centralized or decentralized.

[3] The intermediaries who have access to and control the databases can transform the data into information and then use it to increase their market share.

which means that if you follow a sequence of edges (the lines going from one node to another) on a node by node basis, you will never visit the same node twice. As a consequence, a DAG is an acyclic graph that has a direction. In a DAG, each node stores one transaction. Networks such as IOTA Tangle use proof of work consensus mechanism. Hashgraph uses DAG with a different consensus mechanism, byzantine fault tolerance, and a different validation mechanism. Holochain is another type of DLT that uses a completely different way of storing data. Each agent within a holochain network stores its individual data locally and does not share its transaction information with all its peers within the network, although some nodes will include a backup in case the owner goes offline.

There are many ways in which transactions can be validated and added to the ledger. In the case of blockchain's proof-of-work (PoW) approach to consensus (which will be explained in more detail in the following section), the members of the network compete in terms of validating the transactions in order to be able to add (i.e., mine) a new block and obtain a reward for their work. Although DAG also relies on PoW, to deploy a transaction, a member of the network has to validate two previous transactions (rather than the entire block), which means that each transaction is linked to two random transactions.In blockchain systems, as the network grows, the transaction speed slows due to more data needing to be validated. By contrast, in DAG systems, as the network grows the transaction processing time speeds up because each node has to validate two previous transactions. Both hashgraph and holochain use completely different consensus mechanisms, namely the gossip about gossip protocol and virtual voting. Briefly put, similar to gossiping (i.e., spreading information to the members of the network), when applying the gossip about gossip protocol, when a node (Node X) receives new information (e.g., that a colleague, Lisa, has bought a new car), it passes that information along through a message to a random node (Node Y), and while Node Y then passes the information on to Node Z, Node X passes it to another random node (Node D). This process goes on for so long that the whole network gets to know the information. The message sent by each member of the network contains the information they received, the time that they received it, the nodes from which they received the information, and new information. This explains why it is known as the gossip about gossip protocol, that is, because Node Y is not only sending new information to the network, but also attaching details about the information received previously.

Table 1 *Comparison of the Different Types of DLTs*

	Blockchain	**DAG**	**Hashgraph**	**Holochain**
Basic Structure				
Data Structure	Blocks	DAG	DAG	Each agent runs its own ledger but also shares its ledger with certain authorized peers
Consensus	Global consensus mechanism: Various, although proof of work and proof of stake are two well-known mechanisms	Global consensus mechanism: Proof of work	Global consensus mechanism: Byzantine fault tolerance	No global consensus mechanism: Peer validation based on consensus using other agents' copies of the application
Scalability	Limited	High	High	Limitless, as each node runs its own ledger
Validation	Miner/validator validates each transaction	A transaction occurs if it validates two previous transactions	Virtual voting through gossip about gossip	Each individual node validates its own transaction, while the gossip protocol is used to share information about an agent's behavior
Launch Date	2008	2017	2016	2018
Transaction Fee	High	Low	Low	Low
Example Network(s)	Bitcoin and Ethereum	NXT and IOTA Tangle	Swirlds and NOIA	Holo

Source: Author's elaboration based on different sources.

In hashgraph, the recipient must agree on the transactions included in each event in addition to receiving the message. It is accomplished by virtual voting, in which members can calculate each other's votes by looking at each of their copies of the hashgraph and using the virtual voting algorithm internally. Locally, votes are calculated on the basis of an event's antecedents. More details concerning the different types of DLTs can be found in the work by Zia et al. (2020).

1.2.2 The First Application of Blockchain: Bitcoin

In 2008, an individual or group of individuals named Satoshi Nakamoto put the different pieces of the puzzle together and created a digital currency known as Bitcoin (Nakamoto, 2008).[4] Bitcoin relies on cryptography,[5] a peer-to-peer network, the blockchain structure, and smart contracts[6] to prevent the double-spending problem that was previously solved through the involvement of a third-party financial institution such as a bank.[7]

Authentication. In the case of Bitcoin, the validation and authentication are performed using asymmetric cryptography or a "cryptographic key pair" (Rivest et al., 1978), which entails the use of public and private keys for encryption and decryption. Each participant is assigned a private key that can be used to derive the public keys. To perform a transaction, the sender of the bitcoins must first obtain the public key belonging to the receiver. Then, the sender encrypts the bitcoins using the receiver's public key. The receiver decrypts the bitcoins using his private key, and he can only use the bitcoins after the decryption validates that he is the true owner. To send or receive bitcoins, an individual has to have a digital wallet. Here, a wallet is a computer file that provides access to bitcoin addresses/keys (both public and private).

Payment process. This can best be explained with an example. Alice wants to send five bitcoins to Bob (Figure 3) In order to receive the bitcoins, Bob needs to create

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[4] Bitcoin was not the first attempt to create digital/alternative money to that used by national banks. Indeed, prior to the advent of Bitcoin, DigiCash (developed by Chaum in 1983), e-gold (created by Jackson and Downey in 1996), and BitGold (developed by Szabo [who also invested smart contracts] in 2005) were all designed for the same purpose.

[5] The science of protecting information through the use of mathematical algorithms to encrypt and decrypt messages. Here, "crypto" means hidden or secret, while "graphy" means writing; thus, "cryptography" means secret writing.

[6] Smart contracts combine protocols with user interfaces so as to formalize and secure relationships over computer networks. The objectives and principles associated with the design of such systems are derived from legal principles, economic theory, and theories of reliable and secure protocols (Szabo, 1997).

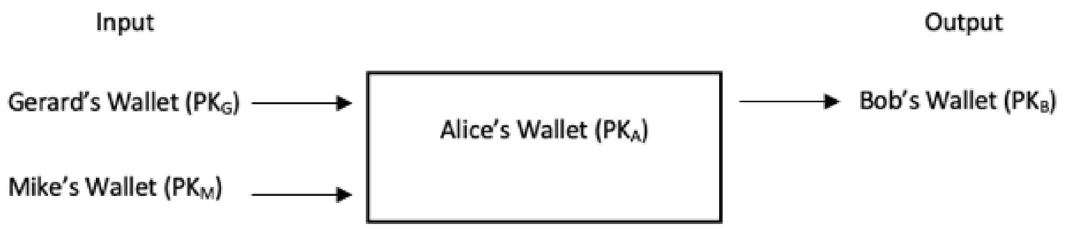
[7] A peer-to-peer form of electronic cash that allows online payments to be sent directly from one party to another without the need to go through a financial institution (Nakamoto, 2008).

a wallet for himself. After creating his wallet, Bob is automatically assigned a private key (also known as a signing key)[8] that can be referred to as SK_B (the signing key belonging to Bob). This private key is associated with Bob's wallet address and used for transaction authentication and validation. Once both Alice and Bob have created their wallets, the blockchain network will only recognize them by their public keys.

When working with Bitcoin, the transactions are pseudonymous, meaning that the real identities of the people involved in a given transaction are not known. Instead, the transactions are known by the public keys (the addresses for receiving bitcoins) involved, which are here referred to as PK. Thus, Alice and Bob should each have a PK, which are referred to as PK_A (the public key belonging to Alice) and PK_B (the public key belonging to Bob). Public keys are derived from a private key, which means that a person can generate as many public keys as she wishes using the same private key. In the Bitcoin ledger, only a transaction between two public keys is shown, along with the time and amount of the transaction. This enables people to maintain their privacy by generating a new public key each time they perform a transaction. Among other things, the encryption and pseudonymous nature of transactions can enable users to circumvent the capital controls imposed by authorities and, therefore, facilitate money laundering and terrorist financing. These issues will be discussed further in Chapter 4.

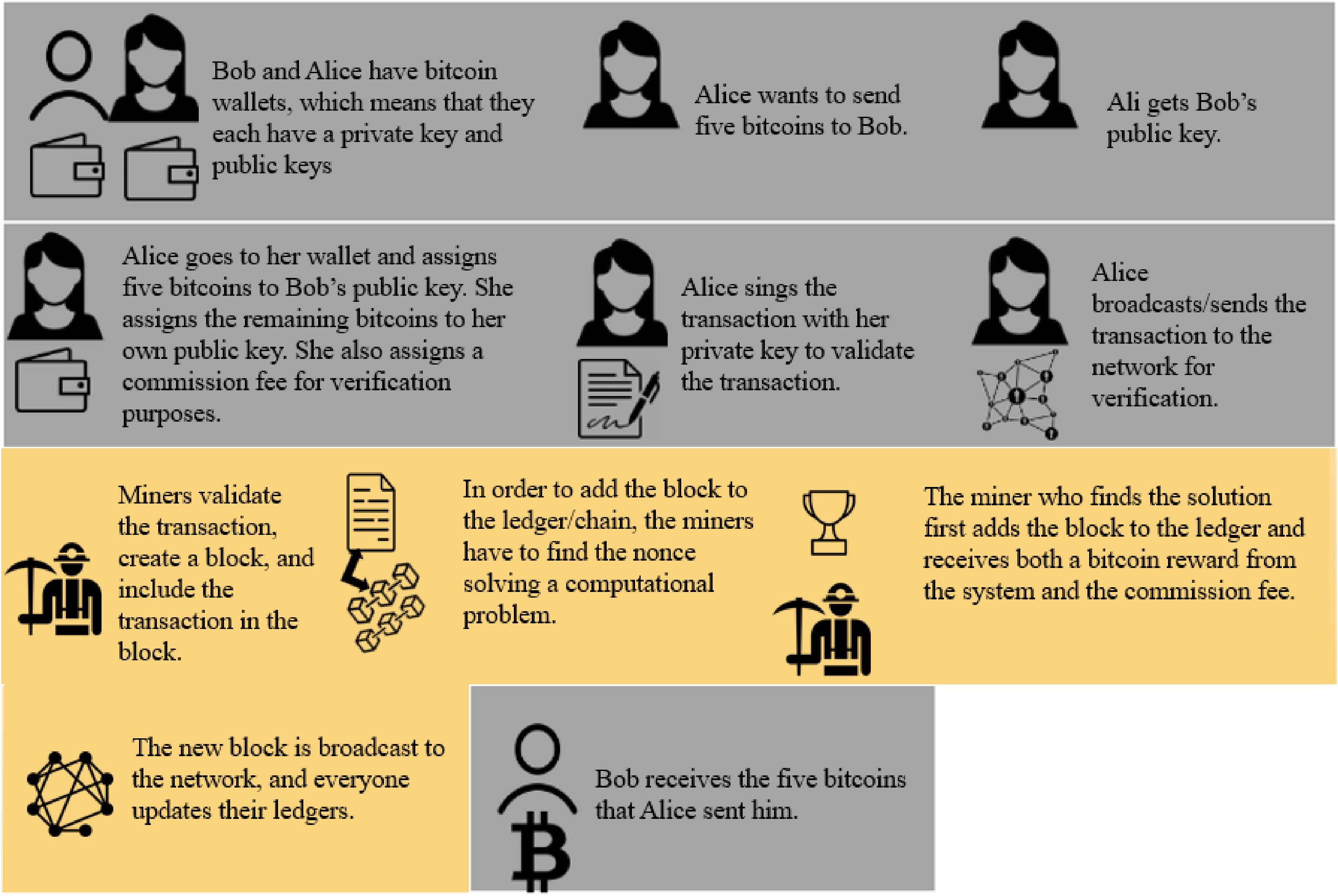
If she wants to send bitcoins to Bob, Alice must have bitcoins in her wallet. She previously received 10 bitcoins from Gerard and 20 bitcoins from Mike, which means that she has 30 bitcoins in her wallet (Figure 2).

Figure 2 *The Components of a Bitcoin Transaction*



[8] A collection of random alphanumeric characters. In the case of Bitcoin, it is 256-bit number, which equates to 32 bytes or 64 characters in the range 0–9 or A–F (e.g., BE9300F42008937A1964022E54000C998762D02938EAD93847ACB095245E94EC).

Figure 3 *The Bitcoin Transaction Process*



The transaction in which Alice sends five bitcoins to Bob will contain information about previous transactions in the form of a cryptographic hash link,[9] which means that Bob can track where the bitcoins that Alice sent him came from. Alice does not need to include full details concerning the previous transactions in the actual transaction with Bob; instead, she includes a hash link to the previous transactions through which she obtained the bitcoins. The link to the previous transactions allows everyone in the network to verify the chain of ownership of the relevant bitcoins and so proves that Alice was the ultimate recipient of the prior transactions. Thus, it eliminates the possibility of Alice cheating the system. As can be seen in Table 2, each transaction involving bitcoins contains a transaction hash, which provides the address of the transaction as well as the transaction fee, date, input, and output.

Table 2 *Bitcoin Transaction Structure*

Transaction Hash	Fee	Date	From/Input	To/Output
ad1e08c0b45f7e7df0e4286a49c7df39734dd25d13ea2862e9370650564aaefb	0.5 BTC	2020-06-19 11:28	3J4jo77ywPPfU58kYSW8CL5wmfRYRZPKwB: 20 BTC 3PFeKgjMq7PqXDKe885DGXVoomn413zw1y 10 BTC	3FwBYCGMs8eDYrthoXVzNHD4KRt9hrwG3M: 5 BTC 14YwdNJFLiMbwKw82TroEdqe964WfLyh8u: 24.5 BTC

Note: BTC = Bitcoin.

Source: The hashes have been derived from a real transaction on Blockchain.com.

So far, this example has focused on Alice's ownership of 30 bitcoins (i.e., the transaction input). Yet, in order to send five bitcoins to Bob, she has to authenticate his identity. As previously mentioned, Bob's identity is specified through his public key, which means that the network will identify him through that public key. To send the bitcoins to Bob, Alice needs to include Bob's public key and the amount of bitcoins that she wants to transfer to him in the transaction output. As she only wants to send five bitcoins to Bob from the total of 30 bitcoins that she owns, Alice has to specify that the

[9] A hash function is a mathematical algorithm or function that transforms arbitrary-size data into a fixed-size value. This means that whatever input "I" that you give to the function gives a fixed-size value as output "O" such that O=H(I). Bitcoin uses SHA-256, which takes any size input data and gives 256 bits/32 bytes or 64 characters as the output. For example, if you give the word "hello" to the SHA256 function, it gives "2cf24dba5fb0a30e26e83b2ac5b9e29e1b161e5c1fa7425e73043362938b9824," while if you give "Hello," it gives "185f8db32271fe25f561a6fc938b2e264306ec304eda518007d1764826381969." Thus, any small change to the input completely changes the output. Moreover, the hash function used in Bitcoin is a one-way hash function that has three properties. First, when given "I," it is easy to compute "O." Second, when given "O," it is difficult to find "I" such that H(I)=O. Third, when given "I," it is difficult to find "I*" such that H(I)=H(I*). Simply put, it is easy to make an omelette from eggs, onion, oil, salt, and tomato, although it is difficult to transform an omelette into its initial ingredients (eggs, onion, oil, salt, and tomato).

remaining 24.5 bitcoins (allowing 0.5 bitcoin for the system fee) should be returned to her in the form of change. Thus, she must reassign 24.5 bitcoins to her own public key. This means that the total of 30 bitcoins is split into three parts: 24.5 for Alice, 5 for Bob, and 0.5 for the system.

Once Alice has assigned the correct amounts of bitcoins to each public key, the transaction is signed digitally with her private (or signing) key. The signature binds Alice's identity to the transaction record. This way, everyone in the network who has Alice's public key can validate the transaction, as Alice is the only one who can provide the signature (private key) corresponding to her public key.

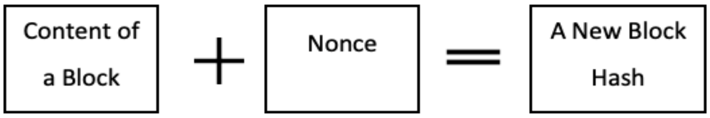
After the transaction is signed by Alice, it is broadcast to the network, meaning that everyone in the network can see Alice's intention to send some bitcoins to Bob. It should be highlighted here that the network can only see the public keys, not the real identities of Alice and Bob. For Bob to receive the bitcoins, the transaction must satisfy the verification process.

Verification process. In traditional ledgers, the transactions are recorded in a transaction notebook or database. Each page of the notebook has a specific capacity or number of lines for recording transactions. Once a page is full, another page is added to the ledger. There are specific people who have the authority to verify transactions and add pages in the ledger. For example, in a bank, it is a bank employee who verifies a transaction and adds it to the bank's ledger. Likewise, in the case of Bitcoin, the transactions are recorded in blocks. Each block has a limited capacity in terms of the number of transactions that can be included in it.

There are specific people known as miners who can verify transactions, include them in a block, and then add that block to the ledger. Once the transactions are broadcast to the network, the miners collect all the transactions, validate them, and store them for execution. Each miner has an inventory of valid transactions that have not yet been processed, which is known as a "mempool." Each time a miner competes in mining a block, the miner selects certain valid transactions from the mempool and includes them in the block.

To make the ledger more secure, incentivize the miners to perform the verification, and eliminate any intention on the part of miners to create invalid blocks (or a chain of blocks), Bitcoin requires the miners to solve a challenge in order to add a block to the ledger.[10] The process is similar to picking a number for a lottery. The miners try to find a random number known as a "nonce" that is included among the prior data in the block and provides a hash that starts with a specific number of zeroes, that is, the "target"[11] (as shown in Figure 3).

Figure 4 *The Process for Generating a New Block*



Finding the nonce is computationally difficult, as the miner has to perform a brute-force attack.[12] When dealing with Bitcoin, the miners compete to find the nonce that corresponds to the target. This consensus mechanism (or means of reaching an agreement to add a block to the blockchain) is known as "proof of work." As finding the solution to the challenge requires significant computational effort and the answer to the problem verifies that the miner has done the necessary work, it is referred to as a PoW consensus mechanism.

When a miner wins the competition, his block is added to the ledger and the system assigns some bitcoins to his public key as a reward. Thus, the miner at the end receives both the block reward (currently, this reward is 6.25 bitcoins [BTC][13]) and the transaction fees offered by the participants who want their transactions to be included in the block (0.5 bitcoins in the example of Alice's transaction). Then, the miner will broadcast the block with the solution to the network. After the block is approved by the majority of miners in the network, it is added to the general ledger. Bob receives the bitcoins that Alice sent him once this process is completed.

The distributed ledger used to store data concerning Bitcoin is known as the blockchain because the blocks are chained or connected to one another ($Block_n$ contains

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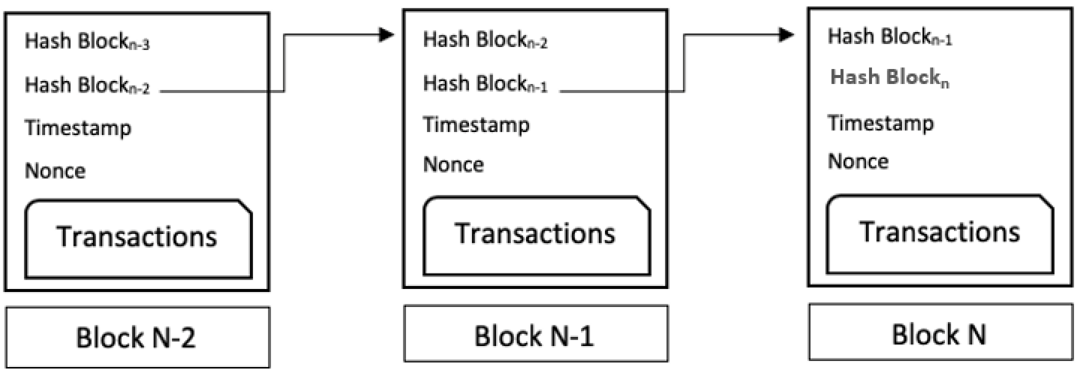
[10] As the miners have to invest (in electricity, machine power, and storage) in order to mine blocks, they have incentives to protect the system from malicious actions.
[11] The number of zeroes is given by the system based on the demand for generating a block, with higher demand rendering the target more difficult.
[12] It involves an attempt to find the password or key used to encrypt a message through trial and error, meaning that the attacker has to try many combinations in order to find the one that corresponds to the encrypted key.
[13] When Bitcoin was created in 2008, the reward for creating a ledger page was 50 bitcoins. After each 210,000 ledger pages or blocks, the amount is halved. The first halving took place in 2012, after which the miners were rewarded with 25 bitcoins. The second halving occurred in 2016, after which the miners were rewarded with 12.5 bitcoins. The most recent halving happened in May 2020. Now, the miners are rewarded with 6.25 bitcoins for including a ledger page in the general Bitcoin ledger.

the hash/encryption of $Block_{n-1}$) in a linear and chronological fashion, meaning that aside from the specific characteristics of the block, the transactions, and the nonce, each block contains the hash of the previous block.

The structure of a block is shown in Table 3. As can be seen from the table, a block contains a block header and a block body. The block header includes a summary of the data or information concerning the properties of the block, including the size, height, and transaction counts,[14] while the block body includes information related to the transactions.

Once a block is added to the general ledger, it is difficult to alter its content. Any changes made to a block change its hash, and since the hash of the block is included in the subsequent block (Figure 5), if an attacker changes the content of a block, they should also change all the blocks that come after it. Recalculating the hashes of the blocks requires a lot of computational power, rendering it expensive and difficult for a hacker to alter the content of a block. This property makes blockchain tamper-proof and so ensures the security of the data in a block.

Figure 5 *Blockchain Structure*



[14] It is outside the scope of the present dissertation to discuss the technical details included in the block header, although more information in this regard is available in Walker (2016).

Table 3 *The Structure and Content of a Block*

Block Hash: 00000000000000000000546111cb7647ed4f4430eab071c73e2c423bc567b0f8c			
Height	648,930	Relayed By	F2Pool
Confirmations	42,550	Difficulty	125.19 T/17.35 T
Block Size	1,143,088 bytes	Block Reward	6.25000000 BTC
Stripped Size	951,856 bytes	Fee Reward	0.43659270 BTC
Weight	3,998,656 WU	Tx Count	2,031
Time	2020-09-18 15:22:59	Tx Volume	25,120.44069966 BTC
Merkle Root	3d0b41a27d9b62f241f0dfd1ee3976926afe0249f2442b888fd8c3fe8919a001	Nonce	0x11a412b8
Version	0x20000000	Bits	0x17103a12

Transactions				
Transaction Hash	**Fee**	**Date**	**From/Input**	**To/Output**
420373222d89dd710797bda56e0fffb8ba21694963c87746fba63d69b8526889	0 BTC	2020-09-18 15:22:59	Coinbase	1KFHE7w8BhaENAswwryaoccDb6qcT6DbYY: 6.25+ 0.5 BTC
ad1e08c0b45f7e7df0e4286a49c7df39734dd25d13ea2862e9370650564aaefb	0.5 BTC	2020-06-19 11:28	3J4jo77ywPPfU58kYSW8CL5wmfRYRZPKwB: 20 BTC 3PfeKgjMq7PqXDKe885DGXVoomn413zw1y 10 BTC	3FwBYCGMs8eDYrthoXVzNHD4KRt9hrwG3M: 5 BTC 14YwdNJFLiMbwKw82TroEdqe964WfLyh8u: 24.5

Source: The header content and transaction hashes have been derived from a real block on blockchain.com.

1.3 Advantages and Challenges

This section analyzes the advantages and challenges of the technology underpinning Bitcoin, that is, the blockchain. Here, the article "the" is included in front of the word "blockchain" so as to more clearly distinguish between the term "blockchain" without the definite article, which refers to any type of blockchain, and "the blockchain" with the article, which refers to the public blockchain that underpins Bitcoin (Morkunas et al., 2019).[15] The findings presented in this section have been compiled after reviewing prior articles and analyzing real industry use cases.

It should be noted that most of the advantages mentioned below are related to the use of different types of technologies as cryptographic keys and encryptions, smart contracts, and distributed/peer-to-peer systems in the blockchain, rather than just to blockchain technology itself or the way blocks are structured, and data are stored (chain of blocks). The combination of all these elements has enabled the development of Bitcoin as a decentralized system, although each element used in the blockchain has its own advantages when used individually.

1.3.1 Advantages

The advantages associated with the decentralized and peer-to-peer network used in relation to Bitcoin are as follows:

Disintermediation. Bitcoin is believed to eliminate the need for intermediaries such as banks because the system is designed in such a way that anyone can perform that role and the transactions do not solely depend on a centralized entity. In addition, the trust in third parties such as banks that enabled them to charge a fee for their work has been transferred to a code run by machines. The miners who own such machines could be considered the intermediaries upon whom the validation of transactions depends. These miners, as previously explained, receive a transaction fee (which is now optional to pay) and a reward from the system, which incentivizes them to perform this task. The reward that a miner currently receives covers the costs associated with running the system, meaning that the miner should not mind including a transaction that does not contain a transaction fee in the block. Yet, once the system stops paying rewards, the miners will solely depend on the transaction fees received from the participants, which suggests that the probability of a miner only including a transaction with a transaction fee or giving

[15] The different types of blockchains will be analysed in Section 1.4.

priority to a transaction with a higher fee might increase. Still, the simple and completely automated peer-to-peer transaction system is believed to lower many costs associated with centralized intermediaries, such as the costs of authentication, verification, processing, safeguarding, and updating the ledger. However, the accuracy of this claim remains a research question that requires further investigation. Moreover, as the system can operate on a 24/7 basis without any human involvement in transaction settlement, the transaction clearing and settlement time can be reduced from days to minutes.

Open access, privacy, and censorship resistance. The Bitcoin system is designed in such a way that anyone can join the network and then read and write transactions. This open access to the system ensures full transparency, taking into consideration privacy as the sender and receiver of the transaction are pseudonymous, which means that although the network participants have access to the ledger and can see the historical records of the executed transactions, they are not be able to identify the people behind the transactions. Instead, the transactions within the system are recorded and identified by the public key, which is a random number generated using an individual's private key. Moreover, as the system is decentralized, no central entity (a nation-state, institution, or organization) can control, filter, temper with, or limit access to the network and the performance of transactions. In addition, the Bitcoin system means that no individual or group of individuals can unilaterally alter the system. Consensus among the majority of people in the network is required if any change is to be made to the network.

No single point of failure. As the Bitcoin system is run by different nodes, if any one node fails or is corrupted, the other nodes will not be affected and the system will continue to operate. The possibility of all the nodes failing at the same time decreases as the number of nodes increases.

Resistance to malicious actions and attacks. As there is no single point or centralized database to attack, it is difficult to manipulate the system or destroy it. The distribution and decentralization render the system secure against malicious actions and attacks.

Resistance to collusion. Here, collusion involves acting in a way that can benefit some at the expense of others. Similar to the situation in the market, in the Bitcoin blockchain, the higher the number of participants, the more difficult it is to collude.

The advantages related to the structure of the Bitcoin system, such as storing data in blocks and applying encryption, are as follows:

Traceability and transparency. As the transactions are linked sequentially to one another and the blocks containing them are timestamped and linked to prior blocks in an immutable way in a public ledger that can be accessed by anyone, it is very easy to track the origin of a given transaction. This characteristic of Bitcoin renders the system transparent and easy to audit.

Immutability and data integrity. In the Bitcoin blockchain, data are stored in an append-only manner and so cannot be changed, reversed, or eliminated. This property both ensures the security of the system and guarantees data integrity. It also renders the system more trustworthy and corruption-free, as the participants know that no one can alter the data.

Security. As the blocks are linked to one another, making a change to one block requires all the proceeding blocks to also be changed. As previously explained, from a computational perspective, it is almost impossible to hack the system, which makes Bitcoin secure.

1.3.2 Challenges

A number of the benefits mentioned above, such as disintermediation, immutability, and transparency, can be seen as double-edged swords, meaning that while such properties make Bitcoin work and distinguish it from centralized systems, they are associated with challenges that limit its applications and may make the underlying technology (i.e., the public blockchain) less appealing to industry use cases. Thus, there are challenges associated with the advantages described above as well as additional challenges concerning decentralization, the structure of the system, and certain technical issues that facing blockchain.

Among the challenges associated with the decentralization of the Bitcoin system are the following:

Disintermediation. Eliminating the intermediary from the system means that the responsibility for a transaction, due diligence concerning the system protocol, and anything related to engagement in the decentralized network is placed on the shoulders of the participants. This means that there is no entity responsible for any loss or error. For instance, the safeguarding of a private key is the sole responsibility of the person who owns the wallet. If a private key is lost or stolen, it cannot be recovered. In addition, once performed, a transaction cannot be revoked. Thus, the person performing a transaction must ensure that their private key is stored somewhere safe and that the public key to which the bitcoins are transferred is correct.

Privacy. As the transactions are stored in a public ledger that can be accessed and traced by anyone, transactional privacy represents a major issue in relation to the Bitcoin blockchain. Jawaheri et al. (2020) showed that while Bitcoin addresses are pseudonymous, there are deanonymization mechanisms through which sensitive information can be disclosed and addresses can be linked to a real identity, which could endanger the privacy of the participants.

Lack of clear regulation. One of the main challenges associated with disintermediated and decentralized systems such as Bitcoin concerns the lack of regulations and laws to enable such systems to be subject to mass adoption. Regulations such as the European General Data Protection Regulation (GDPR) require a legal person or entity for data processing purposes, but in decentralized systems networks of machines and people run the systems. There are no clear guidelines at the European level that address such trivial yet important legal issues concerning DLTs (Chapter 4 discusses in detail the challenges related to financial regulation that DLT firms are currently facing).

The challenges related to the storing of data in blocks within the blockchain are as follows:

Redundancy and scalability. To maintain the consensus across the system with zero downtime and high fault tolerance, the database is replicated and each node contains a complete copy of the ever-growing ledger. This means that the more blocks included in the chain, the larger the size of the database (Zheng et al., 2018). Thus, running a complete node[16] requires sufficient storage.

Latency. In the case of Bitcoin, the transaction rate per second is much lower than that of traditional central payment processing systems such as Visa, which can process thousands of transactions per second. Each block in the Bitcoin blockchain is generated in approximately 10 minutes, and the capacity of each block to include transaction is limited. According to Blockchain.com (n.d) data concerning the period from June 2019

[16] A node that runs the complete ledger and verifies a given transaction. For instance, the miners complete full nodes as they verify transactions in the Bitcoin blockchain.

to June 2020, the average time taken for a transaction to be included in a block ranges between 6 and 390 minutes, while the maximum number of transactions per block is approximately 2800, which means that even if each block is filled to maximum capacity, only 2800 transactions can be processed in around 10 minutes by the Bitcoin blockchain.[17] This latency in terms of the transaction processing time could become a serious problem if the Bitcoin blockchain is adopted more widely (Zheng et al., 2018).

Immutability. While the system's immutability renders Bitcoin tamper-proof and secure, it contravenes the principles of the GDPR and the right to be forgotten. According to the GDPR, the user has the right to request the elimination of their personal data from the data controller's database. In a decentralized system such as Bitcoin, there is not central data controller, and the data cannot be eliminated. This contradiction limits the practical applications of the blockchain.

Some of the other challenges associated with the Bitcoin blockchain are as follows:

Consensus mechanism. As mentioned above, Bitcoin relies on a PoW consensus mechanism in which miners compete to generate blocks. As cryptography is used to generate, verify, and process the transactions, a high amount of electricity is required for the computation and the miners have to invest in powerful devices with high hashing rates (Zheng et al., 2018).

Collusion. The increase in the number of mining pools (i.e., groups of miners who share their processing power to find the solution to a given problem and then share the reward according to the contribution each miner made to finding the nonce and generating a block) has raised concerns regarding the potential for collusion (Göbel et al., 2016). The findings reported by Lehar and Parlour (2020) showed that mining pools facilitate collusive equilibria and enhance the miners' market power. The collusion of miners also

[17] For more information, see the Average Confirmation Time charted provided by Blockchain.com (n.d.).

raises concerns related to 51% attack[18] and forking.[19] Moreover, the collusion of miners can create entry barriers.

Security. Although the Bitcoin blockchain's architecture currently appears to be secured using cryptography, the latest advances in quantum computing have given rise to certain concerns regarding Bitcoin's ability to resist quantum attacks (Ikeda, 2018).

1.4 Types of Blockchains

As the Bitcoin blockchain is a public, peer-to-peer, decentralized ledger that uses PoW as its consensus mechanism, it is associated with certain challenges. Thus, researchers and practitioners have sought to identify solutions that address some of those challenges by introducing new types of blockchains. Indeed, over the last few years, other types of DLTs (as discussed in Section 1.2.2) and different types of blockchains (private, federated, or hybrid) with alternative consensus mechanisms (Table 4) have been proposed and used by firms to render blockchain a suitable technology for various industry use cases.

Table 4 *Different Types of Blockchains and Their Features*

Features	Public	Private	Federated	Hybrid
Access	Anyone	Single organization	Multiple organizations	Authoritative/restricted (only certain elements are private)
Network	Open	Closed	Closed	Closed
Ledger	Open	Closed	Closed	Restricted
Authority and Control	Decentralized	Centralized	Decentralized	Flexible
Transaction Speed	Slow	Fast	Fast	Fast
Consensus	Permissionless	Permissioned	Permissioned	Permissioned
Scalability	Low	High	High	High

[18] "A 51% attack is a potential attack on a blockchain network, where a single entity or organization is able to control the majority of the hash rate, potentially causing a network disruption. In such a scenario, the attacker would have enough mining power to intentionally exclude or modify the ordering of transactions. They could also reverse transactions they made while being in control - leading to a double-spending problem" (Binance Academy, 2018).
[19] Forking refers to the splitting of the chain upon which Bitcoin runs, causing it to go in a different direction with different rules than the existing blockchain, as the two would now have different visions concerning cryptocurrencies (Vishwanathan, 2017).

Data Handling	Read and write access for everyone. Transactions are pseudonymous and transparent.	Only the organization has read and write access.	Multiple organizations have read and write access.	Writing is private (only certain nodes can write), although reading is public.
Immutability	Full	Low	Partial	Partial
Security	High	Low	Medium	Medium
Examples	Bitcoin, Ethereum, NEO, Lightcoin	Multichain, Hyperledger, Corda	Marco Polo, Energy Web Foundation, IBM Food Trust	Dragonchain, XinFin, Kadena

Source: Author's elaboration based on different sources.

1.4.1 Public Blockchain

A public blockchain is a permissionless distributed ledger that allows anyone to enter the network and access the ledger (read and write transactions). Furthermore, as each network member has a copy of the ledger, the amount of storage required increases alongside the number of transactions. This replication of the database makes the system less scalable, as discussed in Section 1.3.2. Although this type of blockchain has a low transaction speed, its data handling is pseudonymous, transparent, and shows full immutability. Aside from Bitcoin, Ethereum and Litecoin are major examples of public blockchains.

1.4.2 Private Blockchain

A private blockchain is controlled by one centralized entity and so is not open to the general public. Only participants from within the centralized entity can read and write transactions, meaning that both the network and the ledger are closed. This type of blockchain is most suitable for organizations that want to use it to make their internal processes more efficient. However, a private blockchain is vulnerable to malicious actions and lacks both the security and the immutability that a public blockchain offers. Yet, a more efficient consensus mechanism can be used (with less people authorized to validate transactions) to render the system more scalable and offer a higher transaction speed. Multichain, Hyperledger, and Corda are examples of private blockchains.[20]

[20] See Tables 4, 5, and 6 in Section 1.5 for some private blockchain use cases.

1.4.3 Federated/Consortium Blockchain

A federated blockchain is controlled by various organizations, which means that its users can benefit from both the public and private features of blockchain technology. Although the blockchain is not open to the public, various organizations hold a copy of the ledger and have access to read and write transactions. Thus, while not fully decentralized, a federated blockchain benefits from the security and immutability features of a public blockchain, solves the scalability problem, and offers a fast transaction speed. Marco Polo, Energy Web Foundation, and IBM Food Trust are all examples of popular federated blockchains.[21]

1.4.4 Hybrid Blockchain

In a hybrid blockchain, while the ledger might be closed and only a few nodes/entities are able to write transactions, the network is open. This means that anyone can see the transactions, although not everyone can add new transactions. The system is controlled by one or a few entities. A hybrid blockchain combines the benefits of private and public blockchains. It is particularly suitable for organizations that do not want to deploy a private or public blockchain and instead want the best of both systems. A hybrid blockchain offers greater transparency, security, and immutability than a federated blockchain, although it offers less than a public blockchain. Dragonchain, XinFin, and Kadena are three examples of hybrid blockchains.

Some features of the different types of blockchains are listed in Table 4. Each type of blockchain is associated with its own set of benefits, and its use depends on the purpose of the project and the entities involved.

1.5 Blockchain Applications

It is believed that blockchain technology has the potential to transform and revolutionize almost every industry. In a survey conducted by Deloitte in 2020, 55% of surveyed company executives reported blockchain to be of critical relevance to their organizations and listed it among their top five strategic priorities (Pawczuk et al., 2020). In addition, in the survey that will be discussed in Chapter 3 of this dissertation, 41 percent of surveyed firm managers in Spain confirmed that their companies foresee the business potential of utilizing blockchain technology. After more than a decade since its

[21] See Tables 4, 5, and 6 in Section 1.5 for federated blockchain some use cases.

application in relation to Bitcoin, thousands of companies have invested in blockchain technology in the hope of making their processes more efficient and keeping pace with the competition. Although the financial applications of blockchain might be the most frequently highlighted in the literature, its potential applications actually extend far beyond finance, with use cases being found in almost all industries.

On the basis of an extensive literature review and desk research, an analysis of the applications of blockchain technology in different sectors has been performed as part of the present study. In accordance with the approach of Crosby et al. (2016), the identified applications will be divided into two categories: financial and non-financial applications. As the non-financial applications of blockchain are numerous, the decision has been made to focus on three sectors, namely supply chain and logistics, healthcare, and energy. Moreover, the applications in each sector have been categorized based on the focus or value of the blockchain use.

1.5.1 Financial Applications: Beyond Bitcoin

In 2017, for the first time, the amount of funding raised by blockchain companies through initial coin offerings (ICOs) exceeded the amount raised through traditional venture capital investment (Sunnarborg, 2017). Furthermore, as of December 2021, more than 698 million transactions had been processed using the Bitcoin blockchain system (YCharts, n.d.). Cryptocurrencies such as Bitcoin and the associated ICOs have completely changed the way assets are transferred. Somewhat ironically, blockchain, a technology that was developed to eliminate the need for trusted third-party intermediaries such as banks, is now used by those intermediaries to remain competitive and ensure that their business is not rendered obsolete by technological advancements. While the Bitcoin blockchain is a public, peer-to-peer, decentralized ledger, most financial institutions use private or federated blockchains involving different consensus mechanisms and elements such as smart contracts and encryption. According to Power (2019), transparency, efficiency, opportunity, cost, accountability, and liquidity are the six domains of finance that can be enhanced through the use of blockchain technology. It is clear that the applications of blockchain, both current and potential, in the financial sector form a broad research area, and many papers have been published on this subject in recent years (e.g., Kowalski et al., 2021; Pana & Gangal, 2021). As part of the present study, an intensive literature review and desk research were performed to identify the most prominent blockchain applications in the financial sector. Table 5 summarizes some of those applications, as well as the solution or value that blockchain offers, along with certain industry use cases.

It appears that blockchain technology is mainly used to make the financial system more efficient through the automation of certain processes using smart contracts, to eliminate some intermediary processes using distributed or peer-to-peer systems, and to render existing systems more secure using the blockchain data-storage mechanism and cryptography (Wu & Liang, 2017). However, in recent years, cross-border payments, consortium banking and security issuance, settlement and clearness, and trade finance seem to have attracted more attention in terms of the use of blockchain (Qian, 2019).

After Facebook (now Meta) announced in 2019 that it would be launching the Libra association and cryptocurrency (which is currently known as Diem), while certain other big companies have announced the intention to issue their own stable coins, governments worldwide have accelerated the process of issuing central bank digital currencies (CBDCs). For instance, China has already rolled out its digital yuan for testing, Riksbank is working with Accenture on implementing a digital krona pilot in Sweden, and the European Central Bank is engaged in discussions concerning the digital euro. In fact, CBDCs have been converted into news headlines, becoming one of the hottest finance topics of 2020 and 2021. Peer-to-peer (P2P) lending, derivates clearing and processing, and regulatory compliance processes such as know your customer (KYC) and anti-money-laundering processes are among the other areas of the financial sector that can be enhanced using blockchain technology.

In short, many financial institutions are already implementing pilots of some or all of the applications mentioned above, which indicates that the mainstream adoption of blockchain technology in relation to finance is not far from becoming a reality.

Table 5 *Applications of Blockchain in the Financial Sector*

Reference	Application	Blockchain Solution and Value	Example/Industry Use Case
Guo and Liang (2016)	Payment	Automated documentation	Ripple's XRP, Diem, Visa B2B, Santander OnePay FX, IBM + CLS (CLSNet)
		Real-time settlement of transactions	
		Real-time tracking of transaction	
		Fraud-proof	
		Lower costs on existing payment rails (e.g., remittances)	
Wu and Liang (2017)	Consortium banking	Faster consortium formation	R3 Corda, IBM (Batavia and We.Trade), Primechain (BankChain)
		Technology integration	
		Digitization of documents	
		Automation of processes, thereby cutting the intermediary costs	
		Reduced settlement periods	
		Improved regulatory environment	
		Documents and data immutability	
		Increased transparency	
		Reduced transaction fee	
Parra Moyano and Ross (2017)	Compliance processes	Contract and collateral automation and management	Cecabank + Grant Thornton, IBM + CLS (LedgerConnect), KYC-Chain, Norbloc + Mashreq Bank + Dubai International Financial Centre, DIFC
		Efficiency gains	
		Cost reduction	
		Improved customer experience	
		Increased transparency	
		Immutability of data can increase trust between parties	
Pana and Gangal (2021)	Primary security issuance, clearing and settlement	Shared record of the transaction	Thailand Public Debt Management Office + Bank of Thailand (bond issuance), Santander, Australian Stock Exchange (ASX) with Digital Asset Holdings, Nasdaq Linq
		Automated equity payment	
		Track the ownership of securities	
		Crypto fundraising	
		Global access to markets	
		Near real-time clearing and settlement of securities	
		Eliminating the need for the reconciliation of duplicative records	
		Lower fees	
Pana and Gangal (2021)		Automatic execution and enforcement of contractual terms	IBM + DTCC, International Swaps and Derivatives
		Automation of records management	

	Derivatives clearing and processing	Lifecycle events and payment management	Association (ISDA), IBM + CLS (LedgerConnect)
		Distributed clearing network to manage cash flows	
		Collateral management	
		Gain visibility in the economic agreements held between entities	
		Near real-time information for financial regulators and central banks	
		Allow the end client to pass payments to counterparties	
		Transfer of information to authorized parties	
		Reduced costs and counterparty risk	
Jessel and DiCaprio (2018)	Trade finance	Digitization of trade finance process	IBM (Batavia and We.Trade), R3 Corda (Voltron and Marco Polo), VAKT
		Automated cross-checking of documents with parties involved	
		Creation of a single and shared source of truth	
		Connect parties that do not initially trust one another	
		Real-time exchange of data and assets between parties	
		Superior audit and compliance capabilities for financial institutions	
		Improved transparency and tracking of trade assets	
		Decreased risk of fraudulent trade	
Qian (2019)	Central bank digital currencies	Optimized payment functions and strengthened authority of fiat money	People's Bank of China Digital Currency Electronic Payment (DCEP), Riksbank e-Krona
		Reduced reliance on payment services provided by the private sector	
		Alleviated regulatory burdens and decreased pressure on the central bank	
		Reduced costs of cross-border payments	
		Reduced time required for payment settlement	
Manda and Yamijala (2019)	Peer-to-peer lending	Improved turnaround time in loan processing	ETHLend, Compound, Maker (Oasis), LENDROID, Dharma, BlockFi, Unchained Capital, Ripio Credit Network, SALT Lending, COLENDI
		Reduced operational risks and improved efficiency of funding	
		Trusted records and better pricing (of interest rates) for lenders	
		Less bureaucratic, easy, and quick application process	
		Added security layer if the platform uses a public blockchain	

Source: Author's elaboration based on a literature review and desk research.

1.5.2 Non-Financial Applications

There are many non-financial applications of blockchain and related use cases can be found in almost all industries. This section reviews the applications of blockchain in three sectors, namely the energy, healthcare, and supply chain sectors. While there might be some sector-specific applications of blockchain, most applications are the same across different sectors and are related to the values that blockchain adds to traditional systems due to its unique data-storage structure and its use of encryption, distributed networks, and smart contracts.

1.5.2.1 Energy

Blockchain technology has the potential to drastically change energy supply and transmission. As the adoption of blockchain is growing in non-financial industries at the same time as environmental concerns are increasing, many entrepreneurs and researchers are taking advantage of blockchain's remarkable capabilities to bring fundamental changes to the energy sector through the implementation of more sustainable and decentralized energy business models.

Many prior studies have investigated the applications of blockchain in the energy sector. Some of the most widely cited of those studies and some real use cases are listed in Table 6. The classification of the applications is derived from the literature, while the real use cases that intend to deliver the described values are derived from industry.

Although P2P energy trading is currently associated with a highly burdensome and uncertain regulatory procedure, one of the most significant applications of blockchain in the energy sector involves the decentralization of the energy markets and the enabling of P2P trading of renewable energies. There is a lot of ongoing research in this field, with scholars such as Neagu et al. (2019) and Xue et al. (2017) having proposed technological frameworks for decentralized energy markets. Some companies, for example, Power Ledger, Prosume, and LO3, have started to implement pilot projects involving energy communities and energy cooperatives in Europe (Olivares-Rojas et al., 2020). Payment, billing, grid management, tracking and certifying the origins of energy sources, fundraising for renewable projects, and changing consumers' habits in relation to greener and more sustainable energy supply and consumption using incentives are some of the applications of blockchain in the energy sector (Gür et al., 2019; Noor et al., 2018; Johanning & Bruckner, 2019). Digitization and the automation of processes via smart contracts and the elimination of intermediary entities enables cost reductions and enhances both the efficiency and the productivity of existing energy systems. Moreover, the use of blockchain increases the level of data security and protects energy systems from cyber-attacks. A combination of blockchain, the internet of things (IoT), and artificial intelligence enables machine-to-machine interaction and serves to take the use of smart meters, electronic vehicles, and smart solar panels to the next level.

To conclude, blockchain technology can facilitate a completely new way of supplying, trading, and consuming energy. Indeed, observations of the experimental and pilot projects within the industry show that blockchain has the capacity to dramatically change the way the energy sector works.

1.5.2.2 Healthcare

Healthcare is another area that can be enhanced by the use of blockchain technology. In a systematic review of the literature, Hasselgren et al. (2020) identified the main applications of blockchain within the healthcare sector. The present study draws on their findings and integrates real use cases and industry pilot projects related to each identified application. Moreover, based on the analysis, the blockchain solution and value associated with each application have been assessed and modified so that only the most important applications are listed in Table 7.

Table 6 *Applications of Blockchain in the Energy Sector*

Reference	Application	Blockchain Solution and Value	Example/Industry Use Case
Gür et al. (2019)	Billing	Automated billing and payment process	M-PAYG, Pylon Network, SunChain, Enercity
		Short delivery time for documents	
		Administrative cost reduction	
		Real-time settlement of payments	
		Increased transparency through sharing transaction details	
Olivares-Rojas et al. (2020)	Smart metering	Traceability of energy consumed and produced	Bankymoon, Pylon Network, Prosume, SunChain
		Increased transparency of the origin and cost of energy	
		Incentivizing behavioral change and demand response	
		Integration of digital currency payments and machine-to-machine payments into smart meters	
		Protects smart meters from cyber-attacks	
Teufel et al. (2019)	Security	Improved data privacy, better identity management, protection from cyber-threats	Electron, Guardtime, Xage + ComEd, Engie
Johanning and Bruckner (2019)	Tokenization	An instrument to attract investment and raise funds	SUNEX, WePower, ImpactPPA, EverGreenCoin, SolarDAO, Prosume, Sun token, SolarCoin, Energi Mine (EnergiTokens or EKT), EcoCoin, RecycleToCoin, OMEGAGrid
		Facilitates green energy investments and asset co-ownership	
		Rewards desired behaviors (e.g., reducing energy consumption, low-carbon or green energy production, rewards for recycling, rewards for sustainable actions such as buying a vegetarian lunch or cycling to work)	
	Decentralized energy trading	Improving wholesale energy markets through digitization and the automation of processes as trading currently involves paper contracts and backend processes prone to both errors and fraud	Enerchain, NEW 4.0 BP + Wien Energie + BTL, Grid+
		Peer-to-peer energy trading eliminates middlemen and enables small-scale consumers to participate in the energy markets	Drift, Restart Energy, SunContract, Alliander (Alva Energy Project), Energy21, Solar Banker, Pylon Network, Prosume, LO3, LO3+EnergieSudwest, PowerLedger, Eneres, Energy Bazaar, EnergyBlock, Greeneum, StromDAO, Engrati (PowerToShare), Hive Power

		Reduces transaction costs by using smart contracts Execution and settlement of complex power purchase agreements using smart contract Improving energy payments	Bittwatt, ClearWatts, VLUX
Pan et al. (2019)	Green certificates and carbon trading	Automatic issuance of carbon certificates and trading Inclusion of small energy producers in claiming carbon credits Reduces costs associated with the procedure for obtaining green certificates and carbon credits Improves and automates audit processes Reduces errors and fraud Tracks the origins of energy sources	Nasdaq + Filament, Volts Markets, Veridium and its token TRG, Poseidon, DAO IPCI, CarbonX, Energy-Blockchain Lab, PowerLedger, Grid Singularity
Noor et al. (2018)	Grid management	Improved balance between supply and demand Automated grid asset verification and increased visibility of distributed assets Improved coordination of transmission and distribution system operations	PONTON (Gridchain), Grid Singularity, TenneT, PROSUME, EvolvePower, PowerLedger, Electron,
Su et al. (2019)	Electronic vehicles/e-mobility	No need for a centralized electronic vehicle charging infrastructure Machine-to-machine payments Improved fault tolerance Elimination of price-setting and collusion between charging stations and/or transport providers Transparency in terms of energy charges Verification and communication platform	Share&Charge, Car eWallet, Prosume, Everty, PowerLedger,

Source: Author's elaboration based on a literature review and desk research.

An in-depth analysis of the identified applications revealed that the decentralization of access to medical records and the transference of ownership of health-related data from institutions such as hospitals, clinics, and research centers to individuals represent the most commonly discussed applications of blockchain in the healthcare sector. Companies such as MediBloc, Bowhead Health, and MedChain seek to help patients acquire and collect their electronic health records and personal health records in one platform and provide access to those records wherever, whenever, and to whomever.

Due to blockchain's immutability, healthcare institutions will no longer need to be so concerned about data loss and cyber-attacks. Aside from medical records, the technology can be used to store and track pharmaceutical products, electronic prescriptions, and infectious diseases. Another positive feature of blockchain systems is their ability to bring together medical doctors, physicians, patients, and researchers on a single platform where they can interact, share data, and collaborate with each other. This ability has resulted in the creation of new business models such as telemedicine and the remote monitoring of patients.

Technology interoperability currently represents a significant challenge facing healthcare institutions. Technical and technological differences between different medical centers often render it difficult to share documents and information; however, blockchain technology makes it possible to design an integrated system in which patients' medical information can be stored and shared with different medical institutions. Moreover, the medical information stored in an integrated blockchain system allows laboratories to identify patients for drug testing and clinical trials.

In summary, many blockchain-based innovative ideas are now introducing new ways of managing data, conducting research, treating diseases, serving society, and doing business in the healthcare sector.

Table 7 *Applications of Blockchain in the Healthcare Sector*

Reference	Application	Blockchain Solution and Value	Example/Industry Use Case
	Electronic health records	Secure and scalable data sharing for collaborative clinical decision making	ETHEAL, Azaad Health, SOLVE CARE, MedChain, medvice, MedBlox, MEDIBLOC, Patientory, Inc., Blupass, Medicalchain, Proof Work, Spiritus, Meditech,
		Sharing/exchange of healthcare data between institutions for clinical and research purposes	
		Trustless, decentralized storage of necessary metainformation and audit logs	
		Patient-controlled collection, archiving, and sharing of health data between healthcare providers increases data privacy	
		Reduces the time required to access a patient's information	
		Smart contracts for access control, distributed storage, and encryption for security	
		Improves data quality and enhances interoperability	
	Personal health records and monetization of patient data	Sharing healthcare data for administrative or economic purposes	Hu-manity.co (Betterpath), Hit Foundation, CITIZEN HEALTH, Bowhead Health, Embleema, Well, Clinico, Pokitdok
		Sharing healthcare data between health institutions	
		Automatic collection of data from wearable devices, manual input, and medical devices, storage in the cloud, and patient-controlled sharing of personal health data with health providers and insurance companies	
		Collection, archiving, and sharing of healthcare data for clinical/ research purposes using blockchain-based framework for secure, interoperable, and efficient access to medical records by patients, providers, and third parties	
	Drug development	Sharing real data in real time to fast track drug development	Embleema
		Increases security of patient consent and data	
	Clinical trial system	Sharing healthcare information for research purposes	BlockchaininHealth, Clinico, CONSILX
		Recruitment of patients for clinical trials	
	Pharma supply chain	Monitor and track the distribution of drugs	iSolve, openledger (Olway), MediLedger, MediLedger
		Simplified payment process	
		Prevent counterfeiting and fraud	

Hasselgren et al. (2020)	Remote patient monitoring	A system that calls smart contracts and writes records of all events on the blockchain, which allows for real-time patient monitoring and medical interventions by sending notifications to patients and medical professionals while also maintaining secure records	Well
	Picture archiving and communications system	Exchange of medical images	VoxelX
	Telemedicine system	Collection and storage of data concerning symptoms for the purposes of automated diagnostics, decision support, and research	doc.com, ETHEAL, MEDICHAIN
		Finding the patient in the context of telemedicine services	
	Infectious disease surveillance system/participatory decision support system	Public health management (monitoring the outbreak of infectious diseases), for example, monitor quarantined people and tracking the spread of COVID-19	Tracetogether (Singapore), Hashlog (Acoer)
	Genomic data	DNA data marketplace, storing data concerning DNA sequencing and selling those data to medical research entities, blockchain enables consumers to authorize access to their personal information and to be compensated for it	NEBULA Genomics, EncrypGen, Genomes.io, Genecoin, DNAtix
	Healthcare cryptocurrencies	Sharing healthcare data for administrative or economic purposes, rewarding activities (e.g., rewards for reviewing dental services, rewards for carrying out daily tasks, free medical services in exchange for sharing health-related data that is later used to generate insights)	doc.com (MTC as currency), DENTACOIN, Well, Mosio's Clinicoin, CoinHealth, minthealth
		Enables decentralization and creation of communities	
		Fundraising for health- and wellness-related projects	
	Provenance and medical histories	A democratized health and wellness ecosystem that uses the blockchain to self-govern data and improve care Decentralizes medical health data by granting access through smart contracts	Proof Work, Spiritus, Meditech,
	Electronic prescriptions	Send and receive electronic prescriptions, track those prescriptions, and predict at-risk patients.	MediLedger, SOLVE CARE, CoverUS,

Source: Author's elaboration based on a literature review and desk research as well as on Hasselgren et al. (2020).

1.5.2.3 Supply chain and logistics

Despite recent advances in digital supply networks, paper processes remain prevalent in the supply chain and logistics sector, which results in reduced transparency, increased costs, and an increased likelihood of errors and fraud. Moreover, in a manual and undigitized process, stakeholders are less involved, and systems are more vulnerable to both corruption and malicious attacks. Thus, organizations have sought to identify ways of increasing transparency and facilitating information sharing among supply networks. Blockchain could serve as a useful tool for companies seeking to make the supply chain more transparent, secure, decentralized, cost-efficient, and responsive to customers' needs. In fact, with the help of this technology, organizations could successfully improve the performance of their supply networks.

A review of the literature was conducted to identify some of the most commonly implemented applications of blockchain in the supply chain and logistics industry, and the results are summarized in Table 8. As each product and industry has its own supply chain, the applications listed in the table are not specific to one industry and can instead be applied to a wide range of industries (e.g., retail, mining, construction, etc.). It should also be noted that while the tracking of digital assets can easily be performed using blockchain technology, the tracking of physical/tangible assets requires blockchain to be combined with IoT technologies (e.g., radio frequency identification [RFID]).

Companies such as IBM, ConsenSys, and Provenance have served as pioneers in this regard and implemented many pilot projects combining blockchain and supply chain technologies. Tracking products throughout the supply chain, transaction processing, and the automation of processes appear to be among the most exciting use cases of blockchain in the supply chain and logistics sector. The use of blockchain and smart contracts also reduces the costs related to intermediation, the level of paperwork, the slow processing time, the costs of bank transfer fees, and the costs of collaterals and contracts. Moreover, the verification of a product's origin, delivery, and ownership can be easily performed using blockchain and the IoT. The ability to track and trace products helps to reduce the risk of fraud, counterfeiting, and malicious actions, and it also increases both transparency and trust. It should be noted that most of the identified applications of blockchain in relation to supply chains are directly related to the main characteristics and benefits of blockchain technology. These advantages make blockchain the perfect match for improving supply chains and rendering logistics more efficient.

Table 8 *Applications of Blockchain in the Supply Chain and Logistics Sector*

Reference	Application	Blockchain Solution and Value	Example/Industry Use Case
De Giovanni (2020)	Smart contracts/ automation	Automating the purchasing process	Skuchain, Shipchain, Vechain
		Automating the material movement based on predefined conditions	
		Decreasing paperwork processing cost and time	
		Checking the quality, authenticity, and availability of goods	
		Preventing acceptance of unverified goods and products	
		Payment release to different parties based on predefined agreements	
Gonczol et al. (2020)	Traceability/tracking	Record the product status at each stage of production	Provenance, Everledger, WaltonChain, TE-Food, Shipchain, IBM
		Trace purchase orders, changed orders, receipts, shipment notifications, and other trade-related documents	
		Trace all the process steps	
		Track the provenance of products such as luxury items, organic goods, and bio products	
		Increases the visibility of the shipment's origin and handing conditions	
Bai and Sarkis (2020)	Transparency	A shared ledger provides participants with access to transaction-related information	SyncFab, Insurwave, ConsenSys + LVMH, IBM
		Share verifiable claims with consumers to improve authenticity and enhance consumer trust	
Cole et al. (2019)	Prevent counterfeiting and fraud	Communicate loads, geo waypoints, and basic compliance information with carriers	Openport, Origintrail, Waltonchain, TE-Food
		Provide more visibility across the supply chain	
		Register the parties involved, price, date, location, quality, and state of the product	
		Secure documentation and certification (e.g., insurance documents, pickup documentation, quality certificates, etc.)	
Cole et al. (2019) and Liu and Li (2020)	Transaction processing	Document every transaction (track cargo, billing, etc.)	SyncFab, Blockverify, Yojee, Vechain, IBM
		Offer transaction transparency possibilities	
		Reduce the need for manual input	
		Visualize recorded transactions on a blockchain (evaluation of driver qualification)	
Abidin and Perdana (2020)	Verification	Verification of products, goods, merchandise, and transactions	Blockverify, Shipchain
		Verify delivery of samples, packages, material, etc. based on agreed conditions	

Source: Author's elaboration based on a literature review and desktop research.

1.6 Discussion

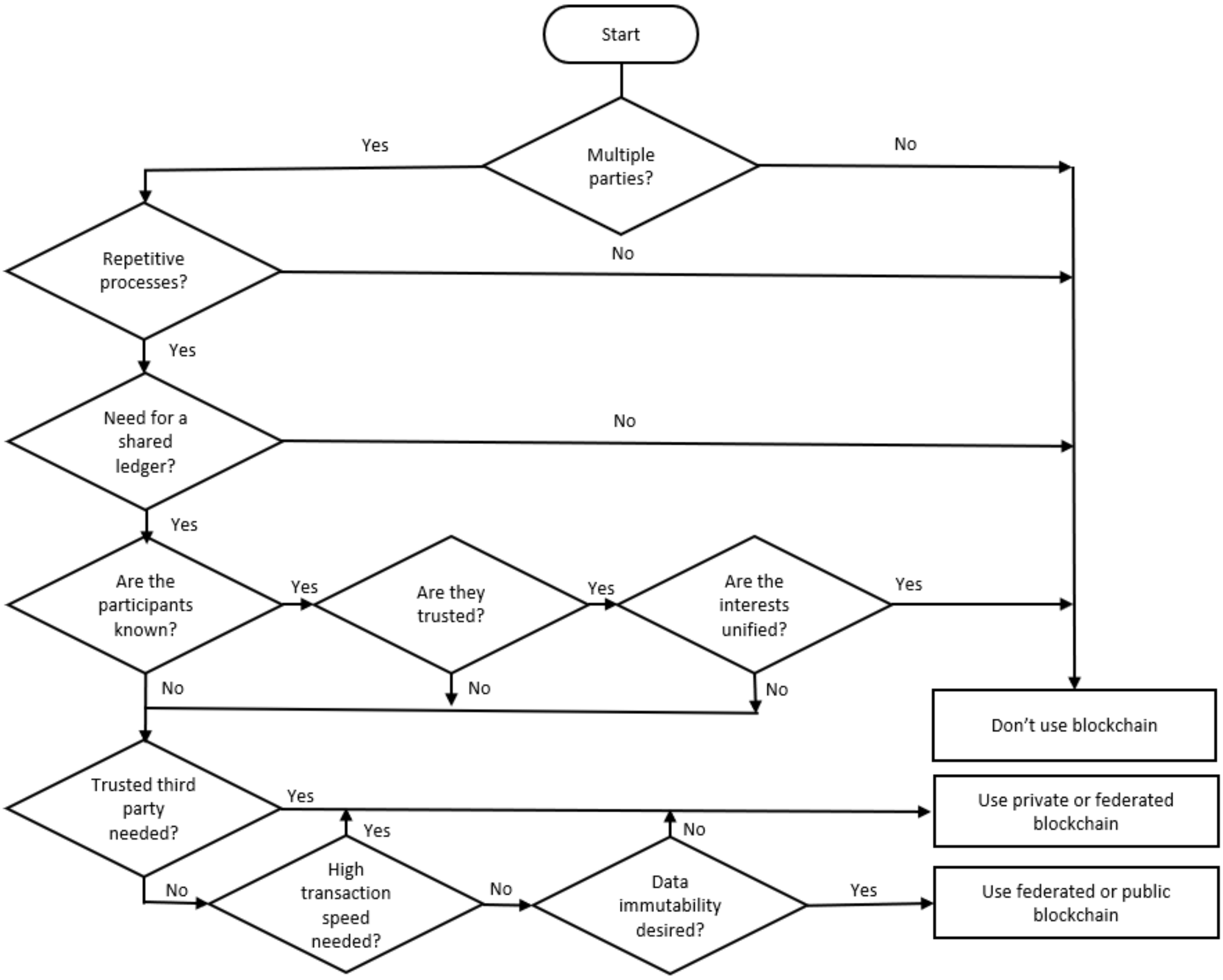
While the previous section discussed the many applications of blockchain technology in sectors such as the financial, healthcare, energy, and supply chain sectors, it must be acknowledged that blockchain cannot currently be applied in all areas. Managers should be able to evaluate and decide when the use of blockchain will add value to a business and be preferable to the conventional, centralized means of storing data and managing ledgers. Thus, an important question facing company managers is the following: When should blockchain be used?

Scholars such as Pedersen et al. (2019) have analyzed the use of blockchain versus the use of conventional centralized databases and designed decision trees and flowcharts to guide managers throughout the related decision-making process. The present study analyzed the proposed frameworks, combined them, and added new decision nodes so as to develop a unique decision tree that can be used by managers to evaluate if the use of blockchain is suitable/recommended or not.

The use of blockchain is only recommended if there are many parties involved in a transaction who all need access to a shared database. Yet, not all transactions involving multiple parties are repetitive. For instance, if a firm wants to buy a building, it does not make sense for that firm to develop a blockchain system to record the transaction even though multiple parties will be involved in the deal. However, a real estate agency or public authority likely to perform the same kinds of transactions multiple times with the same parties might find it beneficial to use blockchain. Even if a process is repetitive and involves multiple parties, a company does not always need to distribute the records and provide access to some or all of the data coming from the involved parties in the ledger, which means that traditional databases are recommended for storing such transactions. In addition, there is not always a need to use blockchain if the participants are known, trusted, and not associated with any conflict of interest.

The next issue that needs to be addressed concerns the question of whether there exists a need for a trusted third party to perform a transaction. Unlike Pedersen et al. (2019), the present study holds that blockchain technology can be used even if a trusted third party is involved in the transaction. This trusted third party can serve as a node in the network or act as a central authority that controls the ledger. This is the case in hybrid blockchain systems. Otherwise, private or federated blockchains are used. Most of the examined industry use cases have been implemented using these types of blockchains. If intermediaries are not needed, the transaction speed is not a concern, and data immutability is desired, then public blockchain systems can be used.

Figure 6 *Blockchain Suitability Decision Tree*



1.7 Conclusion

Blockchain technology has been the subject of considerable interest among researchers and practitioners in recent years. Yet, while the number of publications in this area is growing exponentially, there remain a lot of misunderstandings and confusion concerning the functionality and use of this technology because the material and information available are too technical and complicated for many to comprehend. In light of this, the present chapter has explained the fundamentals of blockchain through a simple and comprehensible example as well as the use of non-technical language.

An intensive review of the prior literature, desk research, and an analysis of recent industrial products and pilots has led to the development of a list of certain key applications of blockchain in the financial, healthcare, energy, and supply chain sectors. Although the potential uses of blockchains are extensive and have the ability to both revolutionize various corporate processes and disrupt existing sectors such as the financial sector, it appears that they have been overhyped. The lack of sufficient knowledge of the technology and the high level of hype surrounding it have resulted in the creation of various applications for which blockchain is not really appropriate. To help address this situation, the present study developed a decision tree that corporate executives can use to assess the suitability of blockchain for certain applications. Moreover, the conceptual results of the chapter can be used as guidelines for future research and industry applications. It is believed that there exists a need for further quantitative studies to evaluate the impacts of blockchain in different sectors as well as to measure its effects on the productivity and efficiency of firms.

Chapter 2: Distributed Ledger Technology as a Catalyst for Open Innovation Adoption Among Small- and Medium-Sized Enterprises

Abstract

Open innovation and DLT are both founded on the underlying principles of distribution and sharing. While open innovation is concerned with sharing knowledge in order to improve innovation processes and performance, DLT is utilized to enhance efficiency, reduce costs, and ensure immutability, traceability, security, and transparency. This chapter investigates the barriers to open innovation currently faced by small- and medium-sized enterprises (SMEs) that the adoption of DLT could solve. To do so, semi-structured interviews were conducted with 11 experts from Spain, Germany, Australia, and India.

The findings of the exploratory investigation indicate that DLT can aid in the resolution of a number of issues associated with open innovation adoption that are not related to the company itself. Rather, the issues in question are associated with external parties and include problems with contracts, financing, lack of trust, raw materials, lack of information, domestic and international market limitations, intellectual property (IP) rights, governmental regulations, and bureaucracy. DLT can also be used to tackle some internal challenges associated with the adoption of open innovation, such as insufficient funding, outdated organizational systems, and lack of trust. When it comes to the difficulties associated with the management of open innovation, the identified external barriers are frequently caused by customers' demands, while the internal barriers are commonly caused by the organizational culture or human nature, which cannot be addressed using DLT. Finally, when integrating DLT, SMEs may encounter additional challenges such as implementation issues, lengthy transition processes, high initial costs, and staffing issues.

2.1 Introduction

Open innovation, which is defined as “a distributed innovation process based on purposely managed knowledge flows across organizational boundaries, using pecuniary and nonpecuniary mechanisms in line with the organization’s business model” (Chesbrough & Bogers, 2014, p. 1), has been studied extensively in recent years. In contrast, DLT, “a novel and fast-evolving approach to recording and sharing data across multiple data stores (ledgers)” (Krause et al., 2017, p. 13), has only recently caught the attention of researchers. Open innovation and DLT share certain common goals in that they both promote the concept of sharing and distribution, that is, the decentralization of authority and control.

Prior studies have confirmed the importance and potential benefits of open innovation in relation to SMEs, although they have also identified several limitations and barriers that prevent its adoption (Parida et al., 2012; Spithoven et al., 2013; Taghizadeh et al., 2020; Van de Vrande et al., 2009). These barriers include a lack of trust in partners, IP issues, and limited financial resources (Bigliardi & Galati, 2016; Laursen & Salter, 2014; Lee et al., 2010; Rahman & Ramos, 2010). However, a thorough investigation of the potential of DLT to remove the barriers facing SMEs when it comes to open innovation has not yet been performed. This constitutes an important gap in the literature, as DLT allows for the recording, sharing, and synchronization of both transactions and data in an immutable, secure, transparent, and traceable manner across a distributed network involving different participants (Treiblmaier, 2019). Thus, it eliminates the need for third-party intermediaries to ensure trust, the validation of transactions, and the transfer of value. As open innovation relies heavily on knowledge sharing, it could benefit substantially from a technology such as DLT, which facilitates information sharing and also secures information transfer using cryptography. DLT also serves to automate the auditing of contracts, which can be used to validate the accounts and financial information issued by an economic entity. This automation could potentially reduce or even eliminate the need for litigation and courts. Furthermore, the transfer of value can be facilitated using smart contracts, while network members can be incentivized through a P2P remuneration system. Based on a narrative literature review, this chapter initially classifies the barriers to open innovation currently facing SMEs into two categories: search barriers (which are split into internal and external search barriers) and management barriers. Semi-structured expert interviews are used to identify the obstacles to open innovation implementation facing SMEs that could potentially be solved or improved by DLT.

To the best of the present author's knowledge, this is the first study to systematically investigate the potential of DLT to solve SMEs' problems pertaining to the adoption of open innovation. The remainder of the chapter is structured as follows. The findings of the literature review are presented in Section 2.2, while Section 2.3 outlines the research methodology, including providing a brief description of the data. In Section 2.4, the results are presented. Finally, Section 2.5 concludes the study and highlights both the limitations of the present research and possible avenues for future research.

2.2 Literature Review

2.2.1 Barriers to Open Innovation Facing Small- and Medium-Sized Enterprises

Spithoven et al. (2013) investigated how SMEs' use of open innovation differs from that of large companies as well as the advantages they reap from it. Their findings show that SMEs, unlike large companies, are more successful at using multiple open innovation practices at the same time. In addition, the authors found that SMEs are more dependent on open innovation than big companies, although both types of enterprises positively benefit from open innovation in terms of the introduction of new products and services to the market (Spithoven et al., 2013). Studies by Lichtenthaler and Ernst (2006), Sağ et al. (2016), and Van de Vrande et al. (2009) revealed that SMEs face substantial barriers in relation to the adoption of open innovation when compared with the situation facing big companies. Piatier (1984) divided the barriers to innovation into two categories: internal (e.g., resource availability, employee resistance) and external (e.g., supply, demand, and environment) barriers. Later, Rahman (2013) adopted the same categories and added the barriers that occur either before or during the open innovation adoption phase. This chapter combines Rahman's (2013) findings with the findings of other researchers to reveal a broader picture of the situation. More specifically, the barriers to the adoption of open innovation are divided into two phases, namely the pre-adoption phase and the post-adoption phase.

Asad et al. (2020) conducted a quantitative study in Pakistan in order to examine the effects of external knowledge, internal innovation, and knowledge management on firms' open innovation performance. Their findings indicated the advancement of open innovation in SMEs through both external knowledge incorporation and the maximization of internal innovation, which also promote knowledge management practices. In turn, knowledge management, which is a key indicator of SMEs' performance, can promote open innovation through the positive roles of external knowledge incorporation and the maximization of internal innovation (Van de Vrande et al., 2009). The authors illustrate how the main managerial challenges facing SMEs when engaging in open innovation practices are related to organizational and cultural issues (Van de Vrande et al., 2009). Administrative issues, financing, and knowledge transfer represent other managerial problems in this regard.

Based on the prior literature, this study divides the barriers to innovation facing SMEs into the pre-adoption phase barriers and the post-adoption phase barriers. Table 9 and Table *10* categorize the literature regarding the barriers during the pre-adoption phase and list numerous problems that SMEs encounter during the internal and external search for knowledge, ideas, and innovation. Rahman (2013) suggested that the external problems in this regard are related to supply, demand, and company environment/culture, while the internal barriers are related to resources, company culture/human nature, and the organizational system. It should be noted that some barriers are not specific to open innovation; rather, they are generic and so apply to any innovation process. The aim of this chapter is to develop a high-level and holistic understanding of the barriers to open innovation, including specific barriers as not-invented-here (NIH) syndrome that experts believe can be improved through the use of technology such as DLT. The pre-adoption phase is further divided into external factor and internal factors in accordance with Piatier's (1984) and Rahman's (2013) classifications of the barriers facing SMEs.

Table 9 *Pre-Adoption Phase: External Barriers to Open Innovation*

External		
Supply	**Demand**	**Environment/Culture**
Lack of information	Customer needs	Government regulation/bureaucracy
Lack of technical knowledge	Customers' perception of the risk of innovation	Intellectual property rights
Lack of administrative knowledge	Domestic and international market limitations	Free-riding behavior
Lack of legal knowledge	Customer demands that are too specific	Policy actions
Insufficient financing		
Problems with contracts		
Lack of trust		

Source: Hadjimanolis (1999), Janesvski et al. (2015), Nerone et al. (2014), Oduro (2019), Rahman (2013), Rahman and Ramos (2010), and Van de Vrande et al. (2009).

Table 10 *Pre-Adoption Phase: Internal Barriers to Open Innovation*

Internal		
Resource	**Culture/Human Nature**	**System**
Lack of funds/capital	Attitude of top management toward risk	Outdated organizational system
Technical expertise (scientific/legal/ technological)	Not-invented-here syndrome	Outdated technological system
Lack of human resources	Employee resistance to innovation	Undefined business model
	High turnover/lack of commitment	

Source: Hadjimanolis (1999), Janesvski et al. (2015), Nerone et al. (2014), Oduro (2019), Rahman (2013), Rahman and Ramos (2010), and Van de Vrande et al. (2009).

Table 11 summarizes the literature concerning the challenges facing SMEs during the post-adoption phase. These problems can be further divided into network and collaboration barriers as well as administration and control barriers. Some such barriers are also not specific to open innovation adoption and are instead related to the firm size and lack of capital/resources. However, these problems still impede SMEs in terms of open innovation, which is why they are classified as barriers to open innovation.

Table 11 *Post-Adoption Phase: Barriers to Open Innovation*

Post-Adoption Phase	
Network and Collaboration	**Administration and Control**
Management of networks	Management of employees' ideas
Partners do not meet expectations	Time management
Insufficient trust	Adoption problems
Limited contact network	Unstructured innovation process
Cognitive, organizational, cultural, and institutional differences	Managers' perceptions of open innovation
Limited ability and insufficient resources to maintain the network	Suboptimal use of employees' talent, knowledge, and qualities

Source: Christensen et al. (2005) and Termeer and Nooteboom (2014).

2.2.2 Distributed Ledger Technology and Open Innovation

As discussed in Chapter 1, blockchain represents a type of DLT in which transitions are stored as timestamped blocks that are linked together to form a chain by cryptographic hashes in order to ensure the security, transparency, privacy, robustness, integrity, and authentication of data. Open innovation is concerned with sharing and distributing knowledge, which both fosters cooperation and leverages distributed innovation processes. By its very nature, innovation is related to the creation of new ideas, and similar to DLT, it is rooted in the principles of decentralization and the distribution of data. Distributing data in a secure and immutable manner involves eliminating numerous problems currently facing open innovation. This chapter uses the terms “DLT” and “blockchain” interchangeably while acknowledging that the former also includes data structures that do not necessarily have a chain-like structure (e.g., DAG).

Narayan and Tidström (2019) proposed blockchain technology to have the ability to harness the open innovation market through decentralization. Indeed, companies in transition can use blockchain-powered open innovation to test new ideas and allow technology to shape the development process (Seulliet, 2016; Treiblmaier & Sillaber, 2020). The distributed nature of DLT enables it to connect multiple stakeholders in a trusted and reliable way, thereby allowing for more robust IP protection, smart contract deployment, privacy and data protection, and regulatory compliance (see Chapter 4). Seulliet (2016) stated that collaboration or competition between large and small firms could lead to trust issues, which may result in demotivation and ineffectiveness in relation to open innovation. In this regard, DLT provides “a technical solution (cryptographic consensus) to the problem of cooperation in joint or group production at scale” (Davidson et al., 2016, p. 13) through the embedment of a trustless system that is governed by computer coding. Thus, DLT’s deterministic algorithms enable firms to transfer value without the need to trust specific intermediaries.

Another problem here concerns the fair sharing of added value (Seulliet, 2016). When it comes to cooperation at the individual level, this problem frequently lies in individuals’ competitive nature. The lack of a system that allows for the recognition, traceability, and capitalization of both ideas and knowledge can demotivate individuals’ drive to innovate. The use of DLT during the open innovation process will, therefore, not only provide a secure way to record ideas from their inception, but also enable the introduction of a decentralized incentive system that should encourage innovators to further develop their ideas and allow them to be appreciated, acknowledged, and remunerated for their work (Rivière, 2018).

2.2.3 Distributed Ledger Technology and Small- and Medium-Sized Enterprises

The adoption of DLT by SMEs mainly affects two key types of operational costs, namely the cost of verification and the cost of networking (Catalini & Gans, 2020). Through the use of a distributed technology, transactions can be verified by all the parties involved in the network without the need for intermediaries or trusted third parties. From an economic perspective, lower transaction costs, a higher level of trust, and more efficient economic coordination all increase the marginal efficiency of investment and exchange (North, 1990). Moreover, from a neoclassical perspective, the adoption of DLT provides marginal productivity gains through either increasing efficiencies or decreasing production process inefficiencies. In accordance with this, Walport (2015) and Böhme et al. (2015) suggested that DLT could improve firms' and governments' productivity. More specifically, DLT can decrease the financial industry's economic costs by reducing the back-office costs that result from the manual reconciliation of conflicting trade data (Priem, 2020). Wang et al. (2019) illustrated the application of blockchain technology and smart contracts in reshaping the traditional credit system. They suggested a blockchain-based credit system without collateral in which SMEs associated with low risk and high quality can easily display their credibility and risk category. Their findings also showed that integrating DLT into hometown investment trust (HIT) funds can lead to more transparency as well as to a reduction in the associate risk, which results in a higher share of investments (Wang et al., 2019).

Rivière (2018) found that DLT can also serve to overcome some of the limitations of open innovation, including trust issues and lack of coordination. Tackling these issues could potentially solve both the free-rider problem and the tragedy of the commons, which are frequently associated with open innovation. In terms of the adoption of DLT by SMEs, cost-reduction incentives and increased total factor productivity will eventually encourage SMEs to adopt DLT. Yet, a key question remains: Which barriers to open innovation can DLT overcome? In other words, how can DLT assist in improving the open innovation process? Although some studies have investigated the barriers to open innovation that SMEs currently face (Spithoven et al., 2013) and some related solutions have been proposed (Sağ et al., 2016), prior studies have not investigated in detail the consequences of DLT uptake by SMEs or how it can facilitate the adoption of open innovation.

2.3 Methodology

In the present study, the expert opinion method is used to explore the potential role of DLT in helping SMEs to tackle some of the problems they face when implementing open innovation. In cases where quantitative methods and statistical techniques are not applicable due to a lack of historical data, the expert opinion method can help researchers to build a conceptual framework and better understand the underlying solutions and technologies. As experts' judgments play a vital role in planning, resource allocation, and decision making, online interviews were conducted (Aengenheyster & Masoliver, 2017) with active members of DLT and open innovation communities. All the interviews were recorded as audio files, and the transcripts of these files were thoroughly analyzed.

All the respondents in this study were given a semi-structured questionnaire that contained multiple open- and closed-ended questions. The questionnaire also contained demographic questions, filter questions, and multiple-choice questions. Moreover, the respondents were given a list of barriers that SMEs potentially face when adopting open innovation, and they were asked to choose among the answers "Yes," "No," or "To some extent" when assessing whether a specific problem could be improved by DLT. In this study, the latter option was evaluated as being slightly positive. The respondents were then asked to elaborate on their initial assessment with a short explanation. All the listed problems were grouped into either management barriers or search barriers.

The semi-structured interviews were conducted in July 2020 with experts on both open innovation and DLT. A total of 53 experts who were identified from professional society databases, citations in books and papers, and academic department lists were contacted via email and LinkedIn. Initial responses were received from 19 experts. Among those 19 respondents, five ultimately declined to participate in the study because they were insufficiently familiar with the technology, while three were unavailable for the interviews. Ultimately, 11 experts from universities, private companies, associations, and organizations located in Spain, Germany, Australia, and India, all of whom had sufficient previous experience with open innovation and DLT, participated in the interviews. The interviews were conducted online on a face-to-face basis and recorded. The anonymity of the respondents was guaranteed. Much effort was dedicated to avoiding bias due to the experts' background, communication between the experts, and communication between the interviewer and the experts. In addition, each respondent was selected based on their professional experience and comprehensive understanding of open innovation and DLT. As Table 12 shows, all the respondents were men, with 46 percent being aged between 41 and 50 years and 31 percent between 31 and 40 years. A master's degree was held by 37 percent of the respondents, a PhD by 36 percent, and a bachelor's degree by 27 percent. Most of the respondents had more than 10 years of experience in the computing and technology, finance and banking, biotechnology, art, and education sectors.

Table 12 *Description of the Data*

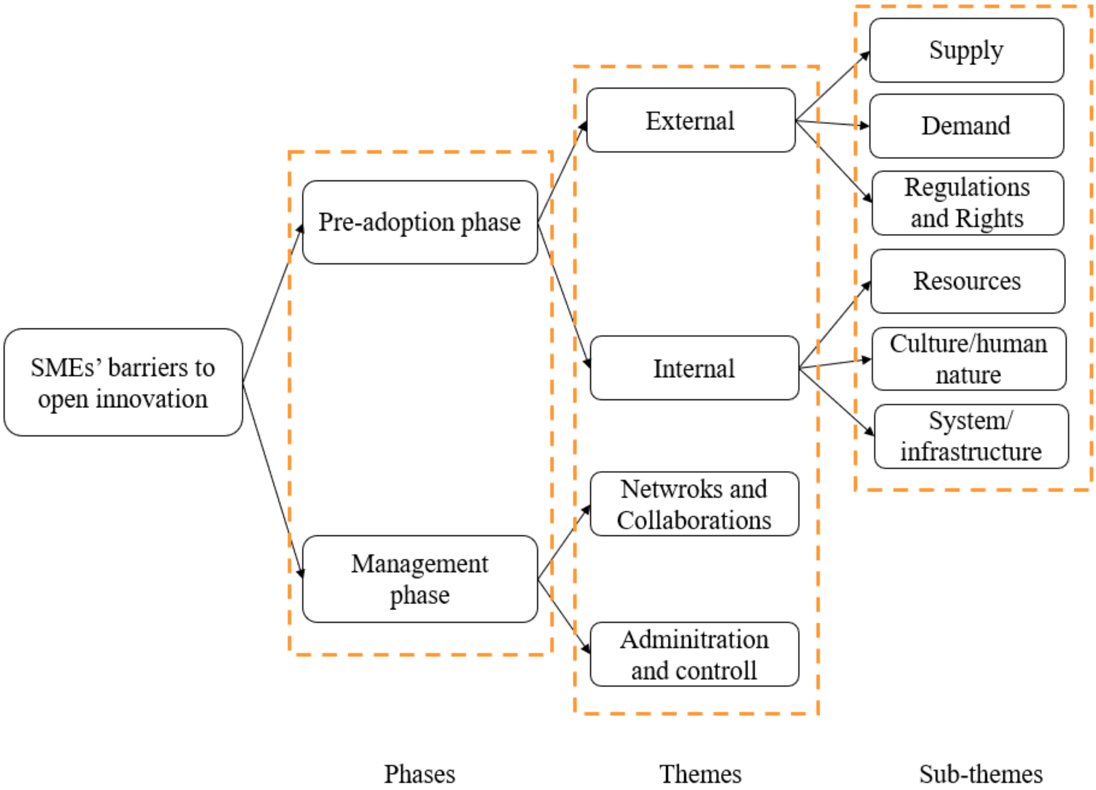
No.	Age	Education	Occupation	Specialty	Experience
1	20–30 years	Bachelor's degree	Blockchain lead	Blockchain	3 years
2	31–40 years	Ph.D.	Research and development manager	Open innovation and blockchain	10 years
3	41–50 years	Master's degree	Media specialist/block chain advisor	Film editing and concept design	20 years
4	31–40 years	Bachelor's degree	Consultant	Finance and blockchain	>20 years
5	41–50 years	Master's degree	Professor	Strategy and organizational behavior	>20 years
6	31–40 years	Ph.D.	Researcher	Open innovation	>11 years
7	41–50 years	Ph.D.	Blockchain engineer	Blockchain architect and developer	>20 years
8	31–40 years	Ph.D.	Research associate	Digital transformation and open innovation	>2 years
9	31–40 years	Master's degree	Entrepreneur	Blockchain/banking and finance	>12 years
10	20–30 years	Bachelor's degree	Business and information technology consultant	Blockchain	>2 years
11	41–50 years	Master's degree	Entrepreneur	Blockchain/biotech	>20 years

To select the respondents, a detailed set of selection criteria were followed, which included four significant steps. First, the respondents were selected based on their interest in the potential outcomes of the study. Second, the respondents were selected because they demonstrated advanced knowledge of the subject. Third, the respondents were selected because they were directly involved in the main component of the study. Finally, the respondents were selected because they had experience in the blockchain industry. Due to the lack of published literature on this topic, the present chapter has outlined the possible themes and sub-themes in order to facilitate the evaluation of open innovation and DLT. Furthermore, the interviewees were given complete freedom to respond during the interview sessions. The collected data were analyzed by means of a content analysis based on the verbatim statements made by the interviewees. The following sections present the resulting clusters and also include some verbatim statements for illustrative purposes. The respondents' responses were synthesized into comments and then broken down into themes and sub-themes. Subsequently, all the responses were analyzed to develop a framework based on the respondents' comments as well as to condense the gathered information concerning open innovation and DLT (Saunders et al., 2019).

2.4 Results

All the respondents (R) agreed that DLT has the potential to boost open innovation within SMEs. In general, they believed that trust plays an important role when it comes to sharing information, ideas, and new technologies. As R10 pointed out, "SMEs primarily engage in open innovation for market-related motives, including meeting customer demands, keeping up with increased global competition, or sharing financial resources for developing new technologies, and trust is the key issue." In addition, R11 argued that "DLT basically changes the rules of engagement in complex scenarios." DLT not only facilitates the securing and certifying information, but also alters the role of connections. Such technology changes the functions of intermediaries as well as the way in which information is provided, received, and verified. Thus, anything that includes "multiple parties, especially if those parties are working in multi-disciplinary projects or different areas of expertise, can benefit from having a trustless ledger that does not depend on a central authority" (R4). The distinctive features of DLT, such as traceability, enable "identifying where information comes from" (R3) and ensure "tracking and rewarding of contributions" (R2), which should "make firms less reluctant when it comes to collaboration and entering relationships with other firms or individuals" (R1). Moreover, R5 provided the example of blockchain projects on the open-source platform GitHub as evidence that DLT can enhance open innovation.

Figure 7 ***Thematic Network Model***



Based on the experts' responses and the content analysis, the structural thematic network shown in **Error! Reference source not found.** was developed. As suggested in the literature, SMEs' barriers to open innovation were divided into two phases: the pre-adoption phase and the post-adoption phase. The two main themes within the pre-adoption phase were identified as external and internal, while the two main themes identified in the post-adoption phase were (i) network and collaboration and (ii) administration and control. Moreover, seven sub-themes (supply, demand, regulations and rights, resources, culture/human nature, environment/culture, and system/infrastructure) emerged within the external and internal themes.

2.4.1 Pre-Adoption Phase

2.4.1.1 Theme 1: External barriers

An effective way for SMEs to benefit from open innovation during the pre-adoption phase involves integrating external innovation into the internal innovation process. Companies are constantly involved in numerous relationships with suppliers, customers, governments, individuals, and other organizations, and they can use those partners to enrich their own innovation portfolio. In addition, SMEs may face problems concerning supply (i.e., companies with whom they collaborate), demand (i.e., consumers for whom they want to innovate), and existing regulations.

Supply. The barriers related to supply that SMEs face during the pre-adoption phase are listed in Table 13. The majority of the experts believed that problems with contracts, financing, lack of trust, and lack of information could be improved through the use of DLT, which can create a shared understanding regarding the underlying data and processes. By contrast, a supplier's lack of administrative, legal, or technological knowledge is less likely to be resolved with DLT.

In general, SMEs are reluctant to do business with parties who have no transparent and trustworthy trading record. One pitfall they experience in their relationships with externals is contractual problems. However, two experts pointed out that managing contracts and transactional protocols is much easier with DLT (R4 and R11). Furthermore, smart contracts help with "operations, risk management, transaction block clearance, and automatic feedback" (R10). In addition, they "offer SMEs the chance to do business with untrusted parties" (R8). Through using smart contracts, SMEs can establish the conditions necessary for the execution of business operations, while the contracts can also autonomously execute value transactions if the specified requirements are met. A total of eight experts believed that with the application of DLT, the management of finances with suppliers will be facilitated for SMEs, as pending transactional issues can be resolved rapidly through "smart contracts and cryptocurrencies" (R1) without any "interventions of a middlemen" (R2). Moreover, as payment can be initiated at a given point of time that "strictly follows the transactional protocol, DLT also safeguards the trust issue" (R11).

Table 13 *Supply Barriers*

Barrier	Yes	No	To Some Extent
Problems with contracts	10	1	0
Financing	8	1	2
Lack of trust	8	1	2
Lack of information	7	5	0
Lack of administrative knowledge	4	6	1
Limited legal knowledge	2	8	1
Lack of technological knowledge	1	10	0

Seven experts believed that DLT can help with sharing information about their suppliers. Through using DLTs, companies can build a "transparent network" (R1) in which they can share information among each another. The use of DLT will also allow supply partners to “access the same source of information” (R7).

Demand. The market structure and pull technology derived from demand are explained by demand barriers, which are also known as market barriers (Segarra-Blasco et al., 2008). Among the demand barriers that SMEs face are domestic and international market limitations, customers’ perception of risk, customers’ needs, and demands that are too specific and challenge them to find solutions that match the problems (see Table 14). Most of the experts believed that the use of DLT would not be of much help in this regard. In fact, only a few experts believed that domestic and international market limitations (the barriers SMEs face while engaging in open innovation in local or international markets) can be improved using DLT. The experts mentioned that the main advantage of a P2P network is the fact that it is not limited to regional and local markets. They noted that “it is possible to break the regional barriers” (R10) because “jurisdiction plays a vital role in limiting the transactions” (R10). Furthermore, they also noted that DLT can serve to open up new opportunities for SMEs in a “global market without limitations” (R7).

Table 14 *Demand Barriers*

Barrier	Yes	No	To Some Extent
Domestic and international market limitations	5	3	3
Customers’ perception of risk	1	9	1
Customers’ needs	0	9	2
Customers’ demands are too specific	0	10	1

Regulations and rights. During the pre-adoption phase, SMEs occasionally face barriers related to IP rights, governmental regulations (e.g., bureaucracy), free-riding behavior on the partners’ side, and policy actions (see Table 15). One of the main fears that SMEs have when engaging in open innovation is losing ownership of their technologies, know-how, and inventions. The costs and inefficiencies associated with the existing patent system discourage SMEs and those in academia from protecting their ideas, which limits collaboration and open innovation. In this respect, DLT is believed to “lower IP costs by eliminating intermediaries” (R8), rendering “it much simpler to record the evidence of the ownership in a time-stamped manner” (R1). This makes the process more transparent and assists in “tracking and monetizing IP” (R10) as well as in “generating contracts” (R5) that can reduce disputes and infringements once executed. SMEs can protect their IP rights during the open innovation process by storing data on distributed ledgers. As blockchain is immutable, it provides a history of ownership and creation that cannot be altered. This is critical for an IP owner, as it precludes another person from disputing a claim to ownership. In the words of R1, "If someone else brings up the same idea, the original creator can use the evidence on the blockchain to sue them." The use of smart contracts on top of the blockchain structure will enable IP owners to define their own roles in terms of granting licenses and obtaining royalties. Using DLT, a token can be generated for each idea. This token and its metadata can then be sent to an IP protection office. Once the IP office validates the novelty of the idea, the owner can decide whether or not to generate other tokens (exclusive or non-exclusive), which will enable other people to use the idea. In addition, the owner could sell or transfer the token to someone else. The token will basically represent the ownership of the IP. This idea is not as futuristic as it may initially sound, as blockchain has already changed IP rights management in the fields of art, music, and sports. Indeed, non-fungible tokens (NFTs) were featured in the headlines of many news articles in 2021. Moreover, the European Union Intellectual Property Office (EUIPO) has launched a forum to assess the usability of blockchain in relation to fighting counterfeiting (Soriano, 2019).

Furthermore, DLT provides an "alternative approach to the existing regulatory system whereby the technology can promote openness and increase transparency between states, citizens, and businesses" (R10). Using DLT, it will be easier for governments to "share information" (R3), "audit the activities of companies" (R1), "verify transactions" (R4), and "detect fraud and crime" (R2). As discussed above, in the case of IP management, if all countries decide to implement a shared blockchain-based database, then the whole process of IP protection will become much simpler, more efficient, and cheaper. Eventually, DLT could be used as a tool for digitalizing the entire process of IP protection. Yet, for that to happen, laws and regulations must accompany the technology, and if not during the same phase, they should at least follow technological advancements as DLT can help to build trust, "enhance transparency and participation" (R6), "reduce strict regulations" (R9), and "cut down business bureaucracy" (R2).

Table 15 *Regulations and Rights Barriers*

Barrier	Yes	No	To Some Extent
Intellectual property rights	9	1	1
Government regulation/bureaucracy	7	1	3
Free-riding behavior	2	2	7
Policy actions	1	5	5

2.4.1.2 Theme 2: Internal barriers

When compared with large firms, SMEs face more internal barriers to the adoption of open innovation due to commonly being associated with insufficient internal resources and expertise. Additional bottlenecks here might include the perceptions of managers regarding open innovation, the lack of skilled employees, and the resistance of employees to innovation. These barriers have been classified into three groups: resources, culture/human nature, and system/infrastructure (see Table 16).

Resources. SMEs require resources to dedicate to open innovation. Some internal resource-related challenges facing most SMEs are a lack of funding, a lack of human resources (including time), and limited technical expertise (i.e., scientific, legal, or technological knowledge). Access to financing is another common problem facing SMEs. Therefore, most of the experts believed that DLT offers new opportunities for SMEs to raise funding for both internal and external activities. As R11 noted, an "ICO using DLT has offered many entrepreneurs and SMEs the chance to raise the capital needed to fund their projects." Indeed, ICOs provide SMEs with a "quick and less regulated financing mechanism" (R3). Several experts also believed that open innovation could offer a solution to lack of funding: "Collaboration with other companies can help SMEs to save costs and have more resources to dedicate to open innovation [...] DLT can be used as the technology base for collaboration" (R8). However, on average, the experts were skeptical regarding the potential of DLT to eliminate the barriers related to limited technical knowledge.

Table 16 *Resource Barriers*

Barrier	Yes	No	To Some Extent
Lack of funds/capital	7	2	2
Lack of human resources	4	4	3
Limited technical expertise (scientific/legal/technological) and knowledge	1	8	2

Culture/human nature. The extent to which the dominant culture is open to change determines an organization's ability to successfully participate in open innovation. In an environment characterized by fluctuating demand, both flexibility and openness are essential. The experts' assessments of the attitude of top management toward risk, high turnover/lack of commitment, employees' resistance to innovation, and NIH syndrome are listed in Table 17. Some experts believed that the use of DLT in relation to open innovation processes would alter the attitude of top management toward risk, as the technology would help them to better manage certain aspects of innovation because "recording ideas in an immutable ledger ensures the authenticity" (R11) and "data security" (R2). Other experts believed that these are internal problems associated with adopting open innovation that DLT is unlikely to solve: "Managerial, social, and psychological techniques need to be used to handle these issues within companies" (R9).

Table 17 *Culture and Human Nature Barriers*

Barrier	Yes	No	To Some Extent
Attitude of top management to risk	3	7	1
High turnover/lack of commitment	3	8	0
Employees' resistance to innovation	2	7	2
Not-invented-here syndrome	0	10	1

System/infrastructure. Occasionally, the internal infrastructure also creates challenges pertaining to the adoption of open innovation by SMEs. The important barriers related to internal systems include outdated organizational systems, outdated technological systems, and undefined business models (see Table 18). Most of the experts believed that decentralized systems could change existing organizational structures as well as the way that organizations work today. Companies have always been centralized entities in which power is concentrated in the hands of a few individuals, although this situation does not necessarily have to remain the same: "Using DLT, organizations can move from traditional centralized or hierarchical systems to a more decentralized system" (R10). In light of their overall flexibility, SMEs might be among the first to begin this transition. Some experts also believed that other operational activities within organizations could be improved using DLT, such as "accounting and financial systems" (R1), the "human resources selection process" (R11), and "data storage and security" (R3). All of these transformations might change the way in which organizations approach open innovation. Some SMEs already benefit from this level of openness, but "to further grow, they need to become even more open" (R6). Such a shift in mindset necessitates "transparent leaders who believe in empowering others within the organization" (R3).

Table 18 *System and Infrastructure Barriers*

Barrier	Yes	No	To Some Extent
Outdated organizational systems	7	1	3
Outdated technological systems	3	4	4
Undefined business models	0	9	2

2.4.2 Post-Adoption Phase

2.4.2.1 Theme 3: Networks and collaborations

Managing networks and establishing collaborations are among the most demanding tasks currently facing SMEs. Moreover, they are associated with numerous barriers, as shown in Table 19. All the experts believed that trust issues could be solved or alleviated using DLT: "Using smart contracts, DLT can run without any human interaction, thereby making a transaction trust-free" (R5). DLT also has the potential to strengthen trust by removing the need for intermediaries, reducing running costs, and enhancing the efficacy of open innovation.

When open innovation emerges from strategic alliances, DLT can be used to increase the trust, security, transparency, and traceability of the data shared across a business network (Lumineau et al., 2021). As described in Chapter 1, DLT involves shared ledgers where many people have joint control over shared information—a characteristic that renders them appropriate for circumstances that require trust and information sharing among various agents. It should also be noted that in strategic alliances that do not require a network of multiple agents, the use of technology might not help (as explained in the decision tree presented in Chapter 1). Several examples of successful collaborative projects involving blockchain were listed in relation to the financial, supply chain, healthcare, and energy sectors in Chapter 1.

However, this applicability does not equally hold for other management activities. On average, the experts believed that DLT cannot help much in cases where limited ability and insufficient resources are available to maintain the network; where partners do not meet expectations; where cognitive, organizational, cultural, and institutional differences exist; and where limited contact networks are available. In sum, the management of networks does not benefit much from the use of DLT. Therefore, network partners should consider the "terms and conditions that need to be executed" (R2) prior to engaging in open innovation.

Table 19 *Networks and Collaborations Barriers*

Barrier	Yes	No	To Some Extent
Trust	9	0	2
Limited ability and insufficient resources to maintain the network	4	4	3
Partners do not meet expectations	3	4	4
Cognitive, organizational, cultural, and institutional differences	3	5	3
Limited contact network	3	6	2
Management of networks	0	8	3

2.4.2.2 Theme 4: Administration and control

The literature review identified several barriers that SMEs may face when it comes to managing open innovation processes (see Table 20). Most experts were skeptical regarding whether such barriers could be overcome using blockchain or another DLT: “Management of open innovation needs managerial skills rather than a technology” (R2). Moreover, while DLT can help to “digitize processes and improve the efficiency of companies” (R6), it is a technology that by itself “cannot change perception, skills, or knowledge” (R10), nor can it change “abilities, qualities” (R11) or the “soft skills needed to manage open innovation” (R6). Although it is believed that the use of blockchain can render the management process more efficient, change an organization’s structure, and reduce friction within existing processes, it is unlikely to strongly affect managerial skills. Aside from technological tools, managers need to have knowledge, experience, and specific qualities and soft skills. However, some experts believed that DLT could help to manage employees’ ideas. For example, “managers can implement reward systems” (R6) so as to incentivize their employees to come up with new ideas. They can also “use DLT to gather, store, and select ideas” (R7) in a “decentralized, transparent, immutable, and secure way” (R8). An organization could develop a blockchain-based co-creation platform in which employees’ ideas are encrypted, time-stamped, and recorded in a tamper-proof manner. Then, for the selected projects, equity tokens could be generated to give partial ownership or a dividend to the creator of the relevant idea (Kondrateva et al., 2020). This way, not only will the employees be recognized for their contributions, they will also be incentivized to come up with new ideas in the future. The same analogy can be applied to instances in which companies would like to engage other stakeholders as customers and suppliers during the innovation process. A reward and recognition system could encourage external stakeholders to contribute to the innovation process, which will enable the company to gain access to new ideas.

Table 20 *Administration and Control Barriers*

Barrier	Yes	No	To Some Extent
Management of employees' ideas	4	5	2
Suboptimal use of employees' talent, knowledge, qualities, and initiatives	3	5	3
Managers' perceptions of open innovation	3	7	1
Less structured or professionalized innovation processes	2	7	2
Time management	1	6	4
Adoption problems	1	6	4

2.4.3 Additional Challenges

Although the use of DLT might support SMEs in many ways, the experts also warned that such technology could generate new problems. Difficulties in terms of systems integration, transition and setup costs, talent acquisition, and legal concerns are among the common problems that SMEs might encounter here.

Integration issues. In most cases, the introduction of a new system is a resource-intensive process. As R8 pointed out, "The integration of data and information from an existing system to a new system is costly and complicated." Indeed, it takes time and money to transfer a company's previous transactions to a new system. In addition, a distributed ledger is not a standalone system; rather, it serves as an underlying information source upon which applications that make use of shared data are built. The implementation of a distributed system is only useful in cases where multiple parties are involved (as discussed in Chapter 1), although it is exactly this coordination that frequently proves to be an issue in and of itself. In this regard, the use of an open-source platform such as GitHub could facilitate the introduction of DLT in order to boost open innovation processes, although it would not solve problems related to the operation of such a system, which might be caused by the conflicting interests of the parties involved.

Transition and setup costs. The development of a distributed and decentralized system requires substantial investment. SMEs are usually restricted in terms of their resources and, therefore, need to prioritize capital allocation. It should be noted here that the transition costs are usually not solely technology development costs, but also include the expenses associated with staff training. In this respect, the implementation of DLT also requires a shift in an organization's mindset, which might include the reallocation of organizational roles as well as the redesign of functional responsibilities. The total costs of such efforts might vary significantly between companies, although they are currently only poorly understood.

Attracting and retaining talent. To successfully implement DLT, SMEs need qualified personnel who understand the nuts and bolts of this fast-moving technology. As there is currently a shortage of talent in the market, it is especially difficult for SMEs to recruit qualified employees at a reasonable cost. In fact, the majority of the available labor force tend to join large companies that can afford bigger information technology (IT) infrastructures and are willing to pay higher salaries.

Legal issues. DLT frequently operates across geographical locations, and as jurisdictions differ among countries, it is difficult to come up with contract rules that can be applied to business partners worldwide (as will be discussed further in Chapter 4). Moreover, there is currently a dearth of commonly agreed upon standards and regulations regarding the use of DLT, especially when it comes to identity management, property management, IP rights, and payments. Such disagreement is slowing the development of the technology. Progress in this area is crucial in terms of facilitating trade among business partners that operate in different jurisdictions.

2.5 Conclusions, Limitations, and Further Research

Both open innovation and DLT are novel concepts capable of shaping the way in which organizations work together and share information. Yet, while open innovation has been extensively investigated over the last decade, DLT has only attracted the attention of innovation researchers in recent years. Distributed technologies are associated with various novel features, including data immutability and shared access, which enable increased information transparency and data traceability. Furthermore, such features allow the deployment of program code that is executed automatically following the occurrence of predetermined conditions.

This study targeted researchers and practitioners in order to better understand the importance of DLT to the innovation process within SMEs, investigating the opportunities that DLT offers for SMEs when it comes to overcoming some of the barriers they face in relation to adopting open innovation. The findings, which are based on interviews conducted with 11 domain experts, reveal that several problems can be solved or alleviated using DLT in this context. These problems include external problems associated with contracts, financing, lack of trust, law of raw materials, lack of information, domestic and international market limitations, IP rights, governmental regulations, and bureaucracy. Moreover, the internal challenges that can be solved using DLT include insufficient funding, outdated organizational systems, and lack of trust. However, the introduction of DLT might lead to additional problems, including integration issues, high costs, lack of talent, and unclear legislation.

This chapter represents one of the first research studies to investigate the use of DLT to foster open innovation within SMEs. The goal was to create an exploratory framework that could serve as the basis for future research. Since the findings of this study are based on qualitative interviews conducted with 11 domain experts, the gathered views might not be representative of other industries or geographical locations. Sector-wise, the sample should not be considered representative, as the respondents were recruited from only a few industries, while location-wise, more than 80 percent of the experts were from Spain. These factors may limit the generalizability of the results. Thus, further empirical research is required to validate the present findings and ensure their generalizability. Although this study captured numerous challenges that SMEs might face when engaging in open innovation practices, it failed to consider the post-implementation phase and how DLT could support post-adoption challenges.

To summarize, the framework presented in this chapter constitutes the basis for further research that delves deeper into how DLT can support SMEs with their open innovation processes. In light of the current innovation landscape, which is characterized by rapid changes and the increasing importance of digitalization, this is a topic that is highly relevant to both academia and industry.

Chapter 3: Determinants of Blockchain Acceptance by Spanish Firms

Abstract

Prior studies have found that organizations are influenced by various factors when it comes to the adoption of technology. Several studies have sought to examine the adoption intention of firms and individuals in relation to blockchain technology. Moreover, there have been many qualitative studies concerning the applications and benefits of blockchain technology in different sectors, the findings of which form the conceptual and theoretical framework for studying firms' adoption of blockchain. However, few quantitative studies have been conducted to identify the factors that influence the uptake of technology by firms. To the best of this researcher's knowledge, the present chapter will be the first quantitative study to use the technology–organization–environment framework to study the adoption of blockchain technology by Spanish firms. As such, this chapter will contribute to the theoretical framework as well as to the limited qualitative empirical literature in this area. The chapter aims to generate a comprehensive understanding of the environmental, technological, and organizational factors that impact firms' intention to adopt blockchain.

The results of this chapter show that environmental factors such as competitive pressure and organizational factors such as competence and top management support foster the adoption of blockchain, while technological factors such as relative advantage, complexity, and compatibility are not significant determinants of blockchain adoption by Spanish firms.

3.1 Introduction

Over a decade has now passed since the introduction of the first application of blockchain, namely Bitcoin. In recent years, blockchain has been the subject of major interest from industry, and as discussed in Section 1.5, several applications of DLT in general and blockchain in particular have been identified in various sectors. While Chapters 1 and 2 found that some companies are adopting blockchain technology in an effort to produce innovative solutions and tackle existing inefficiencies in their business processes, many firms are still not confident regarding its adoption.

A review of the literature revealed that organizations are influenced by various factors when it comes to the adoption of technology. There have been a number of qualitative investigations of the adoption of blockchain, the findings of which have formed a theoretical and conceptual framework for better understanding the adoption process (Clohessy & Acton, 2019; Grover et al., 2019; Lian et al., 2020; Woodside et al., 2017). Yet, only a few quantitative studies have examined the impacts of different factors on the uptake of blockchain by firms. Aside from studies concerning Bitcoin and other cryptocurrencies, only a few quantitative studies regarding the adoption of specific applications of blockchain, for example, in relation to the supply chain (Kamble et al., 2019), can be found in the literature. Moreover, none of these prior studies have investigated the subject in a European setting. Among the studies that can be found, all have a different focus, such as the adoption of cryptocurrencies (Knauer & Mann, 2020). Qualitative studies from countries such as Malaysia, Ireland, and India that have been conducted in one context (e.g., a single country) could form the starting point for research in another context (Wong et al., 2020; Karamchandani et al. 2020). However, as each context has its own peculiarities, the findings cannot be generalized. In light of this, it is vital to analyze unique settings from a firm's standpoint (Chandra & Kumar, 2018).

The present chapter intends to add to the quantitative empirical research in this field. To the best of this researcher's knowledge, this will be the first empirical study concerning the adoption of blockchain technology among Spanish firms. Spanish firms were selected because despite the availability of funding and sufficient technological infrastructure, the technology adoption rate in the country has traditionally been low. This chapter aims to generate a comprehensive understanding of the environmental, technological, and organizational factors that impact the acceptance and adoption of blockchain by firm managers. To achieve this, the study will address the following research question: What are the key factors that influence blockchain's adoption among Spanish companies? The aims of the study are: (i) to review the literature on the adoption of blockchain technology, (ii) to identify the technological, organizational, and environmental factors that influence the adoption of blockchain technology, and (iii) to elucidate the general perspective on the part of firm managers regarding blockchain technology.

The technology–organization–environment (TOE) framework was used as the underlying conceptual framework in this study. To enhance credibility and avoid bias during the data collection process, the data were collected from 800 companies in Spain in May 2021 by a professional data collection company called Netquest. Among the 800 observations, 213 respondents with adequate knowledge of blockchain were selected to validate the conceptual model. Partial least squares structural equation modeling (PLS-SEM) was used to test the proposed conceptual framework. The results showed that the only significant variables were top management support, competence, and competitive pressure. This chapter also discusses the managerial implications of the study's findings. Greater knowledge of the important variables will assist managers in developing a better understanding of the perception of blockchain technology adoption within organizations.

The remainder of this chapter is organized as follows. Section 3.2 presents the findings of the literature review. Section 3.3 describes the theoretical background of the technology adoption theories and the TOE framework. Section 3.4 sets out the hypotheses developed to study the model, while Section 3.5 describes the research methodology adopted to conduct the empirical analysis. Section 3.6 discusses the results obtained from the econometric model and then discusses both the findings and their implications. Finally, Section 3.7 explores the limitations of the study and draws conclusions based on the findings.

3.2 Literature Review

A comprehensive review of the literature concerning blockchain adoption that was published between 2016 and 2021 was performed and the identified studies were divided into qualitative and quantitative research (see Appendix 3.1). Most of the prior studies investigating the factors that influence blockchain adoption have been qualitative. These studies are essential in terms of developing theory and generating a better understanding of the phenomenon of interest, although they can only capture the conceptual framework of blockchain implementation. Thus, there exists a need to empirically test the conceptual framework to provide evidence of its applicability. Helliar et al. (2020) studied the diffusion of both permissionless and permissioned blockchains using a case study methodology. Their study provided insights into the causes and constraints with regard to technological dissemination. Lian et al. (2020) conducted semi-structured interviews to identify the factors that affect users' acceptance and usage intention toward blockchain-based smart lockers. Their results showed that safety, convenience, usefulness, and security are important in relation to adoption of blockchain-based smart lockers. However, the conclusions of the study are specific to the given use case and so cannot be said to represent other applications. Clohessy and Acton (2019) used the TOE framework to investigate the factors that impact the adoption of blockchain by Irish companies through an analysis of secondary databases and literature available online. They concluded that blockchain adoption in Ireland is influenced by technology awareness, top management support, and business size. It is also possible to find preliminary exploratory studies featuring small datasets, although only a few such papers have been published in reputable journals (Duy et al., 2018; Jardim et al., 2021; Koens & Poll, 2019).

A number of quantitative studies have sought to identify the factors that impact the acceptance and adoption of blockchain technology. Knauer and Mann (2020) used the integration of the technology acceptance model (TAM) and the diffusion of innovation theory to identify the key factors that influence German consumers when it comes to investing in blockchain technology, although their focus was principally on cryptocurrencies. Queiroz et al. (2020), Alazab et al. (2021), Wamba et al. (2020), and Kamble et al. (2019) all employed different technology adoption theories to investigate the adoption of blockchain in the supply chains among companies in Brazil, Australia, India, and the United States. Li (2020) used the TAM in combination with a few constructs from the theory of reasoned action to identify the key determinants of the adoption of blockchain technology in Hong Kong. These studies were conducted using samples from various countries[22] and, generally, specific sectors such as the supply chain sector. Moreover, the conceptual frameworks and the analyzed factors differed in each of the studies. To complement these prior studies, this chapter uses the TOE framework to examine the environmental, technological, and organizational factors that impact Spanish firms' acceptance of blockchain technology.

[22] India, Germany, Australia, Brazil, the United States, Bangladesh, Nigeria, and Hong Kong.

3.3 Technology Adoption Models

In light of ongoing advancements in technology, companies have started to update their information systems (ISs) in order to enhance their performance. One of the more well-established areas of IS study is technology adoption, which Carr (1999) defined as "the stage in which a technology is selected for use by an individual or an organization" (p. 1). Many grounded and widely used adoption theories have found practical utility in studying the factors that impact the acceptance and adoption of innovation, including the diffusion of innovation theory (DIT) (Roger, 1962), the TAM (Davis, 1986), the theory of reasoned action (Ajzen, 1985), the TOE framework (Tornatzky et al., 1990), and the assimilation theory (Armstrong & Sambamurthy, 1999). This study utilizes the TOE framework based on its relevance to technology adoption at the firm level, as determined by the literature review (Clohessy & Acton, 2019; Gangwar et al., 2014; Hossain & Quaddus, 2011; Zhu, 2004).

3.3.1 Technology–Organization–Environment Framework

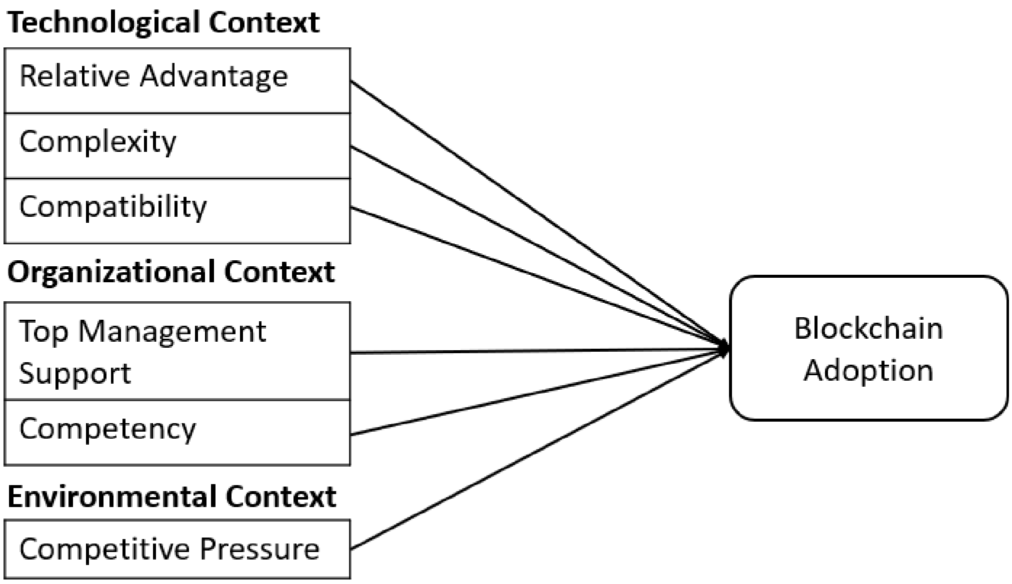
Tornatzky et al. (1990) proposed the TOE framework for studying the factors that impact adoption. The model is popularly referred to as the Tornatzky and Fleischer model, and it was developed on the basis of the DIT. The TOE framework examines the adoption and use of ISs at the firm level, taking into consideration the external and internal factors. The TOE approach involves a generic set of factors that are used to predict the likelihood of technology adoption. Moreover, the TOE model captures the comprehensive theoretical perspective on information technology adoption (Zhu, 2004). The TOE framework offers an advantage over other adoption models when it comes to evaluating technology adoption because it includes technological, organizational, and environmental aspects (Clohessy & Acton, 2019; Gangwar et al., 2014). The framework is also unrestricted by either industry or company size (Hossain & Quaddus, 2011; Zhu, 2004). As a result, the TOE framework provides a comprehensive picture of the various elements that influence a given company's technology adoption.

3.3.2 Contextual Model

While other models can be utilized to examine the adoption of different technological innovations at the organizational level (as will be discussed in Section 3.3), the TOE framework considers not only the technological aspects, but also the organizational and environmental factors that impact technology acceptance and adoption at the corporate level. Academics have advocated the use of the TOE framework to increase the predictive capacity of the resultant model as well as to overcome the limitations of other adoption theories in order to establish a holistic understanding (Abed, 2020).

A number of prior studies have used the TOE framework to explore the adoption of new technologies at the firm level (Abed, 2020; Al-Hujran et al., 2018; Kulkarni & Patil, 2020). Based on these studies, this chapter proposes the conceptual framework presented in Figure 8.

Figure 8 *The TOE Framework*



3.4 Hypothesis Development

The literature review identified certain adoption variables that have been widely used in similar domains and proven to play significant roles in the acceptance of new technologies at the organizational level.

3.4.1 Technological Context

According to Rogers (1962), users' beliefs regarding innovation influence their decision to adopt or reject a new technology. Such beliefs are formed by an individual's knowledge or awareness of the relevant innovation. Thus, the diffusion of innovation occurs in five stages: knowledge/awareness, persuasion, decision, implementation, and confirmation. Moreover, under the persuasion step, Rogers (2003) lists five innovation characteristics that he believes affect an individual's decision to use a given technology, namely compatibility, relative advantage, complexity, trialability, and observability. Davis (1986), however, proposed two theoretical constructs for predicting and explaining the use of technology: perceived usefulness (PU) and perceived ease of use (PEU). For their part, Moore and Benbasat (1991) argued that PEU and PU are analogous to relative advantage and complexity, respectively, in relation to the DIT. Many other studies have used the concepts of relative advantage and complexity, rather than PU and PEU, as technological constructs within the TOE framework. Unlike Gangwar et al. (2015), this chapter holds that due to including relative advantage and complexity, there is no need to include other constructs for PU and PEU because they capture the same effect. This chapter also includes compatibility, as the literature review revealed it to be an important technological determinant of adoption.

Relative advantage. Roger (1962) defined relative advantage as “the degree to which an innovation is perceived as being better than the idea it supersedes” (p. 229). According to Iacovou et al. (1995), relative advantage entails comparing existing technologies to proposed technologies, in addition to assessing the perceived benefits that will follow. The larger the perceived difference between the two, the more likely it is that a firm will have a positive perception of the new technology’s adoption. Li et al. (2010) showed that the relative advantage of e-business over traditional methods was a significant predictor of e-business adoption by Chinese businesses. As discussed in Chapter 1, blockchain offers many advantages that are believed to positively impact its adoption. In light of this, the following hypothesis is proposed:

H1: Relative advantage positively affects the adoption of blockchain technology

Complexity. Technological complexity refers “the degree to which an innovation is perceived as relatively difficult to understand and use” (Roger, 1962, p. 15). New technologies might require new skill sets. The difficulty associated with acquiring these skill sets will negatively impact and stifle the adoption of new technology. In addition, the complexity in terms of understanding the benefits or use of a new technology might negatively impact its adoption. Indeed, the more complex a technology appears to be, the less likely it is to be accepted by a company. Gangwar et al. (2015) and Cooper and Zmud (1990) found that complexity plays a significant role in the adoption of IS technologies. Some companies continue to struggle with understanding how such technology works and how they might benefit from it. Generally, this complexity is associated with the technical or conceptual structure of the technology. Thus, the following hypothesis is suggested:

H2: Complexity negatively affects the adoption of blockchain technology

Compatibility. Compatibility here refers to "the degree to which the innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003, p. 240). Compatibility is perceived as a significant factor in relation to influencing technology adoption. If a new technology is found to be more compatible with the existing needs of an organization, it has a greater likelihood of being adopted in the future (Peng et al., 2012). Blockchain adoption requires firms to develop blockchain-related services that are interoperable and compatible with existing systems. Therefore, if blockchain technology is not compatible with an organization's IT infrastructure, there is lower chance of it being adopted (Kamble et al., 2021). Moreover, blockchain implementation requires additional personnel, skilled professionals, the consumption of extra energy, and extra storage capacity. Thus, blockchain must fit well with the existing business processes in order to avoid wasting excess resources (Clohessy & Acton, 2019). As a consequence, the following hypothesis is posited:

H3: Compatibility positivity affects the adoption of blockchain technology

3.4.2 Organizational Context

Top management support. An organization requires support from its top management to pursue new ideas. In fact, the management plays an integral role in the allocation of resources, the integration of services, and the restructuring and re-engineering of processes (Amini et al., 2014). Here, top management is defined as "the decision-makers who influence the adoption of innovation" (Lai et al., 2014, p.5-6). Furthermore, top management support refers to the degree to which the management understand and are involved in blockchain adoption (Wong, Leung, et al., 2020). Many prior studies have identified top management support as a significant determinant of the adoption of IT (Cruz-Jesus et al., 2019; Khayer et al., 2020; Sabherwal et al., 2006). According to a study conducted by Clohessy and Acton (2019) in Ireland, businesses that have adopted blockchain exhibit high levels of managerial support. In addition, their study found that senior management support for blockchain evolved progressively among adopting organizations and was impacted by the technology's relative advantage and ability to develop new business models. In related studies, it has also been found that top management support is crucial for firms' adoption of new technology (Crosby et al., 2016; Gangwar et al., 2015). As a result, the following hypothesis is offered:

H4: Top management support positively influences the adoption of blockchain technology

3.4.3 Environmental Context

Competitive pressure. Competitive pressure has been recognized as an effective driver of technology adoption since the early years of research on this topic. Iacovou et al. (1995) defined competitive pressure as the degree to which organizations within a specific industry or field compete with one another for resources such as consumers or market share. Ramdani et al. (2009) empirically showed that industry competition has a positive impact on IT adoption. A firm can achieve a competitive advantage and be better able to compete in the market if it has a cost advantage or a lower unit product cost, or it manages to differentiate its product by incorporating new features. The incorporation of blockchain technology in a specific industry (as discussed in Chapter 1) would allow for increased productivity and, consequently, additional cost savings. Likewise, the adoption of blockchain technology can facilitate the incorporation of new services and features into a product. In a competitive market, if some companies within an industry start using blockchain, others might feel pressure to adopt it as well. Thus, the following hypothesis is suggested:

H5: Competitive pressure positively affects the adoption of blockchain technology

Competence. According to some studies, organizational knowledge and competence are both important determinants of firms' perception of a technology and whether or not it should be adopted (Lee & Shim, 2007). Mehrtens et al. (2001) discovered that knowledge among non-IT professionals is a significant predictor of internet adoption among SMEs. Ettlie (2011) studied the factors that influence manufacturing companies' decision to innovate and found that business owners who are more knowledgeable regarding technological innovation are more likely to implement an aggressive technology adoption policy. Therefore, the following hypothesis is formulated:

H6: Competence positively affects the adoption of blockchain technology

3.5 Research Method

An online survey was used to collect the data for this quantitative study. In addition to overcoming the problem of geographical distance, online surveys provide advantages such as wider coverage and time savings. The online survey used in this study was developed to investigate the relationships among the model's proposed constructs.

3.5.1 Participants

In terms of requirement for the study, Netquest,[23] a professional data collection company with an International Organization for Standardization (ISO) quality certificate and more than 10 years of experience gathering online data for research purposes, was contracted to recruit the participants in order to prevent errors associated with data extraction and ensure the high quality of the data. Netquest's online portal and database of panelists from different regions of Spain was used to gather the required data. The participants were filtered based on their sector and position. Only top and middle managers working in 10 selected sectors from the Clasificación Nacional de Actividades Económicas (CNAE) list were eligible to participate in the survey. Two more filter questions were applied to improve the instrument's content validity. The first filter question measured the participants' basic knowledge of blockchain technology, while the second question measured their understanding of the usability of the technology. The initial sample included 800 respondents from different regions of Spain, although only those respondents who answered "Yes," meaning that they knew what blockchain is and had knowledge of its applications, were included in the study. The inclusion of the observations regarding blockchain knowledge helps to ensure the accuracy of the results, although it could also be considered a limitation.

The final sample of 213 respondents satisfied the requirement for a minimum of five observations per parameter of interest (Bentler & Chou, 1987; Bollen, 1989; Kamble et al., 2019). In fact, a sample of 85 observations would have been sufficient for the 17 parameters evaluated in the proposed model. Sideridis et al. (2014) claimed that 70–80 participants are sufficient to model relationships using SEM. Wolf et al. (2013), however, discovered that there is no such thing as a "one-size-fits-all" sample.

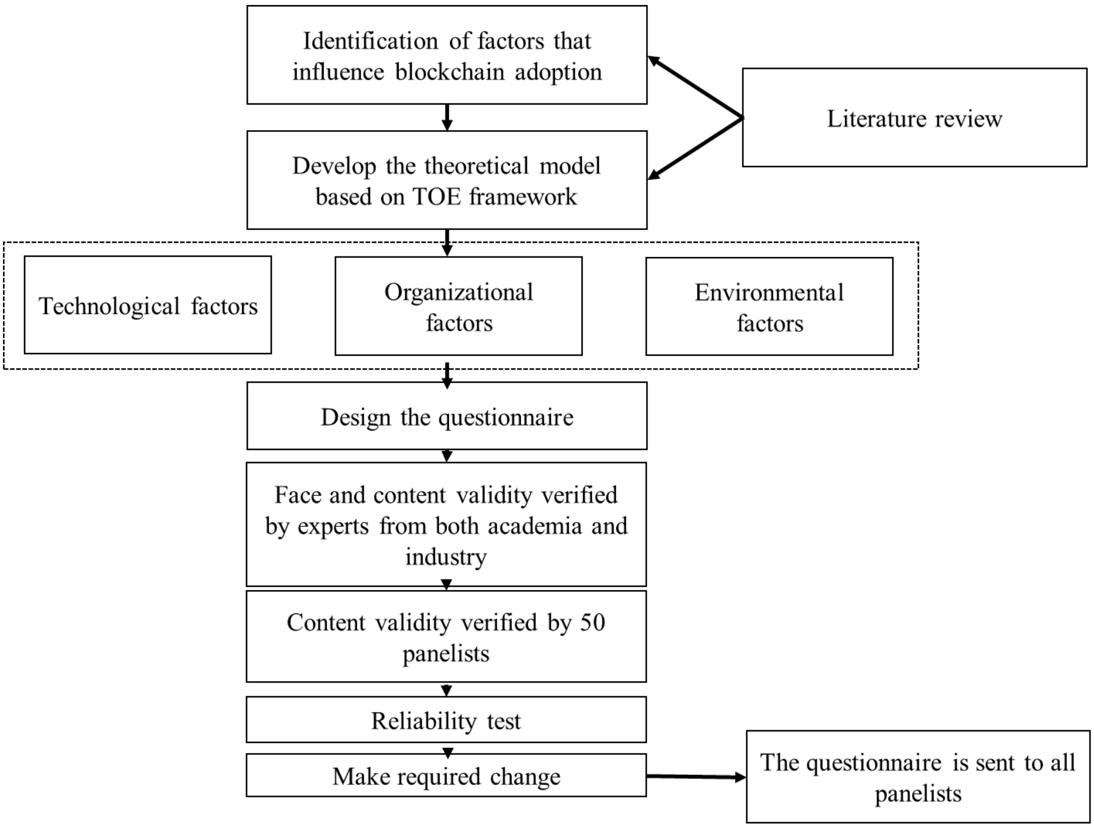
[23] Further information about Netquest is available via the company's website: https://www.netquest.com/es/encuestas-online-investigacion

3.5.2 Instrument Development

When seeking to determine the real relationships among constructs, appropriate instrument development is important. The internal consistency of measurement instruments must be assured, as must the interrater reliability of the instrument results. This study uses the TOE framework to investigate the factors that influence blockchain adoption within Spanish firms. Thus, a questionnaire-based survey instrument was developed. The questionnaire comprised two parts: (i) general questions designed to elicit demographic information such as the respondents' gender, age, education, and position as well as company information such as the size and sector; and (ii) specific questions concerning the factors affecting the adoption of blockchain technology. The questions included in the first phase of the survey were set up as multiple-choice questions, which allowed the respondents to choose the answer that was most relevant to them. The five- and seven-point Likert scales represent the two most common forms of Likert scales used in IS research, although the five-point scale outperforms the seven-point scale. Prior studies have advocated the use of the five-point Likert scale (Babakus & Mangold, 1992; Bouranta et al., 2009; Devlin et al., 2003), arguing that it boosts the response rate and quality while lowering the respondents' "frustration level." It has also been argued that for European surveys, the five-point scale is more appropriate (Prentice et al., 1998). According to Dawes (2008), the interviewer can easily read out the whole list of scale descriptions when using a five-point scale, which is not the case when using longer Likert scales. Thus, a five-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree) was used for the second phase of questions. Moreover, two multiple choice questions were added at end of the questionnaire to measure blockchain adoption. The survey was originally first in English and then translated into both Spanish and Catalan.

Although the utilized measurement items were adapted from prior research as part of the model, they were still pre-tested for face validity and content validity with topic specialists in order to ensure that the scale and the questions were relevant to the notion of blockchain technology adoption (Figure 9). Duplicate and extensive queries were avoided, as were technical and specialized words. To evaluate the instrument relevance and content clarity, feedback was sought from leading academics and researchers in the IS field so as to avoid any problems or non-responses that the respondents might otherwise have encountered while completing the survey. The questionnaire was forwarded to native speakers for proofreading, including a review of any grammatical and wording errors. According to Gould (1994), "the measurement tool must be understandable and perceived as relevant by the subjects to ensure their co-operation and motivation" (p. 99). The specialists were directed with regard to selecting the most appropriate constructs and measurement items for the study. Furthermore, only the measurement items with the highest factor loadings were included in the analysis.

Figure 9 *Flowchart of the Instrument Development and Validation Process*



Validated measures derived from peer-reviewed studies were used in the questionnaire. The items were modified and adapted to meet the needs and requirements of the present study. A description of the measurement items and the relevant references is provided in Table 21. The construct designed to measure blockchain adoption (To what extent is your organization currently using blockchain technology?) included five answer options:

1. We are currently experimenting with blockchain.
2. We are developing prototype applications.
3. We are introducing blockchain applications into our organization
4. We do not use blockchain technology.
5. I do not know

A dummy variable was generated to measure blockchain adoption. It took the value of "1" if options 1–3 were selected and "0" otherwise.

Table 21 Description of Measurement Items for Each Construct

Construct	M. Items	Item Description	Reference(s)
Relative advantage	RA_1	Blockchain will increase transparency	Picoto et al. (2014) Venkatesh and Bala (2008) Knauer and Mann (2020) Clohessy and Acton (2019)
	RA_2	Blockchain will increase the security of data	
	RA_3	Blockchain will increase productivity and, consequently, reduce costs	
	RA_4	Blockchain will enhance organizational flexibility	
	RA_5	Blockchain enables the automatic reconciliation of accounts and transactions and increases accuracy	
	RA_6	Blockchain will improve traceability	
	RA_7	Blockchain will improve internal management	
	RA_8	The adoption of blockchain technology will help to better serve our customers and improve our relationships with suppliers.	
	RA_9	Blockchain will increase employee performance	
	RA_10	Blockchain will increase staff motivation and satisfaction	
	RA_11	Blockchain facilitates improved decision making	
	RA_12	Blockchain will allow increased control over work	
Complexity	Cmplx_1	Blockchain is conceptually difficult to understand from a business perspective	Wamba et al. (2020)
	Cmplx_2	Blockchain is conceptually difficult to understand from a technical perspective	
	Cmplx_3	Using blockchain technology is difficult	
	TMS_1	Our top management provides strong leadership and engages in the process when it comes to information systems	Fernando et al. (2021) Oliveira et al. (2014)

Top management support	TMS_2	Our top management provides enough support for blockchain technology initiatives	
	TMS_3	Our top management understands the benefits of blockchain technology	
	TMS_4	Our top management considers blockchain technology to be strategically important	
Competitive pressure	CP_1	Competition will make it necessary for our organization to implement blockchain	Sutanonpaiboon and Pearson (2006)
	CP_2	To be a leader in my organization's industry, we need to implement blockchain	
	CP_3	Some organizations within our industry have already implemented blockchain technology	
Competence	Cmp_1	Our company has professional staff trained in the use of blockchain technology	Fernando et al. (2021)
	Cmp_2	Our employees have a sufficient level of knowledge regarding blockchain technology	
	Cmp_3	Our employees are familiar with blockchain technology	
Compatibility	Cmpt_1	Blockchain is compatible with the existing information technology infrastructure in the company	Chung et al. (2008) Géczy et al. (2012) Wang et al. (2010)
	Cmpt_2	The use of blockchain is compatible with the company's corporate culture and value system	
	Cmpt_3	The use of blockchain is fully compatible with current business operations	
Adoption	Adp_D	To what extent is your organization currently using blockchain technology?	Venkatesh et al. (2012) Fernando et al. (2021) Picoto et al. (2014)

3.5.3 Sample and Data Collection

To assess the reliability of the measurement items, a pilot study of the questionnaire was performed. More specifically, the questionnaire was distributed to 50 panelists who, at the end of the survey, were asked if they had experienced any difficulties answering the questions. Some respondents requested a definition of blockchain technology in their comments. Thus, information on blockchain technology was provided to those who answered "No" for the first knowledge question. After the results of the first round had been collected, a reliability test was performed. All of the measurement items had a composite reliability score of over 0.7, which is the acceptable threshold (Chiu & Wang, 2008; Lin & Lin, 2008). Next, the second round of the questionnaire was released on April 23, 2021 and 2496 panelists were invited to complete it (Figure 9). The survey was closed when the required number of responses (i.e., 800 observations) was reached. Table 22 shows the demographic features of the sampled companies and the demographic characteristics of the respondents. It should be noted that out of 800 observations, only 213 observations knew what blockchain is and were aware of its applications. Only these 213 observations were taken into consideration during the analysis. As can be seen in Table 22, 79 percent of the sample were men. Most respondents had a bachelor's degree or a master's degree. Some 46 percent of respondents were aged between 41 and 50 years, while 81 percent were middle managers. The sector with the highest number of respondents was the information and communication sector, and 44 percent of respondents represented big companies with more than 1000 employees. The sample was considered representative because company managers from 17 autonomous communities in Spain participated in the survey, although most respondents were from Madrid (79 respondents), Catalunya (43 respondents), and Andalucía (27 respondents).

Table 22 *Sample Characteristics*

Demographics		Number	Percentage
Gender	Male	168	79
	Female	45	21
Education	Upper secondary education	17	8
	Non-university technical/occupational/vocational	19	9
	Bachelor's degree	95	45
	Master's degree	71	33
	Doctorate	9	4
	Other	2	1
Age	20–30 years	10	5
	31–40 years	50	23
	41–50 years	97	46
	51–60 years	54	25
	61+ years	2	1
Position	Senior manager	41	19
	Middle manager	172	81
	Junior manager	0	0
Sector	Agriculture, forestry, and fishing	8	4
	Manufacturing industry	10	5
	Supply of electricity, gas, steam, and air conditioning	11	5
	Water supply, sanitation activities, waste management, and decontamination	3	1
	Wholesale and retail	18	8
	Transport and storage	9	4
	Information and communications	49	23
	Financial and insurance activities	26	12
	Real estate activities	3	1
	Professional, scientific, and technical activities	26	12
	Public administration and defense	26	12
	Health and social services activities	9	4
	Artistic, recreational, and entertainment activities	4	2
	Another sector	0	0
Size	1–50 employees	24	11
	51–100 employees	18	8
	101–500 employees	50	23
	501–1000 employees	27	13
	1000+ employees	94	44
Region/ Autonomous Community	Andalucía	27	13
	Aragón	7	3
	Principado de Asturias	5	2
	Illes Balears	2	1
	Canarias	1	0
	Cantabria	1	0

	Castilla y León	8	4
	Castilla-La Mancha	2	1
	Catalunya	43	20
	Comunitat Valenciana	13	6
	Extremadura	5	2
	Galicia	6	3
	Madrid	79	37
	Murcia	2	1
	Navarra	2	1
	País Vasco	9	4
	La Rioja	1	0

3.6 Results

The PLS-SEM technique was used to perform the quantitative data analysis. This technique uses a component-based approach and allows for the simultaneous examination of measurement and structural models (Fornell & Bookstein, 1982). One key feature of the PLS-SEM technique is its ability to estimate a model with a large number of latent variables and indicators, even with a small sample size (Dijkstra & Henseler, 2015). Moreover, unlike other first-generation regression approaches, causal PLS modelling attempts to maximize the explained variance of the dependent variables (Hair et al., 2021) and accommodate the exploratory nature of the research model (Liang et al., 2007). A measurement model depicts the link between the indicators (items) and their concept, whereas a structural model investigates the relationships among the constructs (Hair et al., 2021).

SmartPLS 3 software was used for the modelling of the latent variables. The model was tested using a two-step procedure. The evaluation of the measurement model's reliability and validity was performed in the first step, while the structural model was assessed in the second step.

3.6.1 Measurement Model

Both reliability and validity tests were performed to assess the measurement model in terms of its convergent and discriminant validity.

3.6.1.1 Indicator reliability and internal consistency reliability

The indicator reliability reveals that relationships among the construct and the measurement items. Squaring the outer loadings of the reflective constructs yields the indicator reliability. The item loading must generally be greater than 0.708 to achieve acceptable indicator reliability (Hair et al., 2021). However, Field (2013) argued that a factor is considered reliable if it has four or more loadings of at least 0.6, regardless of the sample size. For interpretive reasons, Stevens (2012) recommended the adoption of a cut-off of 0.4, again regardless of the sample size. When the frequency distributions of the items change, Tabachnick and Fidell (2007) recommended the adoption of more rigorous cut-offs ranging from 0.32 (poor), 0.45 (fair), 0.55 (good), 0.63 (very good), to 0.71 (excellent). As there are many suggested thresholds, the acceptance of an item can depend on the theoretical judgement of the author. Therefore, it is better to evaluate the internal reliability of each item before discarding it.

Twelve items for measuring relative advantage were included in the survey. Those items with factor loadings of less than 0.75 were dropped to achieve consistency in terms of the number of items measuring each construct and prevent the tendency to make the variable significant by including many items. As such, seven items for measuring relative advantage were ultimately included in the model.

Internal consistency reliability assesses how well different test items probe the same construct and produce similar results. There are different ways of measuring internal consistency, although two widely used methods involve the use of Cronbach's alpha and the composite reliability score (or rho_A). According to Hair et al. (2021), the cut-off point for the composite reliability score is between 0.7 and 0.95. Table 23 demonstrates that the rho_A and the composite reliability (CR) of all the constructs were both more than 0.7, suggesting that the measure is reliable or that the measurement items share 49–50 percent of the variance when measuring the latent variable, while the remainder is the measurement error.

Table 23 *Reliability and Validity Assessment Results*

Construct	Measurement Item	Factor Loading	rho_A	CR	AVE
Adoption	Adp_D	1.0000	1.000	1.0000	1.0000
Competitive pressure	CP_1	0.8358	0.8002	0.8777	0.7053
	CP_2	0.8581			
	CP_3	0.8252			
Relative Advantage	RA_11	0.8364	0.9040	0.9207	0.6243
	RA_12	0.7374			
	RA_3	0.7654			
	RA_4	0.7979			
	RA_7	0.7913			
	RA_8	0.7886			
	RA_9	0.8102			
Complexity	Cmplx_1	0.9075	0.8930	0.9031	0.7017
	Cmplx_2	0.7081			
	Cmplx_3	0.6039			
Compatibility	Cmpt_1	0.8760	0.7874	0.8336	0.6269
	Cmpt_2	0.7601			
	Cmpt_3	0.7317			
Competence	Cmptnc_1	0.8717	0.8593	0.9051	0.7608
	Cmptnc_2	0.8571			
	Cmptnc_3	0.8877			
Top management support	TMS_1	0.6941	0.8264	0.7899	0.5632
	TMS_2	0.8906			
	TMS_3	0.8760			
	TMS_4	0.8742			

3.6.1.2 Convergent validity and discriminant validity

Convergent validity demonstrates that items measuring the same construct are strongly correlated with that construct, thereby indicating that the variance between the items should be high. An average variance extracted (AVE) of higher than 0.5 indicates the acceptable convergent validity of each construct. As can been seen in Table 23, the AVE scores for all the constructs were above 0.5, which satisfied the convergent validity requirements.

While convergent validity measures if the items that need to be correlated are in fact correlated, discriminant validity tests if the items that are not supposed to be correlated are actually unrelated. There are also different ways to test discriminatory validity. The Fornell-Lacker criterion and the Heterotrait-Monotrait (HTMT) ratio are two widely accepted techniques for testing discriminatory validity. The Fornell-Lacker criterion compares the square root of the AVE to the correlation of the latent constructs. It should better explain its own indicator's variance than the variance of the other latent constructs. As a result, the square root of the AVE of each construct should be greater than the correlations with the other latent constructs. Table 24 presents the discriminatory validity results. The diagonal of the table (in bold) shows the square root of each construct's AVE, while the off-diagonal scores show the correlation between the constructs. The results reveal that the AVEs of the constructs are higher than the correlation between the constructs. This means that the constructs satisfy the discriminant validity criteria and, therefore, can be used to test the structural model.

The HTMT ratio measures the similarity between the variables. Henseler et al. (2015) found that the HTMT ratio can achieve higher specificity and sensitivity rates than the Fornell-Lacker criterion. A threshold of 0.9 reliably distinguishes between discriminately valid and non-discriminately valid pairs of latent variables (Gold et al., 2001). The second part of Table 24 shows the results concerning the HTMT ratio. It can be seen that all the constructs have an HTMT score of lower than 0.9, which confirms both the similarity of the results to the results concerning the Fornell-Lacker criterion and the validity of the constructs.

Table 24 *Discriminatory Validity Test Results*

Fornell-Lacker Criterion							
	Adp	CP	RA	TMS	Cmpt	Cmptnc	Cmplx
Adp	**1.0000**						
CP	0.4885	**0.8398**					
RA	0.3482	0.6638	**0.7901**				
TMS	0.5712	0.6476	0.4519	**0.8377**			
Cmpt	0.4322	0.6192	0.5890	0.6429	**0.7917**		
Cmptnc	0.5577	0.5286	0.3813	0.7794	0.5650	**0.8722**	
Cmplx	-0.1883	-0.1384	-0.1087	-0.2175	-0.2340	-0.2844	**0.7505**
Heterotrait-Monotrait Ratio							
	Adp	CP	RA	TMS	Cmpt	Cmptnc	Cmplx
Adp							
CP	0.5414						
RA	0.3574	0.7861					
TMS	0.5971	0.7659	0.5007				
Cmpt	0.4853	0.8153	0.7629	0.8163			
Cmptnc	0.5973	0.6328	0.4345	0.8994	0.7117		
Cmplx	0.1899	0.1849	0.1672	0.2766	0.3599	0.3678	

3.6.2 Assessment of the Structural Model

Prior to the hypothesis testing, the collinearity issue must be addressed. According to Hair et al. (2021), one significant potential issue in structural models is collinearity, which occurs when the value of the variance inflation factor (VIF) exceeds 5. As a consequence, the VIF value must be 5 or lower. As the tested model only consists of formative variables, the inner model VIFs were measured (Table 25). The results show that all the values are lower than 5, indicating there to be no collinearity among the constructs.

Table 25 *Inner Variance Inflation Factor Results for Collinearity*

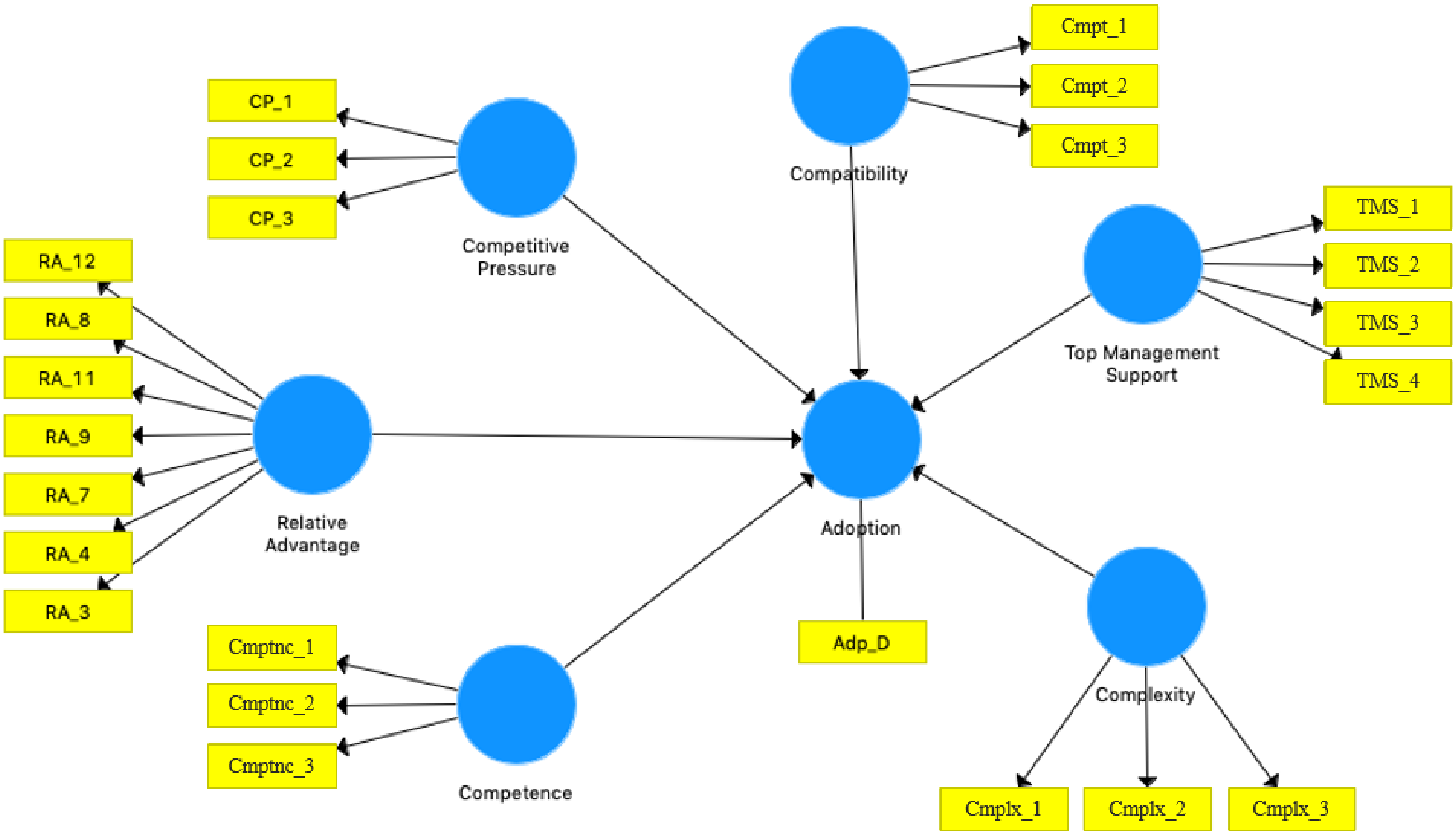
Adoption	**Variance Inflation Factor**
Competitive pressure	2.5093
Relative advantage	1.9883
Top management support	3.3778
Compatibility	2.2139
Competence	2.6748
Complexity	1.1036

Figure 10 depicts the research model in the form of a structural model. Bootstrapping, which involves producing subsamples using randomly selected observations from the initial set of data, was used to generate a subsample. The PLS path model was then estimated using the subsample. This method should be continued until a significant number of random subsamples, generally 5000, have been generated (Hair et al., 2021). The standard error values acquired by means of bootstrapping determine whether or not a coefficient is significant.

Table 26 and Figure 11 present the results of the direct effects and hypothesis testing. As can been seen, the construct with the highest impact on blockchain adoption is competence ($\beta = 0.2630$, $P = 0.0058$). A one unit increase in competence increases blockchain adoption by 0.2630 unit. Top management support ($\beta = 0.2304$, $P = 0.0137$) and competitive pressure ($\beta = 0.1809$, $P = 0.0185$) are also both significant and have positive impacts on blockchain adoption. Thus, hypotheses H4, H5, and H6 are supported.

However, contrary to expectations, complexity ($\beta = -0.0352$, $P = 0.5526$) relative advantage ($\beta = 0.0167$, $P = 0.7984$), and compatibility ($\beta = 0.0054$, $P = 0.9507$) do not have significant impacts on blockchain adoption, although the identified relationships are aligned with the hypotheses. This means that the only factors that impact the adoption of blockchain technology are environmental and organizational factors. Indeed, technological factors do not play a significant role in the adoption of blockchain technology among Spanish firms. Thus, hypotheses H1, H2, and H3 are rejected.

Figure 10 ***The Research Model in the Form of a Structural Model***



To further investigate the accuracy of the model, a number of variables believed to have higher impacts on blockchain adoption, namely transparency, traceability, and accountability, were selected as the latent variables for relative advantage (rather than the variables with the highest factor loadings). Similar results were obtained in relation to the coefficient and significance of the construct (see Appendix 3.3).

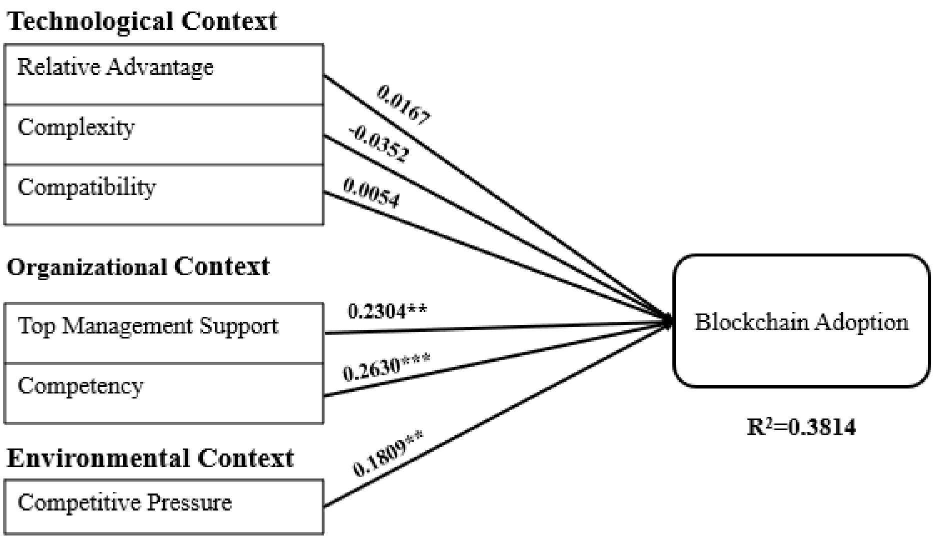
Table 26 *Direct Effects and Hypothesis Test Results*

H	Path	Beta	T Values	P Values	Decision	f^2
H5	CP -> Adp	0.1809	2.3559	0.0185**	Supported	0.0211
H1	RA -> Adp	0.0167	0.2554	0.7984	Rejected	0.0002
H4	TMS -> Adp	0.2304	2.4647	0.0137**	Supported	0.0254
H3	Cmpt-> Adp	0.0054	0.0619	0.9507	Rejected	0.0000
H6	Cmptnc-> Adp	0.2630	2.7604	0.0058***	Supported	0.0418
H2	Cmplx -> Adp	-0.0352	0.5939	0.5526	Rejected	0.0018

*** significant at a 99 percent confidence interval

** significant at a 95 percent confidence interval

Figure 11 *Measurement Model*



The R-squared (R^2) or coefficient of determination represents another important criterion for assessing PLS-SEM results. Hair et al. (2021) proposed a minimum score of 0.10 as an acceptable R^2 level. In the case of the present model, 38.14 percent of the variance of adoption is explained by the independent variables. Chin (1998) suggested that R^2 values above 0.67 are considered high, any value between 0.33 and 0.67 is considered moderate, and any value between 0.19 and 0.33 is considered weak. Thus, the R^2 value for blockchain adoption is moderate (Table 27). This result indicates that the developed path model from the latent variables to blockchain adoption is associated with moderate levels of explanatory power and predictive relevance.

Table 27 *R-Squared of the Endogenous Latent Variables*

Construct	R^2	Result
Adoption	0.3814	Moderate

In accordance with Cohen's (1988) guidelines for assessing the effect sizes of constructs, the Cohen's f^2 coefficient was estimated. The small, medium, and high impacts of an external latent variable on an endogenous latent variable are represented by the values of 0.02, 0.15, and 0.35, respectively (Cohen, 1988; Kock, 2014). Table 26 shows that competence, top management support, and competitive pressure have medium effect sizes (with f^2 of 0.0418, 0.024, and 0.0211, respectively). Moreover, relative advantage (f^2 = 0.0002), complexity (f^2 = 0.0018), and compatibility (f^2 = 0.000) have almost no effect sizes.

3.7 Discussion and Conclusion

As blockchain technology has grown in popularity, many companies have begun to consider how it might be used in several sectors. Every business has its own structure, strategy, and culture. Furthermore, the external environment has an impact on every business. Thus, a company's approach to blockchain adoption is influenced by a mix of organizational, environmental, and technological factors. The main goal of this study was to identify the technological, organizational, and environmental elements that influence firms' willingness to embrace blockchain technology.

The results presented in this chapter show that environmental and organizational factors (competitive pressure, top management support, and competence) have positive impacts on the adoption of blockchain technology. Therefore, the results support hypotheses H4–H6, although there is a lack of evidence in support of hypotheses H1–H3. The implications of the findings, as well as their interpretation and comparison with those of previous studies, will be discussed in the next section, This study contributes to the limited pool of quantitative papers concerning the acceptance and adoption of blockchain technology and investigates the factors that impact the use of such technology in a European context.

3.7.1 Implications, Limitations, and Future Lines of Research

The findings of this study have both theoretical and practical implications. From a theoretical perspective, the findings emphasize the need for a more comprehensive theoretical framework capable of capturing the impact of elements that have not been included in this model (e.g., costs, uncertainty from both the regulatory and technology development perspectives, standardization, etc.). This study focused on three technological factors (relative advantage, complexity, and compatibility), two organizational factors (top management support and competence), and one environmental factor (competitive pressure). It was not possible to explore additional organizational, environmental, and technological factors that may impact blockchain adoption because the study was confined to only these six variables. Despite this study extending the limited qualitative research concerning the acceptance of blockchain technology, there is potential for future studies involving a wider framework, which might result in a more thorough analysis of blockchain adoption among European firms.

From the practical and managerial perspectives, the results of this study show that competence and top management support are crucial for blockchain adoption. These findings are in line with those of Clohessy and Acton (2019) and Orji et al. (2020), although they contradict the findings of Wong, Leong, et al. (2020), who concluded that top management has no effect of blockchain uptake. Top managers have the ability to make strategic decisions and allocate resources for the adoption of new technologies, which can also determine how competent company employees are as well as the knowledge and skills they have with regard to such technologies. It is recommended that top managers educate themselves about the advantages and disadvantages of using blockchain within their organizations so as to be able to make better decisions in this regard.

The findings of this study also suggest that the compatibility of blockchain with organizations' existing technological infrastructure, values, and needs has no impact on its adoption. This outcome is consistent with the findings of De Castro et al.'s (2020) study, which found blockchain to be incompatible with the wealth management industry's legacy infrastructure in South Africa, although it contradicts the findings of Clohessy and Acton (2019) and Kim (2020). In addition, complexity and relative advantage have been shown to have insignificant impacts on adoption. According to De Castro et al. (2020), people with non-IT backgrounds perceive blockchain to be more complex than those with

IT knowledge. As the present survey was conducted among company managers, there is no evidence to suggest how much technical knowledge they had regarding blockchain. In any case, it is crucial to understand the complexity and compatibility of the technology in relation to existing systems prior to determining whether or not to use it.

The results of this study further suggest that competitive pressure has a positive influence on blockchain adoption. This finding suggests that businesses aim to stay ahead of their competitors when it comes to competitiveness. The intensity of the competition motivates businesses to search for new strategies in order to expand and maintain their competitive edge. Prior studies have shown that blockchain adoption is critical for businesses with regard to maintaining their competitiveness (Kamble et al., 2019; Wamba et al., 2020; Wong, Tan, et al., 2020). Thus, it is recommended that company managers involve staff with technical backgrounds in the decision-making process concerning technology adoption, follow technological trends, evaluate the usefulness of new technologies in relation to the company's operations, and ensure that the company does not lag behind competitors in the market.

Blockchain technology providers might need to wait until the technology reaches maturity before finding more clients for their services. The lack of adoption could also be an indicator of a market opportunity, as the results of this study indicate that not many Spanish companies have yet adopted blockchain technology. One of the limitations of this study is the fact that it only takes into consideration observations who had adequate knowledge of blockchain (213 out of 800 observations). This indicates a low level of awareness and a lack of information about blockchain technology among Spanish firms. These findings may inspire IT providers to offer solutions that provide companies with a competitive edge. They may also inspire academia, governments, and the blockchain community to develop improved ways of raising awareness about the technology and its relevance to companies.

Appendix 3.1: List of Reviewed Literature

Table 28 *Review of Qualitative Studies Concerning the Adoption of Blockchain Technology*

Reference	Objective	Method
Chen et al. (2020)	To explore the adoption of blockchain technology in food supply chains through a thematic analysis.	773 news articles in Factiva, 1822 news articles in Nexis, and 115 research papers.
Chang et al. (2020)	To examine the development and impact of FinTech and blockchain within the financial industry. It also draws an outline of the competent use of blockchain in the banking sector.	Interviews –16 Interviewees.
Dal Mas et al. (2020)	To establish a model that can aid in the development of sustainable business models (SBMs) through smart contracts using blockchain technology.	The company's white paper, interviews with the chief executive officer and chief information officers, interviews with the founders of the company, and five interviews with experts in the field of blockchain discussing the company. A total of 11 newspaper articles discussing the company's business idea. A total of 178 comments from investors and other experts collected from dedicated forums.
Koens et al. (2020)	To identify the drivers of the adoption of blockchain technology.	A scenario analysis through a literature review.
Tan and Sundarakani (2020)	To develop a blockchain framework that supports working with freight consolidation businesses.	Case studies and a literature review.
Helliar et al. (2020)	To study permissionless and permissioned blockchain diffusion barriers and drivers, to determine whether they are the same or different, and to explore whether the barriers and drivers change over time.	Five semi-structured interviews conducted in Italy and the United Kingdom.
Orji et al. (2020)	To understand the factors influencing blockchain adoption by the freight logistics industry.	Interviews with 15 Nigerian freight logistics managers.
Koster and Borgman (2020)	To investigate blockchain adoption in the public sector.	Seven blockchain projects, case studies, and 16 semi-structured interviews.

Malik et al. (2020)	To explore the adoption of blockchain within Australian organizations.	Primary data: Semi-structured interviews. Secondary data: Theoretical lens approach, sources from participants, online sources such as the websites of the participants' organizations, government reports, white papers, and a literature review.
Janssen et al. (2020)	To analyze blockchain adoption through institutional, market, and technical factors.	31 out of 800 papers focused on blockchain adoption as an objective. Databases: Web of Science, Business Source Complete, Scopus, and Google Scholar
Clohessy and Acton (2019)	To elucidate the impacts of organizational factors on the adoption of blockchain within companies based in Ireland.	Databases: ProQuest, EBSCOhost, ScienceDirect, PubMed, Web of Science, Scopus, and JSTOR. Gray literature (e.g., book, conference proceedings, and white papers).
Ghode et al. (2019)	To identify and prioritize the factors and challenges that influence the adoption of blockchain technology in the supply chain sector.	Five academicians and practitioners served as experts and reviewed the questionnaire.
Lian et al. (2019)	To find the important factors that affect the acceptance and usage intention of blockchain-based smart lockers.	Two semi-structured interviews with stakeholders.
Grover et al. (2019)	To study the diffusion of blockchain technology.	A literature review (770 articles).
Kalaitzi et al. (2019)	To observe the determinants of blockchain adoption and the perceived benefits in food chains.	Three interviews with supply chain managers from the food industry.
Batubara et al. (2018)	To examine blockchain technology adoption for e-government purposes.	A systematic literature review.
Albrecht et al. (2018)	To analyze blockchain implementation in the context of the energy sector.	A literature review + interviews.
Lou and Li (2017)	To investigate the factors affecting managements' intention to use blockchain technology.	Survey conducted via email and social networks.
Woodside et al. (2017)	To point out future uses of blockchain technology, advancements in blockchain such as Bitcoin, and the potential utilization of blockchain technology in large-scale operations.	The triangulation method, secondary data environmental analysis, text analysis, and financial analysis.

Table 29 *Review of Quantitative Studies Concerning the Adoption of Blockchain Technology*

Reference	Objective	Technology Model	Methodology	Sample	Country
Alazab et al. (2021)	To examine the critical drivers affecting the acceptance of blockchain technology in supply chain management in the Australian context.	UTAUT + TTF + ISS	PLS-SEM	449	Australia
Queiroz et al. (2020)	To understand the blockchain adoption behavior within Brazilian supply chains. More specifically, the study aims to unlock the potential of social influence, taking into consideration workers from the Brazilian supply chains.	DOI + RBV + DC + IT	Partial least squares (PLS), structural equation modeling (SEM)	138	Brazil
Wong, Tan, et al. (2020)	To study the behavioral intention to adopt blockchain for supply chain management purposes.	UTAUT	Multivariate normality test, gamma-exponential method, priori power analysis	157	Malaysia
Wong, Leung, et al. (2020)	To investigate the effects of relative advantage, complexity, upper management support, cost, market dynamics, competitive pressure, and regulatory support on blockchain adoption for operations and supply chain management purposes among small- and medium-sized enterprises (SMEs) in Malaysia.	TOE	Non-linear non-compensatory PLS-ANN approach	194	Malaysia
Nuryyev et al. (2020)	To empirically examine the factors affecting the adoption of cryptocurrency payments in the tourism sector and SMEs (blockchain technology adoption behavior).	TAM	SEM	101	Taiwan

Karamchandani et al. (2020)	To analyze the perception of enterprise blockchain (EBC) among practitioners in the service industry.	Extended TAM	SEM	282	India
Knauer and Mann (2019)	To identify the key factors that influence German consumers in terms of investing in blockchain technology.	TAM + IDT	SEM	157	Germany
Kamble et al. (2018)	To study the adoption behavior concerning blockchain technology in Indian supply chain management.	TAM + TPB + TRI	SEM and confirmatory factor analysis (CFA)	181	India
Wamba et al. (2020)	To address the influence of blockchain on supply chain performance.	TAM + UTAUT + TOE	SEM	India – 344, United States – 394 Total – 738	India and United States
Li (2020)	To identify the predictors influencing the adoption of blockchain.	TAM + TRA	Exploratory factor analyses	117	Hong Kong

Note: UTAUT-Unified theory of acceptance and use of technology, TRA- Theory of reasoned action, TRI- Technology readiness index, TPB- Theory of planned behavior, DOI- Diffusion of innovations theory, DC- Dynamic capabilities, TI- Institutional theory, RBV-Resource-based view, TTF- Task technology fit, ISS- Information system success, IDT- Innovation diffusion theory

Appendix 3.2: Questionnaire

Table 30 *Questions Included in the Questionnaire (English Version)*

Question	Value	Option
Device	1	Desktop
	2	Tablet
	3	Mobile
What is your autonomous community of residence?	1	Andalucía
	2	Aragón
	3	Principado de Asturias
	4	Illes Balears
	5	Canarias
	6	Cantabria
	7	Castilla y León
	8	Castilla-La Mancha
	9	Catalunya
	10	Comunitat Valenciana
	11	Extremadura
	12	Galicia
	13	Madrid
	14	Murcia
	15	Navarra
	16	País Vasco
	17	La Rioja
	18	Ceuta
	19	Melilla
Please select the language	1	Catalan
	2	Spanish
Are you...?	1	Male
	2	Female
How old are you?	1	0–19 years
	2	20–30 years
	3	31–40 years
	4	41–50 years
	5	51–60 years
	6	61+ years
What is the highest level of study you have completed?	1	Upper secondary education
	2	Non-university technical/occupational/vocational
	3	Bachelor’s degree
	4	Master’s degree
	5	Doctorate
	96	Other
	1	Currently employed

What is your current employment status?	2	Retired/pensioner/disabled
	3	Unemployed, I have worked previously
	4	Unemployed, I am searching for my first job
	5	Student
	6	Housework
Indicate your position	1	Senior manager
	2	Middle manager
	3	Junior manager
	4	Other
Which sector does the company for which you work operate in?	1	Agriculture, forestry, and fishing
	2	Manufacturing industry
	3	Supply of electricity, gas, steam, and air conditioning
	4	Water supply, sanitation activities, waste management, and decontamination
	5	Wholesale and retail
	6	Transport and storage
	7	Information and communications
	8	Financial and insurance activities
	9	Real estate activities
	10	Professional, scientific, and technical activities
	11	Public administration and defense
	12	Health and social services activities
	13	Artistic, recreational, and entertainment activities
	96	Another sector
What is the size of the company you work for?	1	1–50 employees
	2	51–100 employees
	3	101–500 employees
	4	501–1000 employees
	5	More than 1000 employees
Have you heard of blockchain technology?	1	Yes
	2	No
Do you know about any use case/application of blockchain technology?	1	Yes
	2	No
The company actively seeks innovative ideas to improve products, procedures, and services. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
The company collaborates with business partners to share ideas. Please	1	Strongly disagree
	2	Disagree

indicate the extent to which you agree or disagree with this statement.	3	Neutral
	4	Agree
	5	Strongly agree
Innovation in this organization is perceived as being too risky and there is resistance to its adoption. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our top management is willing to take risks (financial and organizational) in relation to new technology deployment. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our top management provides strong leadership and engages in the process when it comes to information systems. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our top management provides enough support for blockchain technology initiatives. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our top management understands the benefits of blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our top management considers blockchain technology to be strategically important. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain is conceptually difficult to understand from a business perspective. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain is conceptually difficult to understand from a technical perspective. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
	1	Strongly disagree

Using blockchain technology is difficult. Please indicate the extent to which you agree or disagree with this statement.	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Competition will make it necessary for our organization to implement blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
To be a leader in my organization's industry, it is necessary to implement blockchain. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Some organizations within our industry have already implemented blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain is compatible with the existing information technology infrastructure in the company. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
The use of blockchain is compatible with the company's corporate culture and value system. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
The use of blockchain is fully compatible with current business operations. Please indicate the extent wo which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain technology still requires modifications and developments in order to be useful in our organization. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain technology standards are undergoing frequent changes. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
	1	Strongly disagree

We cannot predict the future of blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
The regulatory body is not yet sufficiently well-established to deal with blockchain issues. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
There might be changes in the regulations that would interfere with our use of blockchain in the future. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Current legal structures do not satisfactorily protect users from problems on blockchain platforms. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will increase transparency. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will increase data security. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will increase productivity and, consequently, reduce costs. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will enhance organizational flexibility. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain enables the automatic reconciliation of accounts and transactions and increases accuracy. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
	1	Strongly disagree

Blockchain will improve traceability. Please indicate the extent to which you agree or disagree with this statement.	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will improve internal management. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
The adoption of blockchain technology will help to better serve our customers and improve our relationships with suppliers. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will increase employee performance. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will increase staff motivation and satisfaction. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain facilitates improved decision making. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Blockchain will allow increased control over work. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
It is feasible/viable to adopt blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our firm can foresee the business potential of utilizing blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree

Our company has professional staff trained in the use of blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our employees have a sufficient level of blockchain technology-related knowledge. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our employees are familiar with blockchain technology. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Our company will not adopt blockchain unless doing so it beneficial. Please indicate the extent to which you agree or disagree with this statement.	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree
Is your organization/company currently implementing or planning to implement blockchain technology?	1	Yes, we are currently implementing blockchain technology
	2	Yes, we plan to implement blockchain technology in the next 12 months
	3	No, but we are considering the possibility of implementing blockchain technology
	4	No, our organization feels that blockchain technology does not suit our needs
	5	I do not know
	96	Other
To what extent is your organization/company currently using blockchain technology?	1	We are currently experimenting with blockchain
	2	We are developing prototype applications
	3	We currently have or are introducing blockchain applications in our organization
	4	We do not use blockchain technology.
	5	I do not know

Appendix 3.3: Changing the Latent Variables Concerning Relative Advantage

Table 31 *The Results of Changing the Latent Variable Concerning the Relative Advantage*

H	Path	Beta	T Values	P Values	Decision
H5	CP -> Adp	0.1809	2.3559	0.0185**	Supported
H1	RA -> Adp	-0.099	1.455	0.165	Rejected
H4	TMS -> Adp	0.222	2.427	0.017**	Supported
H3	Cmpt-> Adp	0.051	0.611	0.556	Rejected
H6	Cmptnc-> Adp	0.250	2.574	0.010***	Supported
H2	Cmplx -> Adp	-0.033	0.567	0.581	Rejected

*** significant at a 99 percent confidence interval

** significant at a 95 percent confidence interval

Chapter 4: The Perceived Impact of Financial Regulation on the Development of Distributed Ledger Technology Firms

Abstract

There is disagreement in the literature concerning the impact of regulation on firms' development and uptake of technology. While some researchers have suggested that regulation impedes firms' development (Jalilian et al., 2007; Poel et al., 2014), others have argued that regulation actually enables firms' development (Mayson et al., 2014; Peck et al., 2018). This chapter aims to foster a better understanding of the impact of financial regulation on the development of token-based DLT firms. To achieve this aim, data derived from in-depth semi-structured interviews conducted with the representatives of 20 European DLT firms during April and May 2019 are drawn on. Interestingly, the results show that financial regulation can both enable and constrain a firm's development.

4.1 Introduction

Regulatory frameworks are sometimes considered drivers of the uptake of technology (Achtenhagen et al., 2017; Peck et al., 2018). By contrast, at other times they are considered to impose excessive compliance burdens (Jalilian et al., 2007; Poel et al., 2014). When it comes to DLT, that is, a shared, replicated, and synchronized database stored in multiple locations at the same time, the regulatory responses at the international level have been quite diverse. In Europe, while countries such as Liechtenstein, Switzerland, Malta, and France have acted as pioneers in terms of passing bills governing the establishment of a regulatory framework for token-based DLT applications, the European Union (EU) has shown some interest in the matter but adopted a more conservative approach.

The use of a P2P network or distributed ledger, cryptography (using codes to protect information and ensure a secure form of communication), and smart contracts (contracts that are auto-executed once a predefined condition is met) means that lots of processes that previously depended on third parties can be disintermediated and automized, as discussed in Chapter 1. Although DLT rose to prominence due to the hype surrounding cryptocurrencies (digital currencies that use cryptography to secure transactions and avoid the double-spending problem) in 2017–2018, it also introduced a completely new way of transferring assets and anything of value, which is known as tokenization. Liechtenstein's pioneering Token and Trusted Technology Service Provider Act, which also governs blockchain, defines a token as "a piece of information on a TT [trusted technology] System which: 1) can represent claims or rights of memberships against a person, rights to property or other absolute or relative rights; and 2) is assigned to one or more TT Identifiers" (Nägele & Bont, 2019, p. 2). In the kind of token "container" model used in this chapter, a token is a digital representation of any right, certificate, obligation, or asset (tangible or intangible), such as a car, a digital identity, a piece of art, an idea, or an innovation. For instance, if the token container is filled with a house, then the token transaction has to comply with the relevant laws concerning real estate ownership.

A regulatory framework should foster the uptake of innovation and prevent fraudulent actions. As the use of DLT is currently growing exponentially, it is giving rise to new challenges in the digital markets worldwide. Some DLT applications do not fit into the established regulatory framework, as they change existing institutions and disrupt centralized systems (e.g., Bitcoin, which is considered in Chapter 1). When using DLT, there is no need to rely on trusted intermediaries for the registration, verification, accountability, and identity of transactions, as discussed in Chapter 1. While the miners could be perceived as intermediaries, the task is really performed by a machine. Moreover, anyone can be part of the mining community and take part in the validation of transactions. As there is no central entity required to comply with regulations, the task becomes even more difficult. Governments are facing the challenge of striking a balance between providing a minimal regulatory framework, which should boost the ecosystem and leave entrepreneurs free to experiment with the most innovative ideas, and ensuring both market stability and the prevention of malpractice. Policymakers must recognize the long-term consequences of the existing lack of regulation for the growth of firms and engage with businesses to draft laws that pave the way for the technology's uptake. Such legislation could help to ensure coordination and community collaboration, which should lead to the establishment of standards and an appropriate regulatory framework.

While there are different types of regulations (e.g., economic, social, institutional, environmental), this chapter focuses on financial regulations. The reason for this is that some of the most prominent use cases of DLT, including its first application (e.g., Bitcoin), are related to finance and financial services, as seen in Chapter 1. Moreover, as token-based DLT applications are related to the transfer of value or rights, the transactions can be subject to financial regulation at any moment. In some European countries as germany, even if an application is not related to finance, the company involved has to comply with financial regulation and undergo an inspection in order to obtain an operational license. This chapter aims to scrutinize the perceptions of small- and medium-sized DLT company owners or managers concerning the financial regulations related to DLT. More specifically, the aim is to answer the following research questions: What challenges are token-based DLT companies currently facing with regard to financial regulations? What are the expected impacts of these regulations on the development of DLT firms? In this way, the chapter seeks to fill the information gap between regulatory institutions and DLT company owners/managers.

Semi-structured interviews were conducted with the representatives of a number of DLT-related companies during April and May 2019. The interview findings not only contribute to the understanding of how regulation can slow or drive the implementation and diffusion of new technology, but can also be used to derive policy recommendations and practical implications for countries that are in the process of developing legislation and legal frameworks regarding DLT. To the best of the present researcher's knowledge, this is the first study to investigate the expected impact of financial regulation on the development of DLT firms.

The remainder of this chapter is structured as follows. The rest of this section provides brief background information concerning DLT, the EU's initiatives, and some existing challenges to DLT financial regulation that companies are currently facing. Section 4.2 reviews the literature on the impact of regulation on DLT firms. Next, Section 4.3 explains the methodology and offers a brief description of the data. Section 4.4 then presents the results of the study. Finally, Section 4.5 discusses the findings, sets out their practical implications, and draws conclusions based on them.

4.1.1 Background

4.1.1.1 Different types of distributed ledger technologies

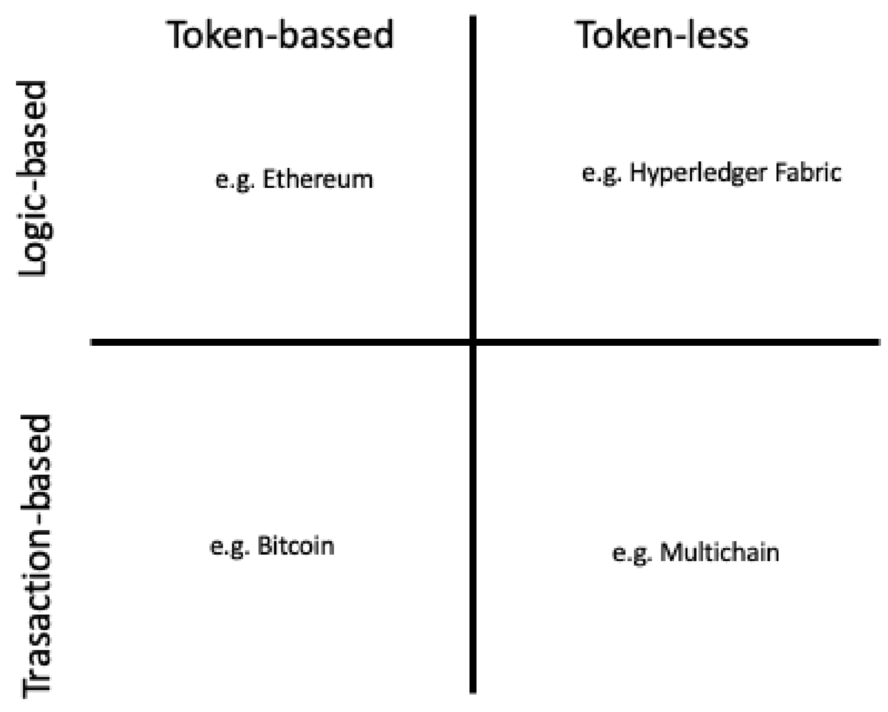
As briefly explained in Chapter 1, there exist different ways to record transactions using DLT, including blockchain. Another way to store and process data in a decentralized fashion is DAG. While some DLTs might use tokens (e.g., Bitcoin and Ethereum[24]), others are token-less (e.g., Hyperledger[25] and Multichain[26]). It should be noted here that although cryptocurrency tokens can be generated using DLT, not all tokens are cryptocurrencies. In addition, tokens can be used as a container (as mentioned above) to transfer a value or a right, such as the ownership, leasing, or lending of a car, a house, a painting, a machine, etc. Tokens can also be used as evidence of an event occurring at a certain time. For example, a token could represent proof of voting, registration of a certificate, or creation of an idea. In some permissionless decentralized networks, tokens are used to incentivize members of the network to maintain the system correctly and keep it updated. In such cases, tokens can be considered the network's fuel. In other cases, tokens can be used as equity (a stake or ownership) or as a claim to a tradable asset. Permissioned networks such as R3 and Corda do not use tokens. In such networks, DLT is used to eliminate middlemen and cut costs, to increase transparency between stakeholders, to track the state of transactions, and to increase both privacy and

[24] Ethereum is a global, decentralized platform for financial and other kinds of applications.
[25] Hyperledger is a multi-project open-source collaborative effort hosted by the Linux Foundation, which was created to advance cross-industry blockchain technologies.
[26] An open-source platform that helps organizations to build their own blockchain applications.

security. Thus, the underlying technology can be used as an instant, tamper-proof, shared database for record keeping without the need for a token to improve an entity's existing internal processes.

Another distinction between the different DLT applications is associated with their running logics (Figure 12). Some platforms have combined smart contracts with DLT in order to enable the running of certain logics or predefined commands (e.g., Ethereum), which are referred to as logic-based DLT. Yet, there are other types of DLTs that aim only to track transactions (e.g., Bitcoin), which are called transaction-based DLT. Although it could be argued that Bitcoin is run through a smart contract, Ethereum allows for the generation of any type of smart contract, not necessarily with the aim of tracking transactions.

Figure 12 *Different Types of DLTs*



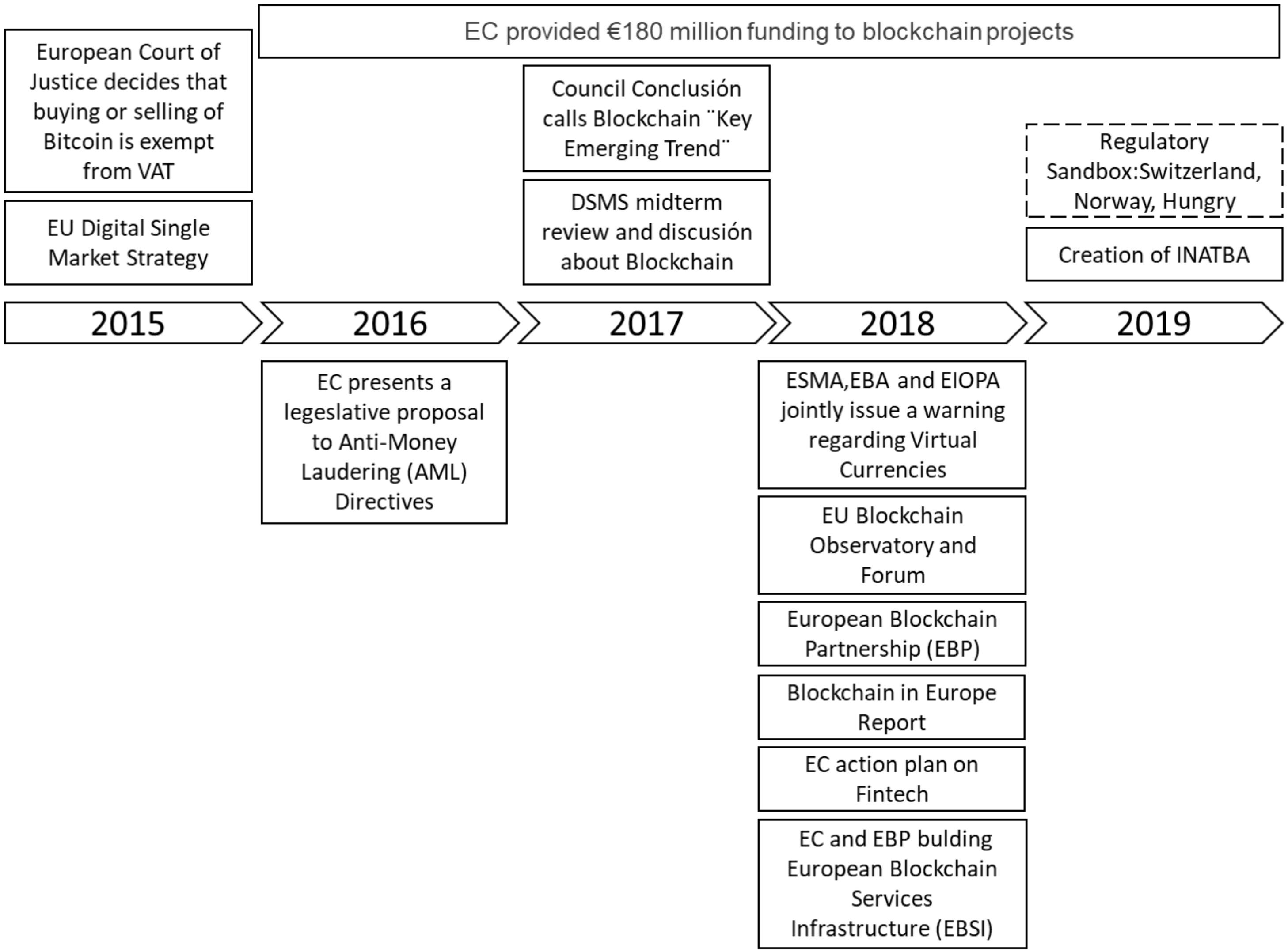
To sum up, DLT is essentially a distributed digital database. It can be combined with other technologies such as smart contracts and/or cryptography to enable a decentralized approach to storing data and transferring value.

4.1.1.2 European Union initiatives

The EU has launched various initiatives to assess the regulatory needs of DLTs. Shortly after the introduction of the first application of the technology (e.g., the Bitcoin cryptocurrency) in 2012, the European Central Bank (ECB) released a report concerning the implications of virtual currencies for monetary policy (ECB, 2012). However, up until 2015, the matter was not assigned much importance. Then, once the acceptance and market capitalization of virtual currencies started growing, the ECB started to analyze cryptocurrencies' potential threats to monetary policy. A timeline of the EU's initiatives related to the development of DLT is provided in Figure 13. It should be noted that the EU's focus to date has mainly been on the financial regulation of cryptocurrencies and its potential impact on monetary policy. Defining a legal framework for other applications of the technology and their potential to decentralize markets across many fields has remained a peripheral issue.

The European Digital Single Market Strategy (DSMS) was created in 2015 to ensure individuals' and businesses' access to online activities (European Commission, n.d.). In the same year, the European Court of Justice (ECJ) announced that any transaction (buying or selling) and exchange of fiat currency for Bitcoin cryptocurrency (and vice versa) is exempted from value-added tax (VAT) (Skatteverket, 2015). A legislative proposal from the European Commission was presented to the European Parliament and Council in July 2016 that obligated all custody wallet providers to implement due diligence processes to prevent, detect, and report protection money laundering and terrorism financing (European Commission, 2016). In 2018, the proposal was approved and published by the European Union (European Parliament, 2018a).

Figure 13 *Timeline of EU Initiatives Concerning the Development of DLT 2015–2019*



On February 1, 2018, the EU Blockchain Observatory and Forum was established to identify, map, and monitor initiatives related to blockchain technology (European Commission, 2018a). Three thematic reports have been published by this initiative since its establishment, namely the *Blockchain Innovation in Europe* (July 2018), *Blockchain and the General Data Protection Regulation* (October 2018), and *Blockchain for Government and Public Services* (December 2018) reports.

Almost one month later, the European Commission released an action plan regarding the opportunities that new technologies such as blockchain and artificial intelligence could bring to FinTech and other economic sectors (European Commission, 2018b). This was followed by the European Blockchain Partnership (EBP) and the publication of the *Blockchain in Europe Report*. The EBP was launched to develop a trusted, secure, and resilient European Blockchain Service Infrastructure (EBSI). It was signed by 26 member states and Norway (European Commission, 2018c). Moreover, the International Association for Trusted Blockchain Applications (INATBA) was founded in March 2019 to establish dialogue with global policymakers and foster the convergence of legal frameworks applicable to the distributed network economy (European Commission, 2019).

Since 2016, the EU has invested over 180 million euros in projects supporting the use of blockchain in technical and societal areas (European Commission, 2019). Although significant effort has been dedicated to rendering the EU an attractive and safe place for DLT companies, such companies still face legal uncertainty and a lack of legal guidelines.

4.1.1.3 Financial regulation challenges that DLT firms face

Decentralization, whereby the need for a central agency is eliminated, represents the disturbance that DLT can bring to the established centralized political, social, and economic systems. The development and introduction of digital currencies, as well as the effects they have had on the economic and banking sectors, are examples of this. Bitcoin's success in terms of disintermediating the monetary system by eliminating the role of central banks and resolving the double-spending problem has raised concerns about national governments' control over monetary policy. Despite the widespread belief that DLT only allows money and payments to be decentralized, it can actually alter the market structures across different sectors. The next generation of DLT has the potential to dramatically automate or digitize tangible and intangible assets, rights, and obligations.

In today's world, it is the responsibility of economic officials to regulate anything associated with value transfer and exchange. Thus, the first applications of DLT primarily related to asset tokenization, such as money, stocks, bonds, and equity, have attracted the attention of the EU's financial regulators. However, while cryptocurrencies have now existed for over 10 years, it seems that governments are still struggling to pin down fundamental issues such as the provision of precise definitions of virtual currencies and tokens in general. In fact, it is not just the definition and classification of tokens that vary across the EU, as the taxation of tokens also seems to be vague and unclear.

The main challenge currently facing token-based DLT firms concerns the lack of a unified EU token definition and classification. For instance, in Germany, while ICOs and security token offers (STOs) are classified as financial instruments, utility tokens do not fall within this classification and so need not be included in a financial prospectus. To date, the Swiss government has acknowledged four categories of tokens: payment tokens, utility tokens, hybrid tokens, and asset tokens. Unlike Germany and Switzerland, which divide tokens into distinct categories, Liechtenstein has established a detailed fundamental definition of a token that captures all types. This has served to broaden the far-reaching scope of Liechtenstein's regulation. Yet, despite such developments, there is still no unified definition and classification of tokens. While some countries are currently engaged in experimentation and have legalized specific types of tokens, others are already working on defining a legal framework for the generic use of tokens so that it encompasses any right.

As the definition and classification of tokens are unified, their absence generates uncertainty concerning taxation as well. Although the ECJ has announced that Bitcoin transactions are exempt from VAT, there is no unified tax treatment of tokens within the EU. For instance, the Danish Tax Council indicated in 2018 that losses from the sale of bitcoins bought as an investment are tax deductible and, further, that earnings are taxable. In France, depending on the type of token issued, corporate revenue tax applies differently. Moreover, personal income tax is applied at a flat rate of 30 percent for tokens qualifying as financial instruments.

The other main challenge currently token-related DLT companies, which may initially seem trivial, concerns the ability to open a bank account. For example, Estonian banks are by law not allowed to open bank accounts for token-generating companies. However, in Germany, some banks allow token exchanges to open accounts, such as

Fidor Bank and VPE Bank. In general, in most other European countries, including the Netherlands, Spain, and Switzerland, DLT companies are struggling to open bank accounts due to their inability to comply with KYC and AML regulations. It is believed that European banks are reluctant to open bank accounts for token-issuing companies due to the market not being fully regulated.

The implementation of the GDPR, which strengthens the degree of data protection throughout the EU, may have caused a conflict between general data protection principles and the key aspects of DLT. Among the challenges that DLT companies are facing in relation to GDPR compliance are the following:

- According to Article 17 of the GDPR, organizations should be able to eliminate personal data once the original purpose for which it was collected has been fulfilled. In other words, users have the right to be forgotten. However, one of the key principles of blockchain technology is immutability or irreversibility. The data stored in blockchain are tamper-proof, meaning that they cannot be altered, which contracts the forementioned article.
- Article 25 of the GDPR states that a data processing system must be built and developed with data privacy issues in mind. To begin with, the incorporation of private data into a public ledger contravenes the availability principle, which states that personal data should not be accessible to unauthorized parties. Furthermore, the confidentiality principle would be violated if it was possible identify users from the transactional data entries stored by DLT.
- Article 4 of the GDPR requires that it be easy to establish who the data controller is. According to this article, data controllers define the objectives for which, as well as the means by which, personal data are processed. As a result, they are designated the primary entity responsible for the obligations and liabilities associated with the processing of personal data. The decentralized structure of DLT calls into question the responsibilities imposed on data controllers by the GDPR. One of the primary benefits of DLT is the elimination of the need for third-party (data controller) involvement. There is no central authority involved in DLT applications such as Bitcoin that administers the system and stores/processes data. This article of the GDPR is likely to collide with business models that aim to achieve decentralization and the elimination of central parties.

It can be concluded that DLT businesses face several significant difficulties owing to the ambiguity of current legislation or the absence of unified DLT legislation within the EU, including coping without a clear classification of tokens, the tax treatment of tokens, complying with the GDPR, and opening a bank account.

4.2 Literature Review

4.2.1 The Impact of Regulation on Firms

Regulation is a tool for protecting both citizens and the environment as well as for fostering economic growth. The impact of regulation on business and the economy has been extensively reviewed in the literature in recent years, and it has been the focus of much discussion among policymakers, academic researchers, and practitioners in the field of economics. A search for the word "blockchain" would have returned more than 20,000 results in 2014, while that number had increased to around 80,500 by 2019. It is not only the number of publications that has increased more than fourfold during the last five years. Debates and discussions concerning the challenges associated with the adoption of blockchain technology have also grown exponentially. While companies seem to be intending to embrace blockchain, regulatory uncertainty remains one of the main barriers to its adoption (Carson et al., 2018). Governments' stance regarding blockchain technology also varies worldwide. While some countries have been totally against the token economy and blockchain, others have tried to create a favorable environment for DLT companies. The EU has been fairly conservative and strict regarding ICOs and STOs, although countries such as Malta, Switzerland, France, and Liechtenstein have followed a more progressive approach and passed bills to establish a regulatory framework for DLT.

A review of the literature identified only a few discussion papers highlighting the importance of the topic as well as some articles concerning the general legislative issues associated with blockchain. As the original idea behind DLT emerged from the activities of anti-system cypherpunks who were against the involvement of trusted third parties in transactions, there are both supporters and opponents of DLT regulation.

The supporters of DLT regulation claim that the inconsistency of established policies and regulatory uncertainty can have negative implications with regard to the adoption and diffusion of DLT. It is believed that the lack of a clear articulation of the government position can limit the applications, hinder the development, and reduce the attractiveness of DLT (Lacity, 2018; Tapscott & Tapscott, 2016). Tsukerman (2015) classified the regulations concerning Bitcoin into those that protect its users (consumers and investors) and those that protect society from its malicious usage, including money laundering, terrorism, drug dealing, and criminal activities. He suggested that governments should accept Bitcoin as a currency and medium of exchange, although they should "deanonymize" it by requiring network participants to reveal their identities (Tsukerman, 2015).

By contrast, the opponents of DLT regulation argue that the technology is still in its infancy and, further, that governmental intervention could prove detrimental to its progress. A study conducted by Yeoh (2017) concerning the regulatory issues associated with blockchain suggested the need for "minimum regulatory brakes" in order not to discourage the innovative spirit that contributes to the transformation of existing systems.

Although the above-mentioned studies all highlighted the importance of DLT regulation, none of them studied the potential impact of regulation, mainly financial regulation, on DLT-related companies, which limits their applicability to the present study. To the best of the researcher's knowledge, this is the first study to investigate the regulatory hurdles that token-based DLT firms have to overcome as well as the technology's expected impact on such firms' development.

4.3 Methodology and Data

Given the need for in-depth qualitative and explorative firm-level studies on the impacts of regulations on businesses (Capelleras et al., 2008; Kitching et al., 2015; Peck et al., 2018), this chapter uses semi-structured interviews conducted with the owners or managers of 20 DLT companies from different European countries to develop insights concerning the impact of financial regulation on the perceptions of the owners or managers of the firms as well as the firms' development.

Desk research was conducted to create a list of DLT companies based in the EU. Emails and LinkedIn messages were sent to potential interviewees. A total of 10 chief executive officers (CEOs) and managers agreed to take part in the study. The sample was then extended to 20 interviewees until data saturation was reached (Guest et al., 2006). The sample comprised representatives of four types of DLT-related companies: DLT consulting firms, DLT token issuers, exchange services platforms, and custody service providers. DLT consulting firms provide legal, technological, and/or financial consultancy services. Exchange service platforms provide exchange services, such as crypto-crypto, crypto-fiat, or fiat-crypto. DLT token issuers use DLT technology to issue tokens as digital currencies, utility tokens, security tokens, or any other right that can be packaged in a token. Custody service providers are third-party entities that safeguard, maintain, and protect other companies' assets or DLT consumers' private keys or identities. Five of the 20 companies were DLT consulting firms. The five associated interviews were used to obtain insights onto the registration process, to better understand the legal and financial challenges that DLT companies face, and more importantly, to acquire background knowledge on the topic. In addition, the interviewees' opinions provided hints of relevance to constructing the semi-structured interviews in such a way as to capture as much information as possible and defining when data saturation was reached. Three of the five interviewees were legal experts who had previously been involved in consultations with different EU countries related to the drafting of DLT-related financial regulations. Thus, their opinions were considered to be biased and, therefore, only used as background information for the researcher. The sample size met the threshold proposed by Creswell (2013) to establish a reliable consensus within heterogeneous samples. Although the sample was homogeneous in terms of the company size and all the companies being involved in DLT, it was heterogeneous with regard to the sector and location. The interviews were conducted during April and May 2019.

The structure of the interviews followed the approach of certain qualitative studies identified in the literature. In the main, the paper by Achtenhagen et al. (2017) was used as a reference in this regard. As can be seen in Figure 15 Percentages of Interviewees by Types of DLT Services, the flow of each interview moved from the company registration to company owners' recommendation to the EU. First, the interviewees were asked to provide a short introduction to their company as well as to narrate the development of the firm since its inception. Then, they were asked about the registration process, including if they had needed to go through licensing, comply with any specific regulation, and/or submit to any audit, and if the company faced any challenges throughout the process. Furthermore, they were asked if financial regulation influenced their businesses and affected the company's growth ambitions. Next, the perceptions of the interviewees regarding the current regulations were investigated. At the end of the interview, they were asked to provide suggestions and recommendations for the EU.

The interviews lasted between 30 and 45 minutes. All of the interviews were recorded and then transcribed. A two- to three-page narrative statement was prepared (Achtenhagen et al., 2017) detailing the thoughts, views, experiences, and attitudes of the interviewees with regard to DLT regulation. Using the verbatim technique, the interview transcripts were analyzed, and keywords, concepts, and recurring issues were highlighted. Moreover, the narrative statements were compared, and a cross-case analysis was performed to identify similarities and differences among the responses. Figure 15 shows the percentages of interviewees by the types of DLT services. it should be noted that 60 percent of the interviewees were involved in token-issuing companies or companies that were planning to issue tokens in the future. Additionally, 25 percent of the sample was comprised of the representatives of DLT consulting companies that provide legal, financial, and technology consulting services. Only five percent of the sample were associated with token exchange services platforms and 10 percent with custody service providers.

A description of the sample can be found in Table 32. It can be seen that the micro firms (companies with fewer than 10 employees) were registered in only one country, while the companies with more than 15 employees were registered in many countries, except for the custodian company based in Liechtenstein.

Figure 14 *Interview Flow*

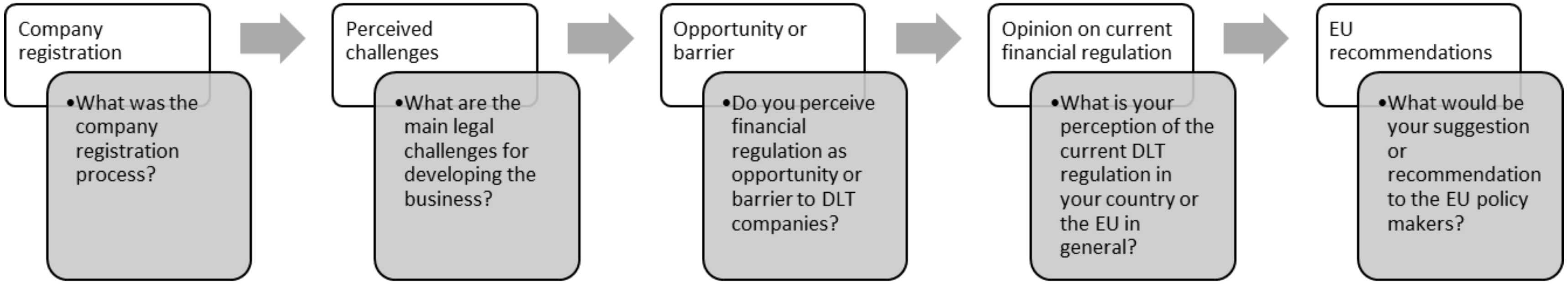


Figure 15 *Percentages of Interviewees by Types of DLT Services*

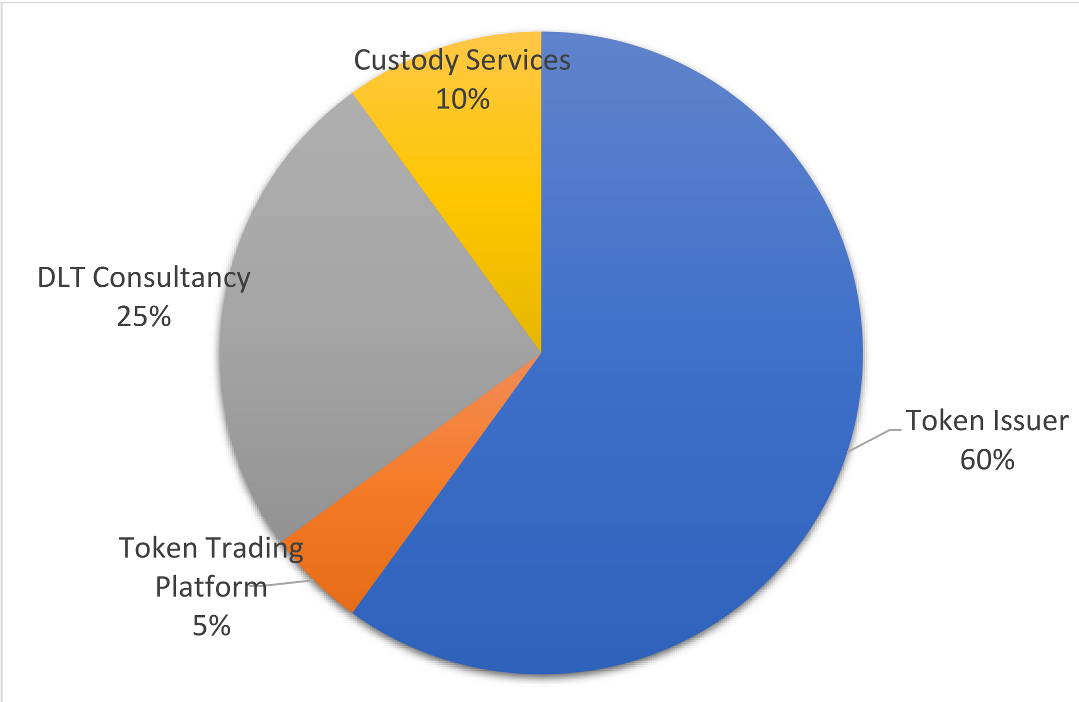


Table 32 *Sample Description*

Firm	Sector	Size	Position	Location	Type
1	Blockchain analytics tools	3	Co-founder and CEO	France	DLT consultancy
2	Identity verification	8	Co-founder and CTO	Malta	Custody service
3	Food supply chain management	4	Founder	Malta	Token issuer
4	Real estate	9	Co-founder	Slovenia	Token issuer
5	Supply chain finance	3	Business developer	Germany	Token issuer
6	Intellectual property	5	Co-founder and business developer	Germany	Token issuer
7	Accelerator	4	Managing director	Malta	Token issuer
8	Blockchain services	25	Marketing director	Malta, Singapore, Korea	Token issuer
9	Token exchange platform	20	Founder and CEO	Liechtenstein, Estonia	Token exchange services
10	Financial services (loan)	50	Co-founder	Switzerland, UK, Malta, Estonia	Token issuer
11	Investment platform	5	Co-founder and CTO	Germany	Token issuer
12	Banking	70	Business developer	Liechtenstein	Custody services
13	Education certification	30	Co-founder and COO	France	Token issuer
14	Agricultural supply chain	10	Co-founder	Switzerland, United States	Token issuer
15	Accounting consultancy	3	Co-founder	Malta	DLT consultancy
16	Computer and network security	7	Founder and CEO	Germany	Token issuer
17	Consulting services	4	Co-founder	Germany	DLT consultancy
18	Consulting services	2	Co-founder	Latvia	DLT consultancy
19	Education	4	Co-founder and CEO	Germany	Token issuer
20	Consulting services	5	Founder	Malta	DLT consultancy

4.4 Results

As the consulting firms had to go through the normal registration process that every company must comply with, they were not faced with any challenges related to financial regulation or obtaining a license. Only two companies had to undergo an extra inspection because the words "DLT" and "blockchain" were mentioned in their application forms. One of the consulting firms that accepted tokens was experiencing some problems opening a bank account and dealing with taxation matters.

> One of the difficulties, even up until today, is to open a bank account, as we do accept cryptocurrencies. Another problem involves finding a tax consultant who is ready and willing to do our tax audit, as some of them do not really understand token transfers (Interviewee 18).

The main results of this chapter have been derived from the interviews conducted with the representations of 15 DLT companies that dealt with tokens directly and had to obtain a financial license in order to operate legally under European financial regulations. Five of the 15 firms had successfully issued tokens in Europe. Moreover, seven were in the process of issuing tokens or planning to issue them in the future. One company was registered as an exchange service platform, while there were also two custody service providers in the sample. The following sections analyze these companies' opinions about financial regulation, the challenges they face, the impact of those challenges on their business development, and their proposed solution or suggestions for the EU.

4.4.1 Opinions Concerning Financial Regulation

As shown in Figure 16, most of the interviewees were positive regarding financial regulation and the availability of a clear framework within which to operate legally. Regulations were expected to be good for companies. The interviewees believed that defining a legal framework for tokens could provide legal certainty and clarify what is and is not allowed. In addition, they assumed that financial regulations could protect consumers, investors, and society in general from scammers and so provide peace of mind to both users and company owners. Working through financial regulations and obtaining a license was associated with trustworthiness, higher quality, and increased credibility. It was also believed that clear and concise regulations could reduce the risk associated with tokens and increase the level of trust in both the technology and tokens in general.

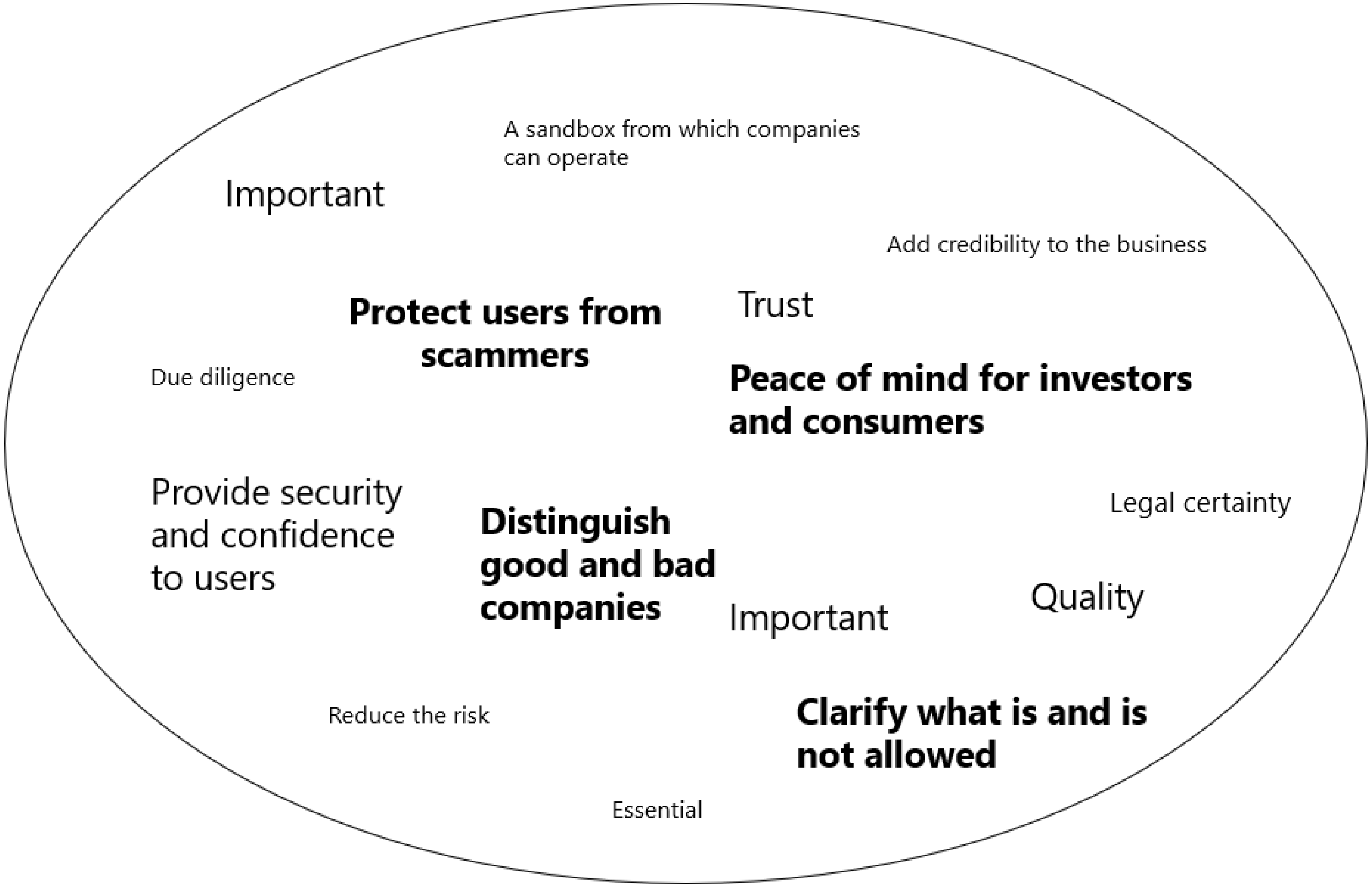
According to one of the CEOs, “Getting all the certificates means that you are adding credibility to your business” (Interviewee 9).

Another CEO mentioned the following: “I think that for us, it is very good to have legislation because it is going to provide confidence and peace of mind to our users” (Interviewee 2). In addition, the interviewees emphasized that over-regulation should be prevented, as excessive systems of regulations are considered to hinder both innovation and creativity. As one company owner stated,

> What’s key is that these regulations should not be saying you must do this or that, because if you are told what to do then innovation is completely stopped. [...] regulations should not limit companies so that innovation that might go against the regulations is not pushed away and not looked down upon and it is still embraced (Interviewee 15).

The interviewees considered minimal financial regulation or the updating of existing regulations to be desirable. It was suggested that policymakers need to understand the technology in order to develop a balanced legal framework that drives innovation and protects society from malicious actions.

Figure 16 DLT Company Owners' and Managers' Perceptions of Financial Regulation



Overall, there was consensus among the interviewees that having a minimal, clear, concise, and DLT-friendly legal framework for companies that deal with tokens was desirable. However, it should be noted that the interviewees expressed the notion that a framework exceeding the minimum level could harm innovation and creativity. Thus, while the company owners exhibited a positive attitude toward a minimal legal framework that protects consumers and investors from malicious actions, they stressed that there was no need for more or excessive regulations.

4.4.2 Perceived Challenges

Most of the companies included in the sample faced some challenges when seeking to comply with financial regulations. When asked about the registration process, the CEO of one DLT company that had passed through the process of issuing a token stated the following:

> There are two ways that a serious company can play. One way is to engage in regulatory arbitrage, meaning that the company, for certain operations, chooses some jurisdictions where the regulation is lighter or non-existent and then for other parts of the business, applies for licenses. The other way is to apply for licenses everywhere that the company wants to operate (Interviewee 11).

It appeared that while it was fairly easy to obtain certificates in some countries, it was much more complicated in others. As of December 2017, all virtual currency exchanges and custodian wallet providers within the EU must go through AML checks. Among the companies that had not yet issued tokens, some had gone through the regular financial company registration process, while others were still in the process of obtaining the require certificate from the authorities. Some of the challenges expected by the company owners and managers, as well as their potential impact on firm development, are presented in Table 33.

Table 33 *Expected Financial Regulation Challenges and Their Impact on DLT Companies*

Challenges	Expected Impacts on Companies
• Lack of unified financial regulation within the EU • Lack of regulation clarity • No guidelines • Difficulties of opening a bank account • Authorities lack DLT knowledge • Slow (time-consuming) certification process • lack of unified tax regime • High costs associated with obtaining a license • Old and not updated regulations • Need to comply with AML/KYC provisions	• Slows down the company's growth • Prevents the company's expansion • Hard to structure the business • Requires putting some plans on hold • Limits innovation • Changes the market strategy

The two challenges that were mentioned by almost all the interviewees were the lack of unified EU financial regulation and the lack of regulation clarity. As mentioned by one of the interviewees above, the lack of unified financial regulation concerning tokens within the EU means that companies have to acquire a certificate in each country in which they operate. Moreover, even when a company wants to apply for a license, as there is currently no clear definition and classification of tokens, the company faces confusion as to what kind of certificate they have to apply for, what kinds of regulations they have to comply with, and their expected tax treatment. This is why prior to applying for a license, companies almost always have to consult a legal firm, which in generally expensive.

In addition, the process associated with obtaining a license was reported to be time-consuming and slow, as the authorities have to go through each case individually. As one of the company owners mentioned, "If the company wants to expand, it needs to acquire licenses in different countries, and this costs money and takes time. Thus, they prevent anything from happening quickly" (Interviewee 6). Another CEO stated that "Still the government does not have a good definition of tokens and there is not a proper process defined for companies to go through" (Interviewee 5).

The five interviewed co-founders mentioned the lack of guidelines to be one of the main challenges facing them. Again, this goes back to the two challenges mentioned above. As the EU countries do not provide a clear definition and classification of tokens or clear financial regulations, they cannot provide clear guidelines. The interviewees believed the existing financial regulations to be old and out of date. As a consequence, new technologies and start-ups working with technologies such as blockchain do not fit within the remit of existing laws. The interviewees considered there to be no need for new regulations; rather, governments just need to update old regulations. Another challenge faced by the interviewees involved dealing with authorities that have only limited knowledge and understanding of DLT. One interviewee stated the following in this regard:

> Most of the challenges that start-ups face are due to the lack of blockchain-related understanding on the government's side. The government should study it in order to come up with a sustainable way to promote technology in the long term (Interviewee 8).

Yet another challenge that the companies dealing with tokens faced involved the difficulty of opening a bank account. Indeed, some 80 percent of the interviewees mentioned that opening a bank account was the main challenge that their company had needed to overcome. Not all companies are able to comply with KYC and AML requirements. Moreover, even if they do comply with these laws, the mere fact of working with tokens can result in bank account rejections. As a co-founder and CEO of a token-issuing company explained, "It is extremely difficult to own cryptocurrencies [tokens] as a company and open a bank account" (Interviewee 7). Another interviewee mentioned that "Right now, start-ups and companies have the hardest time establishing banking relationships" (Interviewee 1).

To sum up, the main challenges that the DLT firms included in the sample faced while working through financial regulations were the time-consuming and costly certification process, the difficult associated with opening a bank account, and the lack of a clear and unified definition and classification of tokens.

4.4.3 Expected Impact of Regulation on Firms' Development

With regard to the impact of financial regulation on DLT firms' development, although the companies included in the sample faced challenges in terms of complying with existing regulations, the main problem they faced actually concerned the lack of clear financial regulations. The certainty and clarity of financial regulations are closely related to firms' stability, expansion, planning, and future growth. At the same time, the interviewees believed existing financial regulations to be time-consuming and costly and, further, to even hinder firm development. Thus, they considered that financial regulation can both impede and enable firm development.

The interviewees reported financial regulation to have two types of impacts on the development of DLT firms. The first type of impact is associated with the negative effects of existing regulations, while the second is concerned with the negative effects of unclear or uncertain regulations.

First, countries such as Malta and Liechtenstein have enacted financial regulations regarding DLT companies. For instance, custody wallet providers and token issuers in Malta have to comply with the requirements of the Digital Innovation Authority (MDIA) Act, the Virtual Financial Asset (VFA) Act, and the Innovative Technology Arrangements and Services (ITAS) Act. Two companies included in the sample had already worked through these regulations, while two other companies were in the process of doing so. One company manager mentioned that the company had moved to Malta in the hope of dealing with better regulations, although its top management had been disappointed because the authorities were still in the process of drafting amendments and asked for more time to review their case:

> As we had to do ICO fundraising, we could not wait six more months for the government to approve the license and so decided to move to another country with an easier certification process (Interviewee 8).

The impact of complying with such regulations was considered to be negative in some cases. One CEO mentioned the following:

> Although complying with financial regulation is not a problem, it is a matter of efficiency. The less you have to comply with, the quicker you can operate and adapt to changing circumstances. It is just time-consuming, and some costs should be taken into account (Interviewee 11).

By contrast, certain company owners believed that going through the process proved their company to provide higher-quality service and to be more trustworthy than competitors. Obtaining a certificate added competencies to the company and could be used as a differentiator:

> VFA agents are gatekeepers with primary due diligence and act as a middleman between the DLT companies and the government. Although costly, it helps to distinguish the good and bad companies (Interviewee 2).

Another interviewee mentioned that "As already said, the cost is high and maintaining those costs for a start-up is a great hindrance, but on the other hand, it enables [the government] to filter the companies" (Interviewee15).

Thus, working through the regulations and acquiring a certificate was considered to have both positive and negative impacts on firms. A certificate can be used as a tool for adding credibility and trust to the business, which can enable growth. However, obtaining a certificate also requires financial resources, which means that the process can impede firm growth.

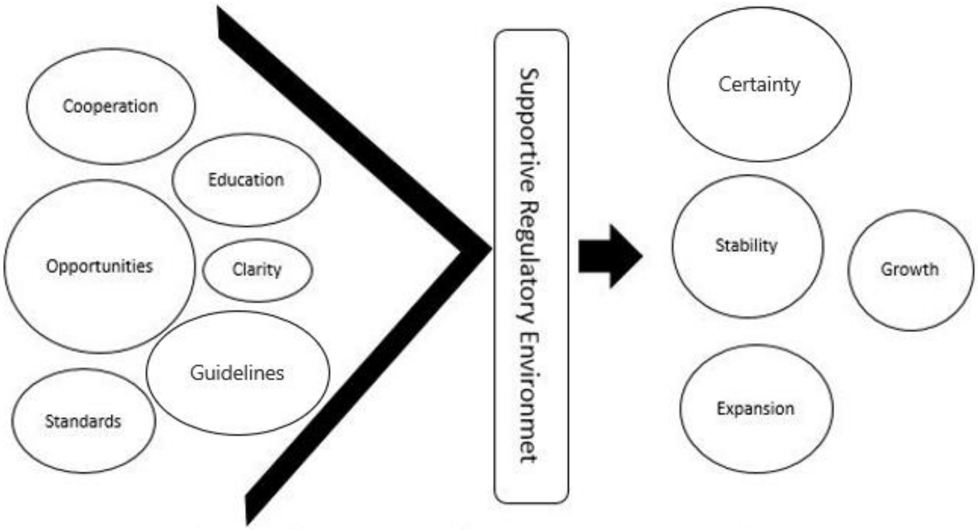
Second, the lack of a clear definition, classification, and recognition of tokens both at the national level and across Europe was said by the interviewees to result in negative impacts on DLT companies' development. Difficulty in terms of structuring the business was reported to be one of these negative impacts. As a company owner argued, "Since there is no unified financial legislation across Europe, it is sometimes hard to structure a business" (Interviewee 12). The lack of clarity with regard to financial regulation was also reported to have caused some companies to postpone issuing tokens or pushed them to change their go-to-market strategy, which was again expected to slow the company's growth. "It is not clear what is allowed and what is banned, so we are unable to grow at the rate that we were hoping. We cannot expand at the same rate that we had planned to" (Interviewee 4). Another co-founder and CEO related the following:

> At the beginning, we wanted to issue a token, but knowing that there are no clear token regulations and that we have to pass through the financial regulations, which is difficult, we have decided to register a non-profit company for now and start with the simple things that do not need lots of regulations. [....] We have changed our go-to-market strategy (Interviewee 5).

In addition, the interviewees believed that the lack of homogenized EU financial regulation meant that companies cannot expand the scope of their operation easily, as they have to apply for licenses in each country in which they want to operate in. As one CEO stated, "We cannot expand and fundraise in an effective way or the way that we had initially planned" (Interviewee 3).

Again, the interviewees considered that while the process is clear in some countries, not having a unified EU regulation requires companies to register in various countries in order to be able to operate in them all, which means higher costs for the companies as well as more capital being expended on regulatory compliance. In other words, the interviewees believed that having minimal, clear, concise, and simple regulations could serve to create a supportive legal framework capable of helping companies to execute their plans, expand their markets, and grow faster (see Figure 17).

Figure 17 *Expected Impact of a Supportive Regulatory Environment on DLT Firms*



In sum, the present findings support Kitching et al.'s (2015) theory concerning the dynamic influence of regulations on firm development. Regulations can provide companies with the opportunity to introduce new products and services, as well as to enhance trust, credibility, and competence, while at the same time requiring resources such as time and money, which can impede growth. Thus, while regulations can enable some companies to operate in a legal environment and provide trust, confidence, and peace of mind to consumers, investors, and users alike, they are associated with certain costs and so are believed to impede firm development.

4.4.4 Proposed Solutions

Given that most of the companies in the sample agreed that it is essential and desirable to have a legal framework that allows DLT companies to grow their businesses in a regulated environment, the interviewees were asked to offer some suggestions or recommendations for the EU.

Education. The interviewees believed that policymakers should educate themselves, pay consultants for advice, or cooperate with start-ups or companies involved with DLT in order to develop a legal framework that is applicable to the technology and does not harm its further development. One company owner stated the following in this regard:

> [The] EU should assign a young team that understands the technology to work closely with start-ups and basically just observe what they are doing. Based on those learnings and findings, they would be able to create great regulation (Interviewee 6).

Another CEO suggested the following:

> Governments should put out a consulting questionnaire to gather a lot of information about the problems that companies are facing and get as many companies or start-ups as possible to participate. Or hold round-table talks and panels with experts to discuss the technology (Interviewee 5).

The interviewees also believed the consumers and users have to be educated as well:

> The best tool is to have the consumer well educated, since having a well-educated consumer means that they know what they are going through and what will be the consequences of their actions (Interviewee 15).

Provide a unified definition and classification of tokens. As mentioned above, the lack of a clear and unified financial regulation was perceived by the interviewees as a main challenge facing DLT companies. As one interviewee stated, “The EU has to provide an unambiguous and unified definition of what tokens are and how they’re going to be treated” (Interviewee 5). Another DLT co-founder and CEO commented, “Governments should define what tokens are. Are they currencies? Are they commodities? Or are they going to be treated as securities?” (Interviewee 1).

Provide guidelines. Once policymakers have been educated and some legal frameworks have been defined, the interviewees believed that companies should be provided with guidelines concerning registration and the requirements for technology providers, token issuers, and custody service providers. “They [policymakers] should educate themselves and then provide guidelines for companies that want to set up in Europe” (Interviewee 8). Another company owner suggested that the “EU can provide guidelines or general benevolence toward blockchain companies and start-ups so that they can provide useful services” (Interviewee 1).

Provide a unified tax regime. The interviewees believed that having a simple and unified tax regime would not only save time, but also reduce the amount of money that has to be spent on accountants and lawyers. As one company owner stated, “Once the government embraces tokens and defines how taxes can be paid, we will be more than happy to pay for it” (Interviewee 9).

Be cautious about not over-regulating. This point was stressed by almost all the company owners. Phrases such as “less is more” (Interviewee 1), “as little as possible, but as much as needed” (Interviewee 6), and “it should not be surpassed” (Interviewee 10) were used by the interviewees to emphasize that by regulation, they do not mean more restrictions or greater regulatory compliances; rather, they only want the government to provide a clear legal framework. An analogy was provided by one of the company owners, who commented that parents cannot prevent their children from swimming simply because they are afraid that the children might drown. The same analogy was applied to DLT regulations as follows:

> [The] EU should be alert not to regulate the market too much and injure the progress of the companies and their innovation just to provide security and peace of mind to the consumers. [...] I do not like the situation where, because of safety, people are not trying to learn how to swim (Interviewee 6).

The same point was mentioned by another CEO:

> Regulations should not put the company under pressure. I mean, the government should come up with a favorable legal framework to support token companies and protect consumers from scammers (Interviewee 14).

Learning process. The interviewees believed that companies should be given the opportunity to test their ideas. They mentioned that governments should set a point after which companies have to obtain a license or go through financial regulations such as the KYC and AML requirements. According to one company owner:

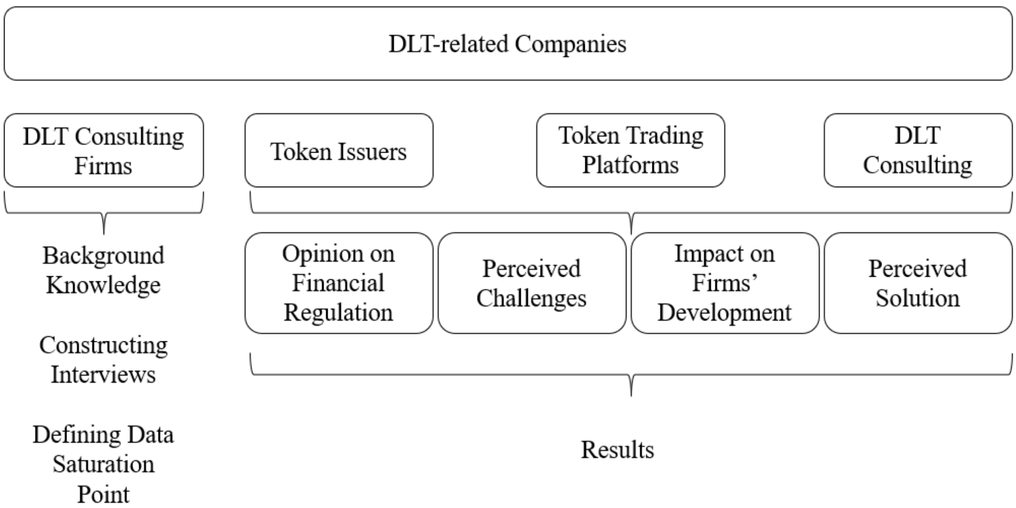
> One way could be that the government lets the companies register and do their activity until they reach a specific volume of sales. As soon as they grow and reach the boundary, ask them to apply for a license (Interviewee 6).

In short, the interviewees believed that educating consumers, investors, and policymakers was key. Moreover, a clear and unified definition, classification, and tax regime supported by guidelines was suggested to enable DLT firms to operate in a regulated environment. However, the interviewees pointed now that a balance should be struck so as to prevent over-regulation. In addition, companies should be assisted through the provision of precise guidelines. The interviewees also suggested that entrepreneurs should be given the opportunity to trial ideas and experiment.

4.5 Discussion and Conclusion

This chapter investigated the impact of financial regulation on the development of DLT companies, mainly token issuers, trade or exchange platforms, and custody service providers, using qualitative semi-structured interviews. First, interviews were conducted with representatives of DLT consulting firms to acquire background knowledge, construct the semi-structured interview questions, and define the data saturation point. Then, the representatives of 15 DLT companies were interviewed to determine the company owners' and managers' perceptions of financial regulation, the challenges that DLT firms face, the impact of those challenges on firm development, and how the challenges could potentially be solved (see Figure 18).

Figure 18 *Level of Analysis and Classification of Results*



The findings presented in this chapter revealed that almost all the company owners and managers included in the sample agreed that there should be a minimal regulatory framework through which companies can operate legally, although policymakers should be cautious about not surpassing the required regulations. The attitudes of the interviewees toward minimal regulation and a clear legal framework were positive. Most of the company owners and managers linked working through regulations to enhanced credibility, trust, peace of mind, quality, competence, differentiation, and security. While many of the companies faced difficulty in opening a bank account, complying with the AML and KYC requirements and the GDPR, paying taxes, and working through the slow and costly regulation process, the interviewees believed that the EU should develop a unified definition, classification, and tax regime for tokens. Such regulation was assumed to enable growth, increase certainty and stability, and even drive innovation.

Thus, the results discussed in this chapter support Kitching et al.'s (2015) theory concerning the dynamic influence of regulations. It is believed that financial regulation can both enable and impede the growth of DLT firms. Abiding by the requirements of existing regulations can prove challenging, time-consuming, and costly, which can hinder expansion and growth. Yet, once a company has worked through the regulations, the associated certification can provide peace of mind and confidence to users, in addition to being associated with a better, more trustworthy, and higher-quality service, which can provide credibility and new competences to the company. The findings also indicate that the lack of a clear and certain regulatory environment can harm companies because they may not be able to execute their plans on time, expand their market, pay taxes, and grow. Therefore, financial regulations should be considered a double-edged sword that depending on how, by whom, and where it is used, can either enable or hinder growth.

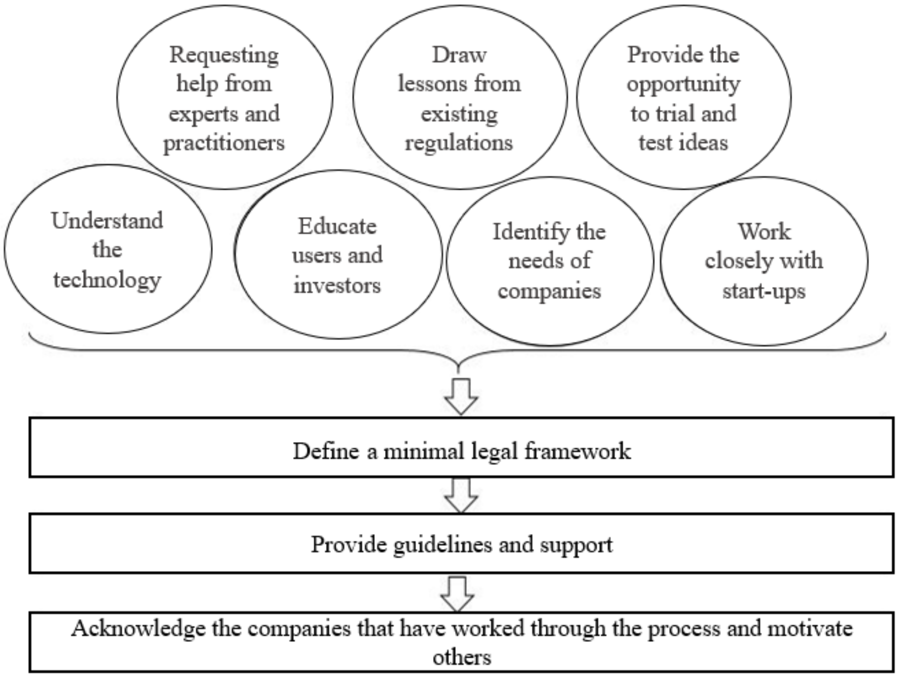
The amount of regulation has also been found to matter. Minimal regulations could pave the way for entrepreneurs to operate, while excessive regulations are presumed to stifle innovation and stop entrepreneurs from testing their innovative ideas. However, what would the limit be for financial regulations? Perhaps "as little as possible, but as much as needed" (Interviewee 6). It is preferable for DLT enterprises to be proactive in terms of establishing how DLT is regulated by EU lawmakers, who may not be DLT savvy.

4.5.1 Practical Implications

This chapter sought to extend the literature concerning the impact of regulation on DLT firms. More specifically, it investigated the impact of financial regulation on the development of DLT firms, a subject that has not previously been investigated. The findings have practical relevance because this topic is one of the most pressing issues when it comes to regulating DLTs within the EU. The findings presented in this chapter not only give a voice to small- and medium-sized DLT companies, but also fill the information gap that policymakers need to address when introducing a legal framework that both protects society and drives innovation.

This study determined that financial regulation can both facilitate and hinder firm growth. Thus, legislators should be cautious when defining a legal framework for DLT so as not to over-regulate the technology and stifle innovation. Some policy recommendations were offered by the interviewed company owners and managers to help lawmakers with defining a practical and supportive legal environment. Examples of these recommendations can be found in Figure 19.

Figure 19 *Proposed Solutions and EU Policy Recommendations*



For a legal framework to work, policymakers (and society) should be educated so as to better understand the technology, work closely with start-ups, consult with experts and practitioners, identify the needs of companies, learn from the regulations enacted in other countries, and provide opportunities for companies to test the technology without being obliged to comply with strict regulations. Once a minimal legal framework has been defined, governments should provide guidelines and support in order to minimize confusion and help companies to reduce both the time and the money that they have to spend on legal compliance. Finally, the companies that have successfully worked through the regulation process should be acknowledged, which should serve to motivate other companies to follow the same path. The findings also suggest that if regulations are carefully designed, they will both ensure the safety of citizens and attract DLT firms, which are considered to form the backbone of any economy.

4.5.2 European Union Initiatives Since 2019

The 5th AML Directive was adopted in 2018 in an effort to combat money laundering, tax evasion, and fraud involving cryptocurrencies, although member states had until January 10, 2020, to change their national legislation in order to comply with the new Directive. Furthermore, the European Commission conducted an in-depth review of the issues faced by enterprises and other institutions when dealing with tokens and DLTs. It acknowledged that categorizing all DLT solutions within the Markets in Financial Instruments Directive and subjecting them to established EU securities market laws might hinder innovation. Relatedly, the European Commission announced its proposed Markets in Crypto Assets (MiCA) Regulation on September 24, 2020, as part of a larger set of publications concerning Europe's Digital Finance Strategy.

Other legislative proposals accompanied the proposed Regulation, including clarification that the existing definition of "financial instruments" —which defines the scope of the Markets in Financial Instruments Directive (MiFID II) —includes financial instruments based on DLT, as well as a pilot regime governing the DLT market infrastructures for such instruments. As a result, the European Commission suggested a pilot program for market infrastructures seeking to experiment with the trading and settling of financial instrument transactions in crypto-asset form. The Senate enacted the Bill for the Digital Transformation of the Financial Sector in November 2020 in Brussels, which created a suitable legislative environment to guarantee that innovation in the financial sector can be conducted efficiently and safely in relation to users. Then, in collaboration with the European Commission, the EBP announced plans for a pan-European "regulatory sandbox" for DLT use cases, which is projected to be operational in July 2022.

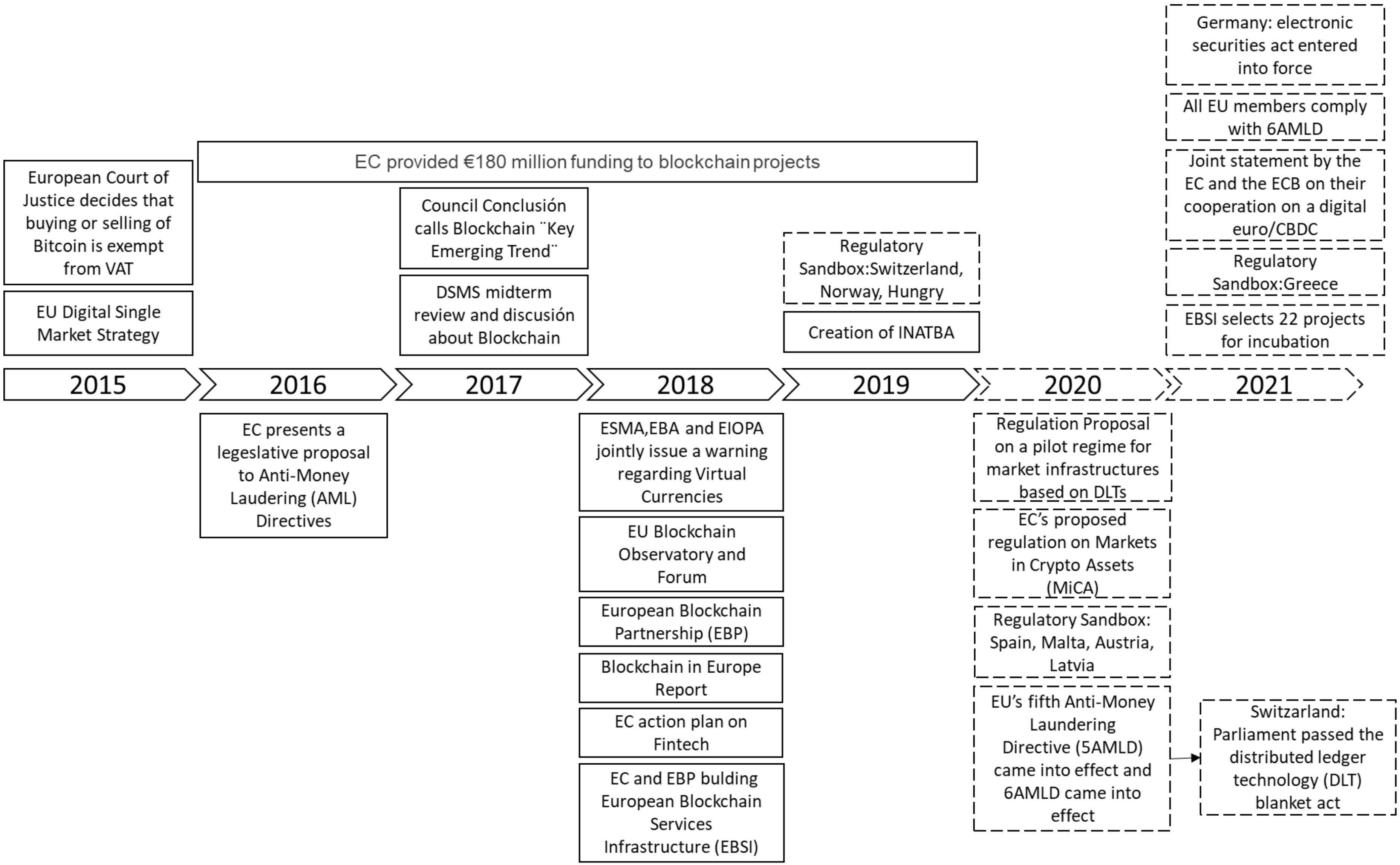
The regulatory sandbox was presented as a testing environment in which the supervisory authority would allow the real-world testing of new technology-based financial initiatives under the control and supervision of a competent body. Similar regulatory sandboxes have previously been introduced in European countries such as Switzerland, Norway, and Hungry. Certain other countries, including Spain, Malta, Austria, and Latvia, introduced country-level sandboxes in which DLT firms are allowed to operate in parallel to the establishment of the pan-European regulatory sandbox.

In Switzerland, the DLT blanket legislation, which selectively changed 10 existing federal laws, was enacted by Parliament in September 2020. The Swiss Federal Council agreed that the first portion of the DLT Act, which concerns register value rights (also known as ledger-based securities), would enter into force on February 1, 2021. The second portion of the DLT Act then entered into force on August 1, 2021, introducing a new DLT trading system license, an extension of the FinTech license to collectively held crypto-based assets, and a contentious expansion of the scope of the Anti-Money Laundering Act.

In addition, the 6th AML and Counter-Financing Directive (6AMLD) came into force in December 2020 (European Parliament, 2020). By June 2021, all crypto companies within the EU were required to comply with the Directive, which increased the severity of criminal punishments while also broadening the reach of established legislation. Criminal culpability was also expanded to encompass the prosecution and punishment of legal entities under the 6AMLD.The Electronic Securities Act, which allows for the issuance of bearer bonds utilizing new technologies such as DLT entered into force in Germany on June 10, 2021 (Ministry of Finance, 2020). It created a legal framework for trading rights through electronic securities registers and provided a new licensing category for maintaining a crypto securities register. One month later, the ECB announced a digital euro initiative. The two-year study phase began in October 2021. Other countries such as Greece also announced the introduction of regulatory sandboxes to enable DLT companies to innovate and trial new solutions.

In 2021, 22 projects were chosen to participate in the EBSI initiative to supply cross-border services and invited to develop their own pilot projects to address business and public administration needs (European Commission, 2021). Some of these regulations, specifically the MiCA, address issues addressed in the present study, including greater clarification concerning definitions, the taxation of crypto assets, licenses, and the operation mechanism for DLT firms, as well as providing regulatory guidelines and assistance to DLT companies. A consider number of initiatives have been implemented, particularly in recent years. Yet, the 28 EU states deal with the issues separately, taking into consideration the European Parliament's remarks but putting them into effect in their own way. More time is required to achieve unified pan-European financial regulation regarding DLTs that addresses all the challenges currently facing firms.

Figure 20 *Updated Timeline of EU Initiatives Related to the Development of DLTs 2015–2021*



Main Findings

This dissertation sought to investigate firms’ uptake of DLTs such as blockchain. It comprises four chapters that each attempted to answer a different research question related to the overall aim of the dissertation. The fundamentals of DLT in general and blockchain in particular were described in Chapter 1, while Chapter 2 systematically investigated the potential of DLT to tackle the barriers to open innovation adoption faced by SMEs. The factors related to DLT adoption were studied in Chapter 3, while Chapter 4 explained the challenges concerning financial regulation currently facing DLT firms. The focus throughout the dissertation was on understanding the applications of DLTs, the factors associated with the adoption of the technology, and the financial regulatory challenges facing DLT firms.

Chapter 1 introduced and defined the main concepts that serve as an introduction to the topic, thereby contributing to a better understanding of the benefits, challenges, and applications of DLT. An extensive literature review was conducted to identify the applications of the technology in different sectors, namely the financial, energy, healthcare, and supply chain sectors. The results showed that the potential uses of DLT and blockchain are immense. In addition, they have the ability to drastically revolutionize various corporate processes and disrupt existing sectors. The excessive hype and lack of knowledge regarding DLT have resulted in the slow adoption of the technology and investments in solutions that do not add value to companies. Thus, a decision tree was designed to help executives evaluate the suitability of blockchain in certain scenarios. The conceptual results of Chapter 1 can be used as guidelines for future research and industry applications.

Chapter 2 investigated the opportunities that DLTs offer for SMEs when it comes to tackling some of barriers they face in relation to the adoption of open innovation. The findings, which were based on expert interviews, showed that various problems can be solved or alleviated using DLT in this context. These problems include external difficulties with contracts, financing, lack of trust, raw materials, lack of information, domestic and international market limitations, IP rights, governmental regulation, and bureaucracy. Moreover, the internal challenges that can be solved include insufficient funding, outdated organizational systems, and lack of trust. The findings also revealed that while DLT can be a beneficial tool for fostering open innovation, SMEs might face challenges such as integration issues, high costs, lack of available talent, and unclear legislation when adopting it.

In Chapter 3, a total of 800 company managers from different sectors in Spain were surveyed to identify the technological, organizational, and environmental factors that impact firms' willingness to adopt blockchain technology. The first consideration was that only a small percentage of firm executives (20–25 percent) knew about the technology and its applications. This finding empirically supported the proposition put forward in Chapter 1 that many company managers still lack sufficient understanding of the technology and its uses. Among the variables included in the conceptual model, competitive pressure, top management support, and competence were all found to have significant impacts on blockchain adoption, while technological factors such as relative advantage, complexity, and compatibility were not found to have significant impacts on managers' decision to adopt DLT.

Using qualitative semi-structured interviews, Chapter 4 investigated in more detail company owners' and managers' perceptions of financial regulation, the challenges that companies are experiencing in that regard, the impact of those challenges on firms' development, and the solutions proposed for authorities and policymakers. The lack of unified financial regulation (including a specific tax regime) for DLT solutions within the EU, the lack of guidelines, the costly and slow nature of the certification process, and need to comply with both the AML KYC requirements and the GDPR were identified as challenges currently DLT firms. While regulation in general was perceived to be a challenge, the firm managers supported the pursuit of regulatory clarity and believed that it could pave the way for entrepreneurs to innovate. They also believed that excessive regulation would stifle innovation and prevent entrepreneurs from testing their most innovative ideas. The results further revealed that the differing perspectives on DLT have resulted in the concurrent yet uneven development of the technology, its use cases, and technological regulation. As a result, the space has become fragmented. Thus, the interviewees suggested that policymakers should educate themselves and society, seek to better understand the technology, work closely with start-ups, consult with experts and practitioners, identify the needs of companies, learn from the regulations enacted in other countries, and provide the opportunity for companies to test the technology without being obliged to comply with strict regulations.

Future Research Directions

As explained in Chapter 1, empirical studies concerning the applications and uses of DLT remain relatively rare because it is still considered a nascent technology and many companies are still in the early stages of adoption. The present study not only serve to help managers evaluate the use of blockchain versus the use of conventional databases, but also provides information on different applications and use cases of the technology in various sectors, including how it can be used as a tool for fostering open innovation and the factors that impact its adoption. The results presented in this dissertation also add value to the technology adoption theories and provide insights for policymakers regarding the regulatory challenges DLT companies face as well as the actions they must undertake to both protect customers and support DLT companies. This study opens up the possibility for further empirical research concerning the applicability of DLT in relation to solving real market problems.

In terms of open innovation, Chapter 2 provided an exploratory framework that can serve as the basis for future research. Further empirical studies are required to validate the present results and ensure their generalizability. Although this study captured numerous challenges that SMEs might face when implementing open innovation practices, it failed to consider the post-implementation phase in which companies have already adopted open innovation and how the technology can support post-adoption challenges. A number of specific areas, such as the use of DLT to improve IP protection, the incentivization of employees, and the involvement of customers and suppliers in the open innovation process, require further detailed investigation. It is suggested that researchers pay attention to the problems that the experts believed DLT could address and conduct further empirical research to validate the related findings.

With regard to the adoption of blockchain, the findings presented in Chapter 3 highlighted the need for a more comprehensive theoretical framework capable of capturing the impacts of elements not been included in the model suggested in this study (e.g., costs, uncertainty from both the regulatory and technology development perspectives, standardization, etc.). While this study extended the limited qualitative research on blockchain technology acceptance, its findings were limited to a specific geographical location. This means that there is potential for future investigations based on a wider framework, which might result in a more thorough analysis of blockchain adoption among European firms. In addition, the investigation of specific use cases of companies that have already adopted DLT should be highly encouraged. Such studies could provide more information about the advantages of the technology in different scenarios as well as the associated costs.

Based on the findings presented in Chapter 4, there have been various developments related to DLT regulation in Europe in recent years. It would be interesting to further examine if DLT will eventually result in the evolution of existing financial legislation or the enactment of new laws in Europe. Future researchers could investigate the differences and similarities among the financial regulations of countries that have already taken a step toward regulating DLT. Furthermore, there is room for empirical studies to determine the impacts of specific regulations such as the GDPR and the KYC and AML requirements on DLT companies, in addition to investigating how companies with exponential growth have handled the related rules.

Concluding Remarks

I would like to begin these closing remarks by returning to the issue that originally inspired this work. DLTs are expected to transform several industries, although they remain in the early stages of adoption. Many related studies have been conducted in recent years, although there remain a number of unanswered questions that require further investigation. With that in mind, I believe that the present study has contributed significantly to the existing literature. Moreover, the findings of the study have implications for both research and practice. I also feel that further empirical investigations could be conducted to confirm and extend the present findings.

References

Abed, S. S. (2020). Social commerce adoption using TOE framework: An empirical investigation of Saudi Arabian SMEs. *International Journal of Information Management, 53*, 102118.

Abidin, N. Z., & Perdana, F. F. P. (2020). A proposed conceptual framework for blockchain technology in Halal food product verification. *Journal of Halal Industry &* Services, 1–8

Achtenhagen, L., Ekberg, S., & Melander, A. (2017). Fostering growth through business development: Core activities and challenges for micro-firm entrepreneurs. *Journal of Management and Organization*, *23*(2), 67–185.

Aengenheyster, J., & Masoliver, C. (2017). Modern catholicism and female identity. *The Maastricht Journal of Liberal Arts, 9*, 49–60.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In Kuhl, K., & Beckmann, J., (Eds.), *Action Control.* (pp. 11–39). Springer.

Al-Hujran, O., Al-Lozi, E. M., Al-Debei, M. M., & Maqableh, M. (2018). Challenges of cloud computing adoption from the TOE framework perspective. *International Journal of E-Business Research*, *14*(3), 77–94.

Al Jawaheri, H., Al Sabah, M., Boshmaf, Y., & Erbad, A. (2020). Deanonymizing Tor hidden service users through Bitcoin transactions analysis. *Computers & Security*, *89*, 101684.

Alazab, M., Alhyari, S., Awajan, A., & Abdallah, A. B. (2021). Blockchain technology in supply chain management: An empirical study of the factors affecting user adoption/acceptance. *Cluster Computing*, *24*(1), 83–101.

Amini, M., Bakri, A., Sadat Safavi, N., Javadinia, S. A., & Tolooei, A. (2014). The role of top manager behaviours on adoption of cloud computing for small and medium enterprises. *Australian Journal of Basic and Applied Sciences*, *8*(1), 490–98.

Armstrong, C. P., & Sambamurthy,V. (1999). Information technology assimilation in firms: The influence of senior leadership and IT infrastructures. *Information systems Research*, *10*(4), 304–27.

Asad, A., Basheer, M. F. , Irfan, M., , Jiang, J., , & Tahir, R. . (2020). Open-innovation and knowledge management in small and medium-sized enterprises (SMEs): The role of external knowledge and internal innovation. *Revista argentina de Clinica Psicologica*, *29*(4), 80–90.

Babakus, E., & Mangold, W. G. (1992). Adapting the SERVQUAL scale to hospital services: An empirical investigation. *Health Services Research*, *26*(6), 767.

Bai, C., & Sarkis, J. (2020). A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research*, *58*(7), 2142–2162.

Barceló, J. (2014). User privacy in the public bitcoin blockchain. *Semantic scholar*. https://www.semanticscholar.org/paper/User-Privacy-in-the-Public-Bitcoin-Blockchain-Barcel%C3%B3/549e7f042fe0aa979d95348f0e04939b2b451f18.

Bentler, P. M., & Chou, C. P. (1987). Practical issues in structural modeling. *Sociological Methods & Research*, *16*(1), 78–117.

Bigliardi, B., & Galati, F. (2016). Which factors hinder the adoption of open innovation in SMEs? *Technology Analysis and Strategic Management*, *28*(8), 869–85.

Binance Academy. (2018). *What is a 51% attach?* *https://academy.binance.com/en/articles/what-is-a-51-percent-attack*.

Blockchain.com. (n.d). Average confirmation time. https://www.blockchain.com/charts/avg-confirmation-time.

Bollen, K. A. (2014). Structural equations with latent variables. John Wiley & Sons.

Bouranta, N., Chitiris, L., & Paravantis, J.. (2009). "The relationship between internal and external service quality." *International Journal of Contemporary Hospitality Management*, *21*(3), 275–293

Capelleras, J. L., Mole, K. F., Greene, F. J., & Storey, D. J. (2008). "Do more heavily regulated economies have poorer performing new ventures? Evidence from Britain and Spain." *Journal of International Business Studies*, *39*(4), 688–704.

Carr, Jr V. H. (1999). Technology adoption and diffusion. *The Learning Center for Interactive Technology*. http://www.icyte.com/system/snapshots/fs1/9/a/5/0/9a50b695f1be57ce369534ac7378580%0A1745a8180/index.html.

Carson, B., Romanelli, G., Walsh, P., & Zhumaev, A. (2018, June 19). Blockchain beyond the hype: What is the strategic business value? *McKinsey Quarterly*, 1–13.

Castro, P. D., Tanner, M., & Johnston, K. (2020, March). Perceived factors influencing blockchain adoption in the asset and wealth management industry in the Western Cape, South Africa. In *International Development Informatics Association Conference*, (pp. 48–62). Springer, Cham.

Catalini, C., & Gans, J. S. (2020). Some simple economics of the blockchain. *Communications of the ACM*, *63*(7), 80–90.

Cearley, D., Burke, B., , Smith, D., , Jones, N., , Chandrasekaran, A., Lu, C., Karamouzis, F. (2020). Top 10 strategic technology trends for 2020 : A Gartner trend insight report. Gartner. https://www.gartner.com/en/documents/3981959/top-10-strategic-technology-trends-for-2020-a-gartner-tr.

Chandra, S., & Karippur N. K. (2018). Exploring factors influencing organizational adoption of augmented reality in e-commerce: Empirical analysis using technology-organization-environment model. *Journal of Electronic Commerce Research*, *19*(3), 237.

Chaum, D. (1983). Blind signitures for untraceable payment. In Chaum D., Rivest R.L., Sherman A.T., (Eds)., *Advances in Cryptology*., pp. 199–203. Boston, Springer.Chesbrough, H., & Bogers, M.. (2014). Explicating open innovation: clarifying an emerging paradigm for understanding innovation keywords. In Chesbrough, H., Vanhaverbeke,W., , & West, J. (Eds.), *New Frontiers in Open Innovation*, (pp. 3–28.) Oxford: Oxford University Press.

Chin, W. W. (1998). Commentary issues and opinion on structural equation modeling clear reporting. *MIS Quarterly*, *22*(1), vii–xvi.

Chiu, C. M., & Wang, E. T.G.. (2008). Understanding web-based learning continuance intention: The role of subjective task value. *Information and Management*, *45*(3), 194–201.

Chung, B. Y., Mirosław J. S., Henry C. L., and Young H. K. (2008). Analyzing enterprise resource planning system implementation success factors in the engineering – construction industry. *Journal of Computing in Civil Engineering*, *22*(6), 373–382.

Clohessy, T., & Acton, T.. (2019). Investigating the influence of organizational factors on blockchain adoption: An innovation theory perspective. *Industrial Management and Data Systems*, *119*(7), 1457–91.

Cohen, J. (1988). Statistical power analysis for the behavioural sciences. New York: Routledge.

Cole, R., M., Stevenson, & Aitken, J.. (2019). Blockchain technology: Implications for operations and supply chain management. *Supply Chain Management*, *24*(4), 469–83.

Cooper, R. B., & Zmud , R. W.,. (1990). Information technology implementation research: A technological diffusion approach. *Management Science*, *36*(2), 123–139.

Creswell, J. W. (2013). Qualitative inquiry and research design: Choosing among five approaches (3rd ed.). Los Angeles, CA: Sage.

Crosby, M., Pattanayak, P., , & Verma, S.. (2016). Blockchain technology – Beyond Bitcoin. *Applied Innovation Review*, *2*, 2–16

Cruz-Jesus, F., Pinheiro, A., , & Oliveira, T.. (2019). Understanding CRM adoption stages: Empirical analysis building on the TOE framework. *Computers in Industry*, *109*, 1–13.

Davidson, S., De Filippi, P., & Potts, J.. (2016). Economics of blockchain. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2744751.

Davis, F. D. (1986). A technology acceptance model for empirically testing new end-user information systems: Theory and results. (Doctoral Dissertation, Massachusetts institute of technology). http://hdl.handle.net/1721.1/15192.

Davis, F. D., Bagozzi, R. P., , & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*(8), 982–1003.

Dawes, J. (2008). Do data characteristics change according to the number of scale points used. *International Journal of Market Research*, *50*(1), 61–104.

De Giovanni, P. (2020). Blockchain and smart contracts in supply chain management: A game theoretic model. *International Journal of Production Economics*, *228*, 107855.

Devlin, S. J., Dong, H. K., & Brown, M. (2003).. Selecting a scale for measuring quality. *Marketing Research*, *5*(3), 12–17.

Dijkstra, T. K., & Henseler, J. (2015). Consistent and asymptotically normal PLS estimators for linear structural equations. *Computational Statistics and Data Analysis*, *81*, 10–23.

Duy, P. T., Hien, D. T. T., Hien, D. H., & Pham, V. H. (2018, December). A survey on opportunities and challenges of Blockchain technology adoption for revolutionary innovation. In *Proceedings of the Ninth International Symposium on Information and Communication Technology*, (pp. 200–207).

Ettlie, J. E. (1990). What makes a manufacturing firm innovative? *Academy of Management Perspectives*, *4*(4), 7–20.

European Commission. (2021). *EBSI, the first EU-wide blockchain Infrastructure is surging ahead*. https://ec.europa.eu/info/news/ebsi-first-eu-wide-blockchain-infrastructure-surging-ahead-2021-oct-14_en

European Parliament. (2020). *Directive (EU) 2018/843 of the European Parliament and of the Council of 30 May 2018 amending Directive (EU) 2015/849 on the prevention of the use of the financial system for the purposes of money laundering or terrorist financing, and amending Directives 2009/138/EC and 2013/36/EU (Text with EEA relevance).* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L0843

European Commission. (2018b). *European countries join Blockchain Partnership*. https://digital-strategy.ec.europa.eu/en/news/european-countries-join-blockchain-partnership

European Commission. (2018c). *European countries join Blockchain Partnership*. https://ec.europa.eu/digital-single-market/en/news/european-countries-join-Blockchain-partnership

European Banking Authority. (2018). *Warning: ESMA, EBA and EIOPA warn consumers on the risks of Virtual Currencies*. https://www.eba.europa.eu/sites/default/documents/files/documents/10180/2139750/313b7318-2fec-4d5e-9628-3fb007fe8a2a/Joint%20ESAs%20Warning%20on%20Virtual%20Currencies.pdf?retry=1

European Commission. (2018a). *EU Blockchain Observatory and Forum*. https://digital-strategy.ec.europa.eu/en/policies/eu-blockchain-observatory-and-forum

European Banking Authority. (2018). *ESAs warn consumers of risks in buying virtual currencies*. https://www.eba.europa.eu/esas-warn-consumers-of-risks-in-buying-virtual-currencies

European Commission. (2010). *European system of financial supervision: The EU has introduced a specific supervisory architecture, consisting of 3 European supervisory authorities and a board to monitor systemic risks*. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/financial-supervision-and-risk-management/european-system-financial-supervision_en

European Parliament. (2018b). *Anti-money laundering: MEPs vote to shed light on the true owners of companies*. https://www.europarl.europa.eu/news/en/press-room/20180411IPR01527/anti-money-laundering-meps-vote-to-shed-light-on-the-true-owners-of-companies

European Parliament. (2018a). *Anti-money laundering: MEPs vote to shed light on the true owners of companies*. https://www.europarl.europa.eu/news/en/press-room/20180411IPR01527/anti-money-laundering-meps-vote-to-shed-light-on-the-true-owners-of-companies

European Commission. (2016). *Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2015/849 on the prevention of the use of the financial system for the purposes of money laundering or terrorist financing and amending Directive 2009/101/EC*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016PC0450&rid=4

European Commission. (n.d). *A Europe fit for the digital age: Empowering people with a new generation of technologies*. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age_en

European Central Bank. (2012). *Virtual currency schemes*. https://www.ecb.europa.eu/pub/pdf/other/virtualcurrencyschemes201210en.pdf

European Central Bank. (2016). Distributed ledger technology. *In Focus*, https://www.ecb.europa.eu/pub/annual/special-features/2016/html/index.en.html.

Fernando, Y., Rozuar, N. H. M., & Mergeresa, F. (2021). "The blockchain-enabled technology and carbon performance: Insights from early adopters." *Technology in Society*, *64*, 101507.

Field, A. (2013). Discovering statistics using IBM SPSS statistics. (4th Ed . pp. 1-952). Los Angeles, London, New Delhi, Singapore, Washington DC: Sage.

Fornell, C., & Bookstein, F. L. (1982). Two structural equation models: LISREL and PLS applied to consumer exit-Voice theory. *Journal of Marketing Research*, *19*(4), 440–52.

Gangwar, H., H., Date, & R., Ramaswamy. (2015). Understanding determinants of cloud computing adoption using an integrated TAM-TOE model. *Journal of Enterprise Information Management*, *28*(1), 107–30.

Gangwar, H., Date, H., & Raoot, A. D. (2014). Review on IT adoption: Insights from recent technologies. *Journal of Enterprise Information Management*, *27*(4), 488–502.

Géczy, P., Izumi, N., & Hasida, K. (2012). cloudsourcing: Managing cloud adoption. *Global Journal of Business Research (GJBR)*, *6*(2), 57–70

Göbel, J., Keeler, H. P., Krzesinski, A. E., & Taylor, P. G. (2016). Bitcoin blockchain dynamics: The selfish-mine strategy in the presence of propagation delay. *Performance Evaluation*, *104*, 23–41.

Gold, A. H., Arvind M., and Albert H. S. (2001). Knowledge management: An organizational capabilities perspective. *Journal of Management Information systems*, *18*(1), 185–214.

Gonczol, P., Katsikouli, P., Herskind, L., & Dragoni, N. (2020). Blockchain implementations and use cases for supply chains-A survey. *In IEEE access*, 11856–11871.

Gould, Al. (1994). The issue of measurement validity in health-care research. *British Journal of Therapy and Rehabilitation*, *1*(2), 99–103.

Grover, P., Kar, A. K., & Janssen, M. (2019). "Diffusion of blockchain technology." *Journal of Enterprise Information Management*, *32*(5), 735–757.

Guest, G., Bunce, A., , & Johnson , L. (2006). How many interviews are enough?: An experiment with data saturation and variability. *Field Methods*, *18*(1), 59–82.

Guo, Y., & Liang, C. (2016). Blockchain application and outlook in the banking industry. *Financial Innovation*, *2*(24), 1–12.

Gür, A. Ö., Öksüzer, Ş., & Karaarslan, E. (2019, April). Blockchain based metering and billing system proposal with privacy protection for the electric network. In *2019 7th International Istanbul Smart Grids and Cities Congress and Fair (ICSG)*, (pp. 204-208). IEEE.

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). A primer on partial least squares structural equation modeling (PLS-SEM) (3rd ed.). Thousand Oaks, CA: Sage.

Hasselgren, A., K., Kralevska, D., Gilgoroski, S. A., Pedersen, A. F. (2020). Blockchain in healthcare and health sciences—A scoping review. *International Journal of Medical Informatics*, *134*, 104040.

Helliar, C. V., Crawford, L., Rocca, L., Teodori, C., & Veneziani, M (2020). Permissionless and permissioned blockchain diffusion. *International Journal of Information Management*, 54, 102136.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135.

Hossain, M. A., & Quaddus, M. (2011). The adoption and continued usage intention of RFID: an integrated framework. *Information Technology & People*, *24*(3), 236–256.

Iacovou, C. L., Benbasat, I., & Dexter, A. S. (1995). Electronic data interchange and small organizations: Adoption and impact of technology. *MIS Quarterly*, *19*(4), 465–485.

Ikeda, K. (2018). Security and privacy of blockchain and quantum computation. *Advances in Computers*, *111*, 199–228.

Jalilian, H., Kirkpatrick, C., & Parker, D. (2007). The impact of regulation on economic growth in developing countries: A cross-country analysis. *World Development*, *35*(1), 87–103.

Jardim, L., Pranto, S., Ruivo, P., & Oliveira, T. (2021). What are the main drivers of blockchain adoption within supply chain? –An exploratory research. *Procedia Computer Science*, *181*, 495–502.

Jessel, B., & DiCaprio, A. (2018). Can blockchain make trade finance more inclusive? *Journal of Financial Transformation*, *47*, 35–50.

Johanning, S., & Bruckner, T. (2019). Blockchain-based peer-to-peer energy trade: A critical review of disruptive potential. In *2019 16th International Conference on the European Energy Market (EEM)*, (pp. 1–8). IEEE.

Kamble, S., Gunasekaran, A., & Arha, H. (2019). Understanding the blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*, *57*(7), 2009–2033.

Kalaitzi, D., Jesus, V., & Campelos, I. (2019). Determinants of blockchain adoption and perceived benefits in food supply chains

Khayer, A., Talukder, M. S., Bao, Y., & Hossain, M. N. (2020). Cloud computing adoption and its impact on SMEs' performance for cloud supported operations: A dual-stage analytical approach. *Technology in Society*, *60*, 101225.

Kim, S. H. (2020). A study on blockchain technology adoption and intention of logistics firms in Korea. *Journal of the Korea Society of Computer and Information*, *25*(2), 231–239.

Kitching, J., Hart, M., & Wilson, N. (2015). Burden or benefit? Regulation as a dynamic influence on small business performance. *International Small Business Journal*, *33*(2), 130–147.

Knauer, F., & Mann, A. (2019). What is in it for me? Identifying drivers of blockchain acceptance among German consumers. *The Journal of the British Blockchain Association*, *3*(1), 10484.

Kock, N. (2014). Advanced mediating effects tests, multi-group analyses, and measurement model assessments in PLS-based SEM. *International Journal of E-Collaboration (IJeC)*, *10*(1), 1–13.

Koens, T., & Poll, E. (2018). The drivers behind blockchain adoption: The rationality of irrational choices. In *European Conference on Parallel Processing*, (pp. 535–546). Springer, Cham.

Kondrateva, G., Elodie de, B., Chantal, A., & Eric, S. (2020). The potential use of blockchain technology in co-creation ecosystems. *Journal of Innovation Economics & Management*, *37*(1), 9–27.

Kowalski, M., Lee, Z. W., & Chan, T. K. (2021). Blockchain technology and trust relationships in trade finance. *Technological Forecasting and Social Change*, *166*, 120641.

Krause, S. K., Natarajan, H., , & Gradstein, H. L.. (2017). Distributed ledger technology (DLT) and blockchain. *FinTech Note*, http://documents.worldbank.org/curated/en/177911513714062215/Distributed-Ledger-Technology-DLT-and-blockchain.

Kulkarni, M., & Kanchan P. (2020). Blockchain technology adoption using TOE framework. *International Journal of Scientific and Technology Research*, 9(2), 1109–1117

Lacity, M. C. (2018). Addressing key challenges to making enterprise blockchain applications a reality. *MIS Quarterly Executive*, *17*(3), 201–222

Lai, H. M., Lin, I. C., & Tseng, L. T. (2014). High-level managers' considerations for RFID adoption in hospitals: An empirical study in Taiwan. *Journal of Medical Systems*, *38*(2), 1–17.

Laursen, K., & Ammon J. S. (2014). The paradox of openness: Appropriability, external search and collaboration. *Research Policy*, *43*(5), 867–878.

Lee, C. P., & Shim, J. P. (2007). An Exploratory Study of Radio Frequency Identification (RFID) Adoption in the Healthcare Industry. *European Journal of Information Systems*, *16*(6), 712–724.

Lee, S., Park, G., Yoon, B., & Park, J. (2010). Open innovation in SMEs-An intermediated network model. *Research Policy*, 39(2), 290–300.

Lehar, A., & Parlour, C. A. (2020). Miner collusion and the BitCoin protocol. *SSRN*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3559894.

Li, D., Lai, F., & Wang, J. (2010). E-business assimilation in China's international trade firms: The technology-organization-environment framework. *Journal of Global Information Management*, *18*(1), 39–65.

Lian, J. W., Chen, C. T., Shen, L. F., & Chen, H. M. (2020). Understanding user acceptance of blockchain-based smart locker. *The Electronic Library*, *38*(2), 353–366

Liang, H., Saraf, N., Hu, Q., & Xue, Y. (2007). Assimilation of enterprise systems: The effect of institutional pressures and the mediating role of top management. *MIS Quarterly*, 31(1), 59–87.

Lichtenthaler, U., & Ernst, H. (2006). Attitudes to externally organising knowledge management tasks: A review, reconsideration and extension of the NIH syndrome. *R&D Management*, *36*(4), 367–86.

Lin, H. F., & Lin, S. M. (2008). Determinants of e-business diffusion: A rest of the technology diffusion perspective. *Technovation*, *28*(3), 135–45.

Liu, Z., & Li, (2020). A blockchain-based framework of cross-border e-commerce supply chain. *International Journal of Information Management*, *52*, 102059.

Lott, J.R, & North, D.C. (1992). Institutions, institutional change and economic performance. *Journal of Policy Analysis and Management*, *11*, 156–59.

Lumineau, F., Wang, W., Schilke, O., & Huang, L. (2021). How blockchain can simplify partnerships. *Harvard Business Review Digital* Articles. 1–8

Manda, V. K., & Yamijala, S. P. (2019). Peer-to-peer lending using blockchain. *Advance and Innovative Research*, *6*(1), 61–66.

Marlin, D. (2017). What is blockchain and how will it change the world? *Forbes*, 1–6. https://www.forbes.com/sites/danielmarlin/2017/12/22/what-is-blockchain-and-how-will-it-change-the-world/?sh=267711157560.

Mehrtens, J., Cragg, P. B., & Mills, A. M. (2001). A model of internet adoption by SMEs. *Information and Management*, *39*(3), 165–76.

Ministry of Finance. (2020). *Gesetz zur Einführung von elektronischen Wertpapieren*. https://perma.cc/F6A3-ABQM

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2*(3), 192–222.

Morkunas, V. J., Paschen, J., & Boon, E. (2019). How blockchain technologies impact your business model. *Business Horizons*, *62*(3), 295–306.

Nägele, T., & Bont, P. (2019). Tokenized structures and assets in Liechtenstein law. *Trusts & Trustees*, *25*(6), 633–38.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. *Bitcoin.org* https://bitcoin.org/bitcoin.pdf.

Narayan, R., & Tidström, A. (2019). Blockchains for accelerating open innovation systems for sustainability transitions. *Blockchain Economics: Implications of Distributed Ledgers*, 85–101.

Neagu, B. C., Grigoraş, G., & Ivanov, O. (2019). An efficient peer-to-peer based blokchain approach for prosumers energy trading in microgrids. In *2019 8th International Conference on Modern Power Systems (MPS)*, 1–4.

Noor, S., W., Yang, M., Gup, K. H. Dam, X., Wang. (2018). Energy demand side management within micro-grid networks enhanced by blockchain. *Applied Energy*, *228*, 1385–1398.

North, D. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press

Olivares-Rojas, J. C., Reyes-Archundia, E., Gutiérrez-Gnecchi, J. A., Cerda-Jacobo, J., & González-Murueta, J. W. (2020). A novel multitier blockchain architecture to protect data in smart metering systems. *Transactions on Engineering Management*, *67*(4), 1271–84.

Oliveira, T., Thomas, M., & Espadanal, M. (2014). Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors. *Information and Management*, *51*(5), 497–510.

Orji, I. J., Kusi-Sarpong, S., Huang, S., & Vazquez-Brust, D. (2020). Evaluating the factors that influence blockchain adoption in the freight logistics industry. *Transportation Research Part E: Logistics and Transportation Review*, *141*, 102025.

Pan, Y., Zhang, X., Wang, Y., Yan, J., Zhou, S., Li, G., & Bao, J. (2019). Application of blockchain in carbon trading. *Energy Procedia*, *158*, 4286–4291.

Pana, E., & Gangal, V. (2021). Blockchain bond issuance. *Journal of Applied Business & Economics*, *23*(1), 217–26.

Parida, V., Westerberg, M., & Frishammar, J. (2012). Inbound open innovation activities in high-tech SMEs: the impact on innovation performance. *Journal of Small Business Management*, *50*(2), 283–309.

Parra Moyano, J., & Ross, O. (2017). KYC optimization using distributed ledger technology. *Business & Information Systems Engineering*, *59*(6), 411–423.

Pawczuk, L., R., Massey, J., Holdowsky, & Hansen, B. (2020). Deloitte's 2020 Global Blockchain Survey. https://www2.deloitte.com/content/dam/insights/us/articles/6608_2020-global-blockchain-survey/DI_CIR 2020 global blockchain survey.pdf.

Peck, F., Jackson, K., & Mulvey, G. (2018). Regulation and growth-oriented small businesses in North-West England. *Journal of Small Business and Enterprise Development*, *25*(2), 294–312.

Pedersen, A. B., Risius, M., & Beck, R. (2019). A ten-step decision path to determine when to use blockchain technologies. *MIS Quarterly Executive*, *18*(2), 99–115.

Piatier, A. (1984). *Barriers to Innovation*. London: Frances Pinter.

Picoto, W. N., Bélanger, F., & Palma-dos-Reis, A. (2014). A technology–organisation–environment (TOE)-based m-business value instrument. *International Journal of Mobile Communications, 12*(1), 78–101.

Poel, K., Marneffe, W., Bielen, S., Van Aarle, B., & Vereeck, L. (2014). Administrative simplification and economic growth: A cross country empirical study. *Journal of Business Administration Research, 3*(1), 45.

Power, J. (2019). Blockchain Finance–Massive Disruption or Status Quo?. *Journal of Management and Innovation*, *5*(1). 1–14

Prentice, R. C., Witt, S. F., & Hamer, C. (1998). Tourism as experience: The case of heritage parks. *Annals of Tourism Research*, *25*(1), 1–24.

Priem, R. (2020). Distributed ledger technology for securities clearing and settlement: benefits, risks, and regulatory implications. *Financial Innovation*, *6*(1), 1–25.

Qian, Y. (2019). Central Bank Digital Currency: optimization of the currency system and its issuance design. *China Economic Journal*, *12*(1), 1–15.

Queiroz, M. M., Wamba, S., De Bourmont, M., & Telles, R. (2021). Blockchain adoption in operations and supply chain management: empirical evidence from an emerging economy. *International Journal of Production Research*, *59*(20), 6087–6103.

Rahman, H. (2013). Open innovation in SMEs: From closed peripheries to networked paradigm. In *Small and Medium Enterprises: Concepts, Methodologies, Tools, and Applications*. In Cruz-Cunha, M., and J.Varajão, (Eds). *E-business issues: Driving competitiveness*. (pp. 378–393). IGI Global.

Rahman, H., & Ramos, I. (2010). Open innovation in SMEs: From closed boundaries to networked paradigm. *Issues in Informing Science and Information Technology*, *7*(4), 471–178.

Rangel, N. (2017). *8va edición del Eurecat Mobile Forum estará centrada en blockchain, FinTech y ciberseguridad*. Criptonoticia. https://www.criptonoticias.com/comunidad/eventos/8va-edicion-eurecat-mobile-forum-estara-centrada-blockchain-fintech-ciberseguridad/

Ramdani, B., Kawalek, P., & Lorenzo, O. (2009). Predicting SMEs' adoption of enterprise systems. *Journal of Enterprise Information Management*, *22*(1/2), 10–24.

RainerB., Christin, N., , Edelman, B., , & Moore, T. (2015). Bitcoin: Economics, technology, and governance. *Journal of Economic Perspectives*, *29*(2), 213–38.

Rivière, J. M. (2018). Blockchain technology and IP–investigating benefits and acceptance in governments and legislations. *Junior Management Science*, *3*(1), 1–15.

Roger, E. M. (1962). *Diffusion of Innovations*. New York: Free Press.

Sabherwal, R., Jeyaraj, A., & Chowa, C. (2006). Information system success: Individual and organizational determinants. *Management Science*, *52*(12), 1849–1864.

Sağ, S., Sezen, B., & Güzel, M. (2016). Factors that motivate or prevent adoption of open innovation by SMEs in developing countries and policy suggestions. *Procedia-Social and Behavioral Sciences*, *235*, 756–763.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students*. Pearson.

Segarra-Blasco, A., Garcia-Quevedo, J., & Teruel-Carrizosa, M. (2008). Barriers to innovation and public policy in Catalonia. *International Entrepreneurship and Management Journal*, *4*(4), 431–451.

Seulliet, E. (2016). Open innovation, co-création: Pourquoi la blockchain est une petite révolution. *Harvard Business Review France*, 1–9. https://www.hbrfrance.fr/chroniques-experts/2016/07/11628-open-innovation-co-creation-pourquoi-la-blockchain-est-une-petite-revolution/.

Sideridis, G., Simos, P., Papanicolaou, A., & Fletcher, J. (2014). Using structural equation modeling to assess functional connectivity in the brain: Power and sample size considerations. *Educational and Psychological Measurement*, *74*(5), 733–758.

Skatteverket v D. H., (2015). *Judgment of the Court (Fifth Chamber)*. https://perma.cc/7Q6Q-MM9V

Soriano, J. (2019). *Using blockchain in the fight against counterfeiting - EUIPO launches a Forum to support concrete solutions in that field*. EUIPO. https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/News/Blockchain_Forum_launch_PR_en.pdf

Spithoven, A., Vanhaverbeke, W., & Roijakkers, N. (2013). Open innovation practices in SMEs and large enterprises. Small Business Economics, *41*(3), 537–562.

Stevens, J. P. (2012). *Applied multivariate statistics for the social sciences*. Routledge.

Su, Z., Wang, Y., Xu, Q., Fei, M., Tian, Y. C., & Zhang, N. (2018). A secure charging scheme for electric vehicles with smart communities in energy blockchain. *IEEE Internet of Things Journal*, *6*(3), 4601–4613.

Sutanonpaiboon, J., & Pearson, A. M. (2006). E-commerce adoption: perceptions of managers/owners of small-and medium-sized enterprises (SMEs) in Thailand. *Journal of Internet Commerce*, *5*(3), 53–82.

Sunnarborg, A. (2017). *ICO investments pass VC funding in blockchain market first*. Coindesk. https://www.coindesk.com/markets/2017/06/09/ico-investments-pass-vc-funding-in-blockchain-market-first/

Szabo, N. (1997). Formalizing and securing relationships on public networks. *First Monday*, *2*(9).

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics* (Vol. 5, pp. 481–498). Pearson.

Taghizadeh, S. K., Nikbin, D., Alam, M. M. D., Rahman, S. A., & Nadarajah, G. (2020). Technological capabilities, open innovation and perceived operational performance in SMEs: the moderating role of environmental dynamism. *Journal of Knowledge Management*, *25*(6), 1486–1507

Tapscott, D., & Tapscott, A. (2016). *Blockchain Revolution: How the Technology behind Bitcoin Is Changing Money, Business and the World*. Penguin Publishing Group.

Teufel, B., Sentic, A., & Barmet, M. (2019). Blockchain energy: Blockchain in future energy systems. *Journal of Electronic Science and Technology*, *17*(4), 100011.

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *Processes of technological innovation*. Lexington books.

Treiblmaier, H. (2019). Toward more rigorous blockchain research: Recommendations for writing blockchain case studies. *Frontiers in Blockchain*, *2*, 1–15.

Tsukerman, M. (2015). The block is hot: A survey of the state of Bitcoin regulation and suggestions for the future. Berkeley Technology Law Journal, 30(4), 1127–1170.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273–315.

Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS* Quarterly, *36*(1), 157–178.

Van de Vrande, V., De Jong, J. P., Vanhaverbeke, W., & De Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. *Technovation*, *29*(6–7), 423–437.

Vishwanatan, V. (2017). *What is forking and how it impacts cryptocurrencies such as bitcoin*. Mint. https://www.livemint.com/Money/UdAe9RnVOwPHKH3f3VUQ5L/What-is-forking-and-how-does-it-impact-cryptocurrencies-such.html

Walport, M. (2015). *Distributed ledger technology: Beyond block chain*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf.

Walker, G. (2016). *Block header: A summary of the data in the block*. https://learnmeabitcoin.com/technical/block-header

Wamba, S. F., Queiroz, M. M., & Trinchera, L.. (2020). "Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation *International Journal of Production Economics*, *229*, 107791.

Wang, R., Lin, Z., & Luo, H. (2019). Blockchain, bank credit and SME financing. *Quality and Quantity*, 53(3), 1127–40.

Wang, Y. M., Wang, Y. S., & Yang, Y. F. (2010). Understanding the determinants of RFID adoption in the manufacturing industry. *Technological Forecasting and Social Change*, 77(5), 803–815.

Wong, L. W., Leong, L. Y., Hew, J. J., Tan, G. W. H., & Ooi, K. B. (2020). Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. *International Journal of Information Management*, *52*, 101997.

Wong, L. W., Tan, G. W. H., Lee, V. H., Ooi, K. B., & Sohal, A. (2020). Unearthing the determinants of Blockchain adoption in supply chain management. *International Journal of Production Research*, *58*(7), 2100–2123.

Woodside, J. M., Augustine Jr, F. K., & Giberson, W. (2017). Blockchain technology adoption status and strategies. *Journal of International Technology and Information Management*, *26*(2), 65–93.

Wu, T., & Liang, X. (2017, August). Exploration and practice of inter-bank application based on blockchain. In *2017 12th International Conference on Computer Science and Education (ICCSE)* (pp. 219–224). IEEE.

Xue, L., Teng, Y., Zhang, Z., Li, J., Wang, K., & Huang, Q. (2017, September). Blockchain technology for electricity market in microgrid. In *2017 2nd International Conference on Power and Renewable Energy (ICPRE)* (pp. 704–708). IEEE.

YCharts. (n.d). *Bitcoin statistics*. https://ycharts.com/indicators/reports/bitcoin_statistics

Yeoh, P. (2017). Regulatory issues in blockchain technology. *Journal of Financial Regulation and Compliance*, *25*(2), 196–208.

Zheng, Z., Xie, S., Dai, H. N., Chen, X., & Wang, H. (2018). Blockchain challenges and opportunities: A survey. *International Journal of Web and Grid Services*, *14*(4), 352–375.

Zhu, K. (2004). The complementarity of information technology infrastructure and e-commerce capability: A resource-based assessment of their business value. *Journal of Management Information systems*, *21*(1), 167–202.

Zia, M. F., Benbouzid, M., Elbouchikhi, E., Muyeen, S. M., Techato, K., & Guerrero, J. M. (2020). Microgrid transactive energy: Review, architectures, distributed ledger technologies, and market analysis. *IEEE Access*, *8*, 19410–19432.