MASTER

Blockchain in the supply chain domain
a technology adoption model

Cioffi, M.C.

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Blockchain in the supply chain domain: a technology adoption model

By M.C. Cioffi

Student number: 1177788

Master of Operations Management & Logistics

Supervisors:

B. Ozkan – TU/e, IE&IS

P.W.P.J. Grefen – TU/e, IE&IS

T. Kik – Accenture

Abstract

In the domain of the supply chain, Blockchain attracts the attention of both scientific and business worlds. This technology promises revolutionary solutions to the problems that affect the current supply chain structure. Nevertheless, the adoption characteristics of this technology are largely unexplored. Moreover, the existing knowledge about its applicability in the supply chain domain is rather fragmented and sparse. Therefore, this research investigates the use cases and related characteristics of Blockchain in the supply chain domain, aiming for a clear and comprehensive model that summarizes them. Moreover, a technology adoption model is built in order to explore the determinants of the Blockchain adoption within companies in the supply chain domain. In particular, the main Blockchain characteristics are mapped to the Technology, Organization, Environment (TOE) framework by Tornatzky and Fleischer (1990). The developed Blockchain adoption model explores the relationships between the intention to adopt Blockchain (IAB) and technology risks (TER), business performance (BUP), technology and regulation immaturity (TRI), business integration (BUI), competitive pressure (COP). Moreover, it explores the relationship between cross-organizational data performance (CDP) and BUI. An online questionnaire is used for data collection and 73 responses are collected from companies active in the supply chain domain. The hypotheses are tested with the application of partial least squares structural equation modelling (PLS-SEM). The data analysis reveals significant negative relationships between TER and IAB, and between TRI and IAB. Moreover, significant positive relationships are highlighted between COP and IAB, and between CDP and BUI. The other two hypotheses are, instead, rejected. This model provides evidence about the importance of solving challenges like security, scalability and technology integration to foster companies to adopt Blockchain. Moreover, it shows that the main advantages provided by the technology are confirmed from both adopters and non-adopters. In this sense, the results of this research contribute to extend the understanding of the factors that influence the adoption of Blockchain in the supply chain domain.

Executive summary

This executive summary describes the main steps performed in this research. First, an introduction of the subject is outlined. Then, problem and research methodology are reported. Lastly, the main results and conclusions are discussed.

Introduction

Blockchain is a revolutionary technology that promises to change the way transactions are executed. The Blockchain revolution started in the financial sector, with the birth of a cryptocurrency called Bitcoin. Nowadays, its use is spread across numerous domains, managing different types of data transactions. One of this thriving domain is supply chain. Supply chain is currently facing several problems due to the increasing complexity of its structure. Most of the production activities are not executed in house anymore, but they are outsourced to external companies spread worldwide. In this articulated network, each participant owns only a partial and incomplete copy of the information about products and related processes. This generates an opaque and asymmetric structure that increases the complexity of the companies' operations. Blockchain is a promising technology, whose characteristics can be exploited in the supply chain domain to overcome its main challenges. In particular, thanks to its transparency, reliability and decentralization it can bring several advantages in terms of process efficiency, network trustworthiness and supply chain synchronization. For these reasons, Blockchain applications in this domain are increasingly explored from both researchers and practitioners.

Problem and methodology

Although the large interest in this technology, the adoption rate from the company side is still low. Moreover, the knowledge about Blockchain in this domain is fragmented and the overall possibilities unclear. Therefore, this research aims to, firstly, understand the main applications of Blockchain in this domain, in terms of use cases and related characteristics. Secondly, it investigates which characteristics are determinants of its adoption from a company perspective. In particular, the following two research questions guide this research:

1. What are the most important use cases of Blockchain in the supply chain domain and the related characteristics?
2. What are the determinants of the adoption of Blockchain in the supply chain domain from a company perspective?

The ultimate goal of this research is the development of an artifact and, in particular, of a technology adoption model, in order to understand the factors that move a company to adopt Blockchain. For this reason, the design science research methodology (DSRM) by Peffers et al. (2007) was followed. The DSRM is used to produce successful artifacts, which could be either a construct, a model or a method (Peffers et al., 2007). The DSRM is articulated in six steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication (Peffers et al., 2007). In this case, the problem identified was the lack of understanding about the main use cases and related characteristics of Blockchain in the supply chain domain, and their causal relationships with the intention to adopt the technology. Therefore, a quasi-systematic literature review (quasi-SLR) was performed to collect the main Blockchain use cases in the supply chain domain. Then, the related characteristics were extracted. Since the output of the quasi-SLR presented a lack of understanding in terms of possible Blockchain threats and challenges, an additional

screening was performed to integrate this shortage. From the final pool, the main characteristics were selected and grouped into generic constructs. These constructs were used to build the technology adoption model. In particular, the constructs were mapped to the components of the Technology Organization Environment (TOE) framework by Tornatzky and Fleischer (1990). Lastly, the model hypotheses were defined and a web-survey was created in order to collect the data needed for the analysis. The model was implemented in SmartPLS 3.0 (Ringle et al., 2015) and PLS-SEM and bootstrapping were used to test the hypotheses (Hair et al., 2014).

Results

The output of the first part of the research showed the production of a comprehensive model of the Blockchain use cases described in literature and the related characteristics. In particular, this model showed how the inherent characteristics of Blockchain, applied to the supply chain use cases, can bring several advantages in the supply chain domain (*Figure 1*).

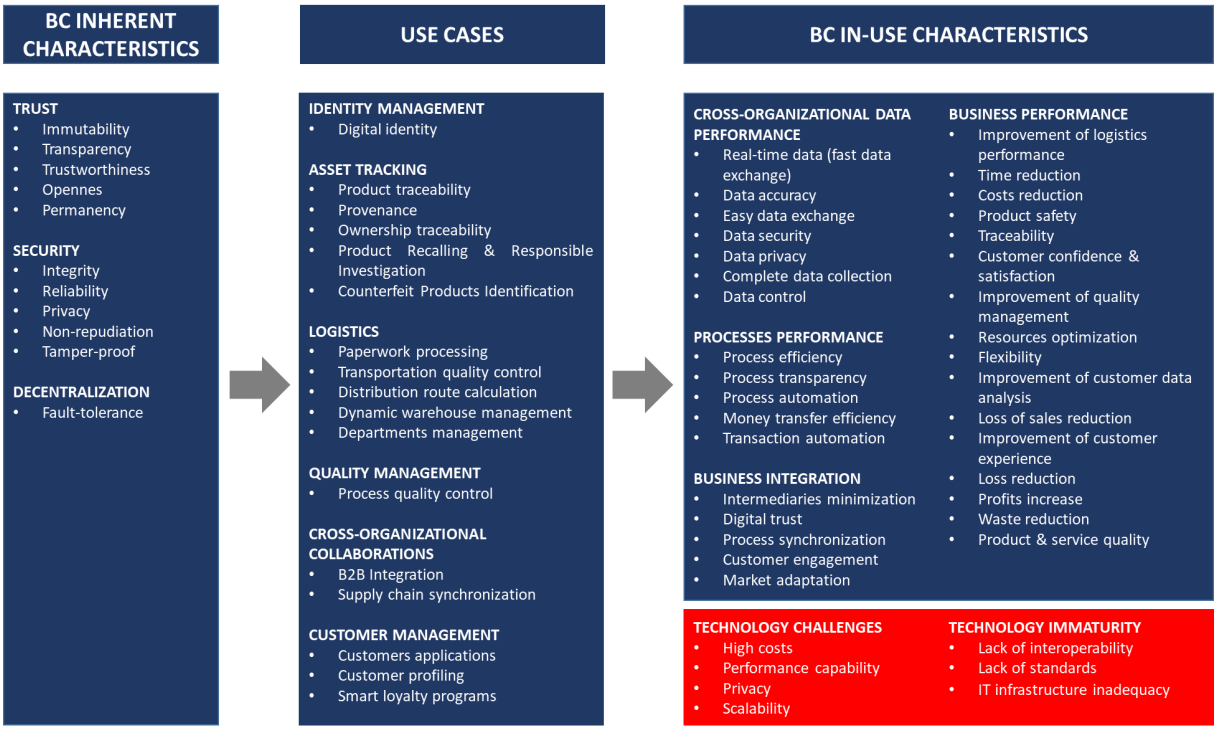

Figure 1. Blockchain use cases and related characteristics (RQ1)

Then, selecting and grouping the main characteristics, the following six constructs of the adoption model were outlined: technology risks (TER), business performance (BUP), technology and regulations immaturity (TRI), business integration (BUI), cross-organizational data performance (CDP), and competitive pressure (COP). The test of the hypotheses of the technology adoption model showed two significant negative relationships between TER and IAB, and between TRI and IAB. Moreover, two

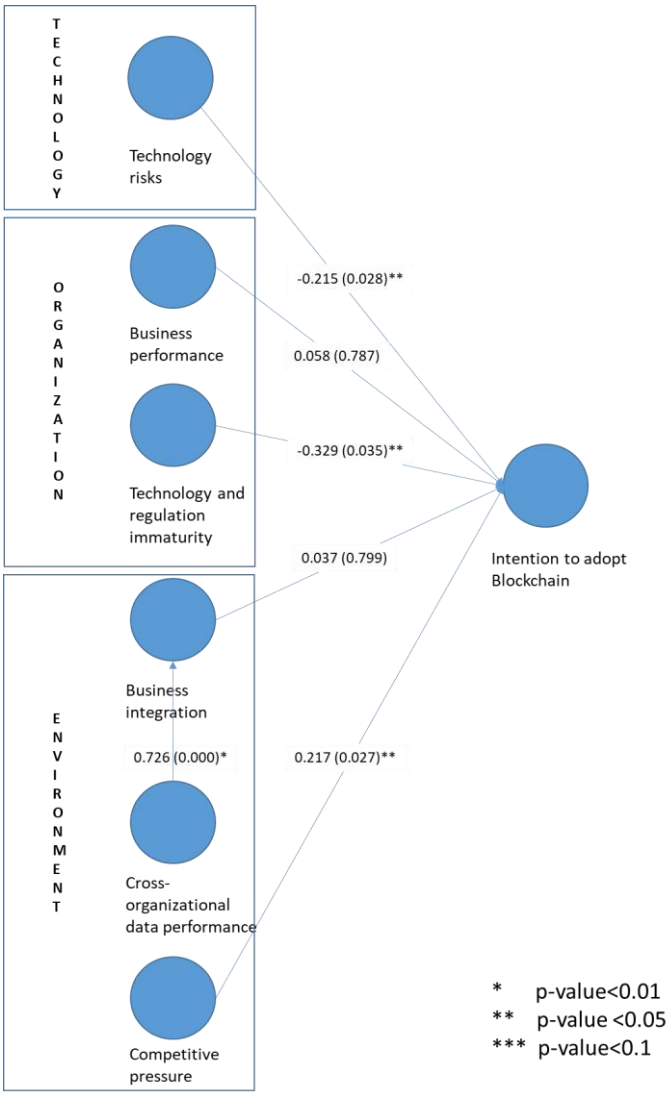

Figure 2. PLS-SEM results of the technology adoption model (RQ2)

positive significant relationships were highlighted between COP and IAB, and between CDP and BUI (*Figure 2*).

Conclusions

This research contributes to the extension of the body of academic literature in different ways. First, it provides a complete model that presents the most meaningful Blockchain characteristics in the supply chain domain, related to the single use cases. In this way, researchers can now dispose of a model that summarizes the main Blockchain applications discussed in literature. Second, this research represents a first attempt to study the Blockchain adoption in the supply chain domain with the application of the TOE framework. The technology adoption model developed in this research investigates for the first time the causal relationships between Blockchain characteristics and the companies' intention to adopt the technology. Since the adoption of the technology is determinant for its diffusion, clarifying the main obstacles is important to improve the development of the technology.

This study also identifies limitations and suggestions for future research. In particular, the newness of the topic and the data availability were discussed as main limitations. Moreover, recommendations like the analysis of possible moderating effects were provided for future analyses.

Lastly, the practical implications of this research were discussed. The insights provided from the developed adoption model were identified as main contribution to Blockchain practitioners. Understanding the factors that obstacle the diffusion of the technology can help them to develop targeted measures for companies that are hesitant about Blockchain adoption. In particular, the relevant influence of the Blockchain challenges on the adoption decision suggests to practitioners to focus their attention on that, trying to solve the main issues and clarifying the misunderstandings about the technology. Moreover, the results about competitive pressure indicate the utility of underlining the competitive situation in order to foster the adoption among companies.

Preface

This Master thesis is submitted for the Master program 'Operations Management & Logistics' at the Eindhoven University of Technology (TU/e) and has been performed for the Information Systems Group of the faculty of 'Industrial Engineering & Innovation Sciences'.

This thesis represents the finalization of two years of work at this university that were full of learning experiences. In this regard, I would like to thank different persons who helped me to achieve this important goal.

First of all, I would like to thank my first supervisor Baris, who was a solid guide for me along this intricate path. Thanks for your patience and for having been always able to reassure me in the most difficult and stressful phases. Second, I would like to thank my second supervisor Paul for his contribution in important steps of my thesis and for his valuable inputs. I also want to thank Tom, my company supervisor, for giving me the chance to deepen the study of this very interesting and trending topic, and for his guidance and inspiration during this work.

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A mia nonna, per avermi cresciuta come una figlia. Alla sua infinita pazienza. Ai suoi preziosi insegnamenti. Alla forza e perseveranza che mi ha sempre trasmesso e che mi hanno portato fin qui. A te, un bacio volante.

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Maria Chiara Cioffi,

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AVE	Convergent validity
BC	Blockchain
BUI	Business integration
BUP	Business performance
CDP	Cross-organizational data performance
COP	Competitive pressure
CR	Composite reliability
EDI	Electronic data interchange
ERP	Enterprise resource planning
GPS	Global positioning system
HACCP	Hazard Analysis and Critical Control Points
IAB	Intention to adopt Blockchain
IT	Information technology
PLS	Partial least squares
PLS-SEM	Partial least squares structural equation modelling
Quasi-SLR	Quasi Systematic Literature Review
RFID	Radio frequency identification
SC	Supply chain
SLR	Systematic literature review
TAM	Technology adoption model
TER	Technology risks
TOE	Technology organization environment framework
TPB	Theory of planned behavior
TRI	Technology and regulation immaturity
TU/e	Eindhoven University of Technology

1. Introduction

In a digital world managed by contracts, transactions and records, a revolution can change the way the administrative control is managed and regulated (Iansiti and Lakhani, 2017). This revolution started in 2009 with an alternative currency called Bitcoin that is issued by automated consensus among users from the network. Bitcoin can be exchanged through the Internet in a decentralized, trustless system that uses a public ledger called Blockchain (Swan, 2015). Blockchain is going to radically modify the way data is stored and connected. Every record can be stored in a shared and transparent database and contracts can be embedded in digital code (Iansiti and Lakhani, 2017). In this way, the existing business world that still relies on third parties can be challenged by the Blockchain technology (Beck & Müller-Bloch, 2017). The Blockchain ability to automate mechanisms of trust without a central authority can mitigate the risks and make operations more efficient (Benton & Radziwill, 2017). This can bring to a revolution in which insurance companies or banks might disappear (Beck & Müller-Bloch, 2017). In this context, Iansiti and Lakhani (2017) picture the next future as a world where individuals, machines and algorithms interact and cooperate.

Tian (2016) mentioned five main features that characterize any Blockchain-based system: decentralization, trustworthiness, collective, reliability and anonymity. Although Blockchain gained popularity as the baseline technology of Bitcoin cryptocurrency, its properties can bring advantages in many more applications. Indeed, several Blockchain deployments outside finance have been largely investigated like, for example, crowdfunding, governance and supply chain (Benton, & Radziwill, 2017; Kshetri, 2018).

Supply chain, in particular, is a thriving environment in which companies are trying to exploit this technology. As stated by Nakasumi (2017), nowadays, the global competition is bringing organizations to feel a high market pressure in terms of prices and performance. Therefore, differently from the past, most manufacturers do not produce in house anymore, but they focus only on the core competencies, almost completely outsourcing the manufacturing operations. In this way, every organization is only a component of a supply chain that is spread on a global level (Nakasumi, 2017). This structure inevitably leads to a high level of complexity in the supply chain management, where each organization has its own strategic and operational goals (Nakasumi, 2017).

The complexity and diversity of the global supply chain pose the types of challenges Blockchain seeks to address (Casey & Wong, 2017). Using immutable data, distributed storage and controlled user access, Blockchain can improve the transparency and traceability issues of the existing supply chain system (Abeyratne & Monfared, 2016). By capturing data from any point along the chain, the overall supply chain system can gain greater flexibility (Casey & Wong, 2017). Nevertheless, some challenges still threaten the diffusion of this technology. Different systematic literature reviews revealed security as one of the most important challenges. Indeed, even if it should be one of the main strengths of Blockchain, numerous scholars still question it (Batubara et al., 2018). Furthermore, technical challenges like scalability and interoperability affect the efficient integration of this technology in the existing systems. Lastly, from a legal point of view, the lack of Blockchain regulations obstructs a clear technology integration with the existing policies (Yli-Huumo et al., 2016; Sadhya & Sadhya, 2018). As stated by Crosby et al. (2016), Blockchain, as all the radical innovations, presents significant risks in its adoption (Crosby et al., 2016). Because of the infancy of Blockchain, the technology is still poorly understood and the intent to adopt it for supply chain is unknown (Francisco & Swanson, 2018).

This thesis is aimed, first, at understanding and categorizing the main Blockchain applications and respective characteristics in the supply chain domain. Second, it investigates the causal relationships of the main characteristics with the intention to adopt Blockchain in the supply chain environment.

1.1 Research objectives

As introduced in the previous section, the supply chain domain could offer various applications to Blockchain along the chain of suppliers, manufacturers, logistics enterprises, wholesalers and retailers, consumers. In the past, the production process took place almost entirely inside the company. Today, the high price pressure and global competition brought organizations to outsource almost the entire production process to external companies (Nakasumi, 2017). This introduces a complexity that the existing centralized supply chain systems seem striving to manage. In particular, Tian (2016) in his research defines the biggest problem as the current monopolistic, asymmetric and opaque information system. This could result in a serious trust problem, such as fraud, corruption, tampering and data falsification (Tian, 2016). Blockchain has the potential to solve these issues, ensuring product quality, reducing risks and frauds, and providing factories, distributers and retailers with real-time data about their products (Lu & Xu, 2017). Thanks to the numerous opportunities that Blockchain can offer in the supply chain domain, the possible applications are multiples. Nevertheless, the literature offers only fragmented knowledge about the Blockchain applicability and its related advantages and challenges. Therefore, there is not a general and comprehensive knowledge of the main use cases and the related factors that specifically identify the use of this technology in the supply chain context. Indeed, it is still not clear what are the most meaningful characteristics that are perceived as benefits, and what are the most relevant threats that characterize the application of this technology in the supply chain domain. Therefore, the first question that this research aims to answer is the following;

1. What are the most important use cases of Blockchain in the supply chain domain and the related characteristics?

After having highlighted the most important characteristics of this technology in the supply chain domain, the next step of this research consists in the identification of the determinants of the adoption of this technology. The topic of technology adoption is widely accepted in the academic research (Sadhya & Sadhya, 2018), as technology adoption traditionally enhances its diffusion. Therefore, understanding the determinants of the technology adoption is extremely important (Kamble et al., 2018). Moreover, established and exhaustively tested theories like “TOE framework”, “TAM model” or “Theory of Reasoned Action” support this kind of study (Sadhya & Sadhya, 2018). Nevertheless, in the Blockchain case, there is a lack of knowledge concerning its adoption in the industry, especially in the supply chain context (Kamble et al., 2018). As stated by Kamble et al. (2018), people are still hesitant in its adoption and, consequently, there is a slow adoption rate of Blockchain. The existing literature concerns mostly conceptual expositions, showing a lack of empirical evidence regarding the adoption of this technology (Kamble et al., 2018). This is probably due to its novelty and its recent research investigation in the supply chain domain. Indeed, all the papers that analyze the Blockchain applicability in the supply chain domain date back to the 2016 at most. A recent study conducted by Kamble et al. (2018), tried to close this gap analyzing the adoption of Blockchain in the supply chains-Indian context. Nevertheless, the framework used in their research (Technology Acceptance Model) focuses the attention on the end-users perception about the technology usefulness and ease of use (Kamble et al., 2018). This focus can be limitative, excluding from the scope company-related factors

that can be fundamental in understanding the determinants of the company adoption decision. Therefore, this research aims to close this gap, formulating the following research question:

2. What are the determinants of the adoption of Blockchain in the supply chain domain from a company perspective?

1.2 Research Design

This research explores the applicability and adoption of Blockchain in the supply chain domain. In particular, the ultimate goal is the development of a technology adoption model. To achieve this objective, the design science research methodology (DSRM) is followed (Peffers et al., 2007). DSRM is a research process used for conducting design science (DS) research in information systems (IS). DS involves a rigorous process of artifact development to solve observed problems, to give a contribution to research, and to communicate the results to the appropriate audience. In particular, an artifact is any designed object (a construct, a model, a method) that has an embedded solution to an understood research problem (Peffers et al., 2007).

The DSRM is articulated in six phases (*Figure 3*). It starts with the problem identification. Then, it proceeds with the definition of the objectives of a solution, which, in this case, is the development of a technology adoption model. Afterwards, the design and development followed to achieve the solution are described. Demonstration and evaluation provide a practical analysis of the quality of the artifact. Lastly, communication defines the main audience of the research (Peffers et al., 2007). The DSRM can be entered in different points. If the research is triggered by the identification of a problem, the process starts from activity 1 (problem-centered initiation). If researchers are instead stimulated by a specific industry or research need, the process can start from activity 2 (objective-centered initiation). If there is already the idea of an artifact that is not yet a solution, the process can start from activity 3 (design & development-centered initiation). Lastly, if the research starts from the observation of a solution that worked, the process can start from activity 4 (client/context initiated) (Peffers et al., 2007). Since this research starts with the identification of a specific problem, it is problem-centered and, therefore, it starts from activity 1 (identify problem and motivate). The description of the single activities performed in each one of the six steps of the DSRM is explained in detail in Chapter 3.

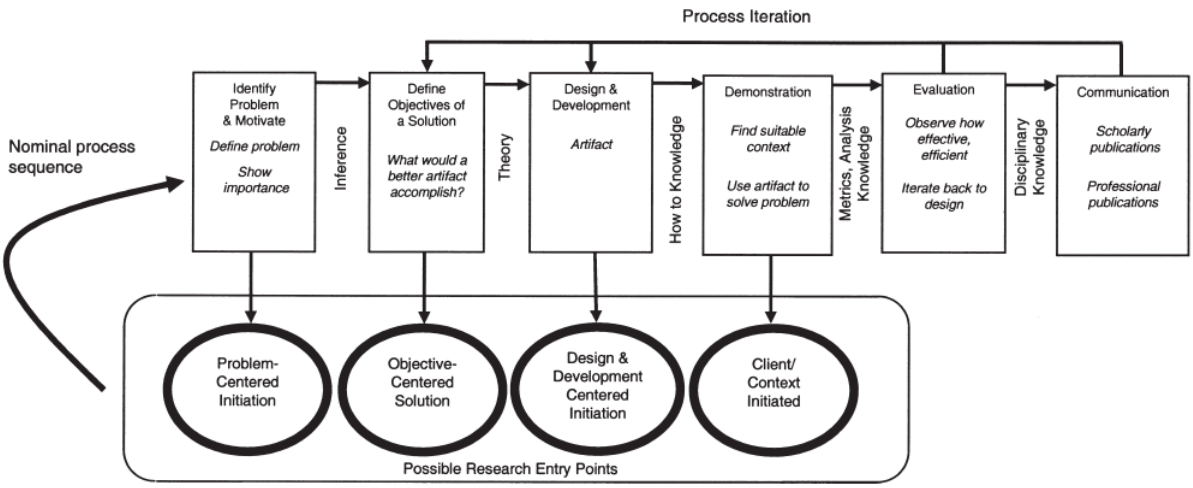

Figure 3. DSRM process model from Peffers et al., 2007

1.3 Report outline

The next chapter provides a theoretical background of the Blockchain technology and its opportunities in the supply chain domain. Chapter 3 explains the research design followed in this thesis. Chapter 4 answers the first research question. Performing a quasi-SLR, this chapter describes the main Blockchain use cases and related characteristics in the supply chain domain. Chapter 5 answers the second research question. In this part, the Blockchain adoption model in the supply chain domain is developed built on the findings of the first research question. This part includes the formulation of six hypotheses about the possible determinants of Blockchain adoption and their evaluation. Chapter 6 draws the main conclusions and limitations of the research, describing also the practical implications and providing some suggestions for future studies.

2. Background and Literature Review

This chapter is articulated in four main sections. In 2.1 the current supply chain ecosystem is discussed. In 2.2 the main concepts and basic principles of Blockchain are described. In 2.3 the Blockchain potentialities in the supply chain domain are presented. In 2.4 a summary of the chapter is provided.

2.1 Supply Chain

Modern supply chain systems are extremely large and complicated, because sources and suppliers are spread on a global level and feed production lines are settled in different continents (ElMessiry & ElMessiry, 2018). In this complex and competitive supply chain environment, information is one of the most important resources. Every day a huge amount of data is produced and exchanged across organizations (Nakasumi, 2017). Nevertheless, Mattila et al. (2016) state that the current supply chain arrangement is affected by problems as disparity of information and informational asymmetries between companies. This happens because each party of the supply chain stores its own partial copy of the product data, fulfilling its own informational needs. Therefore, since each party has its own imperfect copy, failures can easily occur in the update procedure of the data (Mattila et al., 2016).

Abeyratne and Monfared (2016) describe another important problem of the current supply chain system. In their research, they state that, nowadays, it is extremely difficult to be aware of how, when and where a product was originated, manufactured and used. Indeed, before a product finally reaches the consumer, it goes through a long chain of manufacturers, suppliers, distributors, retailers, of which customers are not aware of. From the point of view of manufacturing industries, if operations are not performed in a correct and safe way, there is the possibility of environmental damages, unethical labor and counterfeit products (Abeyratne & Monfared, 2016). In this context, no single system exists that is able to globally record and trace the product through the supply chain (ElMessiry & ElMessiry, 2018). Furthermore, as described by Imeri and Khadraoui (2018) in their research, during the transportation process, several challenges are evident in the existing systems. The main reasons are the intensity of the operations and the presence of a high number of stakeholders involved. These stakeholders have to communicate in order to exchange information about the transportation and delivery processes. These communications need to be documented. However, with the traditional systems (e-mails, phone, centralized databases), this procedure requires numerous communications. For example, only for transporting the containers after their arrival at the distribution point, approximately two hundred of communications are required. This kind of inefficiencies causes delays, human errors and higher possibilities to lose information (Imeri & Khadraoui, 2018, Casaldo-Vara et al., 2018). Moreover, the central authority that hosts the information can manipulate it. Therefore, data integrity and non-repudiation are not ensured. These factors can lead to a lack of trustability (Imeri & Khadraoui, 2018).

Several studies have been conducted to analyze the benefits of information sharing throughout the supply chain. As stated by Nakasumi (2017), sharing data like inventory levels, machine loads and sales forecasts can improve the performance of operations such as product cycle time and fulfil rate, decreasing also the order fluctuations. Nevertheless, the existing systems show some shortages in their applicability. EDI network is a possible solution to improve the data visibility of the supply chain, but its costs are quite high, especially for small businesses (Nakasumi, 2017). On the other hand, trying to reach visibility through the same ERP package generates the problem of sharing confidential information also with competitors. Therefore, an access controllable database system is needed (Nakasumi, 2017). Moreover, the existing centralized systems require the presence of intermediaries

which delay the overall process time (Miller, 2018). Lastly, transaction data is difficult to trust when it can be subject to steals and misuse (Nakasumi, 2017). As stated by Caro et al. (2018), there are IoT-based traceability and provenance systems that are built on a centralized infrastructure. Nevertheless, these solutions still present unsolved problems like data integrity, tampering and single points of failure (Caro et al., 2018).

As it is possible to notice from the previous discussion, the current supply chain system is affected by several problems that lead to inefficiencies and dissatisfaction. Moreover, the existing solutions are not able to fulfill the requests coming from the supply chain domain. Starting from these issues, numerous organizations and researchers have investigated new methods to share information along the supply chain. Nowadays, the technology that is gaining increasingly popularity is a distributed ledger called Blockchain.

2.2 What is Blockchain?

Blockchain is considered the main revolution of Bitcoin. Nevertheless, with the years, Blockchain found its own dimension. In particular, Beck and Müller-Bloch (2017) describe two different Blockchain generations. The first one sees a Blockchain that was only designed to support cryptocurrencies. The second generation of Blockchain moved away from Bitcoins, allowing all kind of transactions to be recorded in the public ledger. In this way, Blockchain became a generically programmable platform that could be used for a wide variety of implementations (Beck & Müller-Bloch, 2017).

But what is exactly a Blockchain? A Blockchain is a public ledger in which all the digital events executed among the network's participants can be recorded (Crosby et al., 2016). The ledger is composed by chains of blocks and in each block it is stored a list of transactions (Beck & Müller-Bloch, 2017). Before being recorded in the public ledger, the events are verified by consensus of many of the participants (Crosby et al., 2016). This consensus is reached through a validation procedure that asks the resolution of advanced cryptographic puzzles. This operation is also called "mining". Only when the puzzle is solved, the new block can be added to the chain (Beck & Müller-Bloch, 2017). The Blockchain grows every time a new transaction is executed, adding the new blocks to the Blockchain in a linear and chronological order. Each node that is connected to the Blockchain immediately downloads a copy of the whole Blockchain, from the genesis block to the last one (Swan, 2015). Moreover, once the information is recorded in the system, it can never be erased (Crosby et al., 2016). In this way, the Blockchain has complete information about the transactions history, preserving the old and new versions of each information (Swan, 2015). Indeed, the highly cryptographic features of the process make every tampering tentative practically impossible (Beck & Müller-Bloch, 2017).

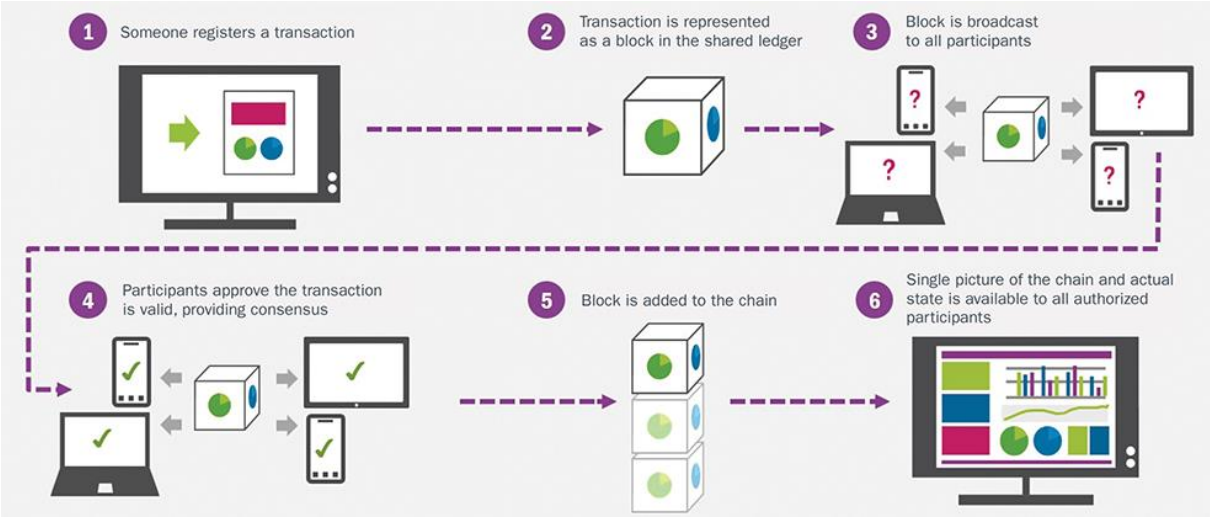

Figure 4. How Blockchain works (Canaday, 2017)

2.2.1 Blockchain basic principles

Distributed Database

No single parties have the entire control of the information, but each party of the network has the access to the whole database and its history. Moreover, the network has the power to verify the records stored on the Blockchain directly, without the need of intermediaries (Mudliar, & Parekh, 2018).

Peer-to-peer transmission

The communication is performed directly between peers, instead of using a central node as orchestrator. Each node of the network stores and forward information to all other nodes (Mudliar et al., 2018).

Asymmetric key cryptography

Blockchain exploits the potentialities of the public key cryptography, in order to safeguard the security of the operations. Therefore, in order to execute any type of exchange, the user needs to be assigned both a public and a private key. The whole network knows the public one, which uniquely identifies the user in the network. The private key is used to digitally sign transactions and must be kept secret by the user. In this way, only the user who is able to generate a valid signature with his private key can claim the ownership of the transaction (Puthal et al., 2018).

Computational logic

Another important property of Blockchain lies in its digital nature. This nature of the ledger ties the transactions to a computational logic that allows their programmability. In this way, it is possible to create rules and algorithms that trigger transactions between nodes in an automatic way (Mudliar, & Parekh, 2018). An example of this characteristic are the smart contracts. Smart contracts are represented by computer code that is implemented on the Blockchain. They work executing a set of predefined rules through a series of *if this then do that.* In this way, they guarantee that the rules that were established by the network participants are followed, without the need for an intermediary

(Morabito, 2017). In this sense, smart contracts can bring privacy protection, automation and intelligence into a Blockchain-based system (Chen et al., 2017). Since smart contracts are implemented on the Blockchain, they inherit all the Blockchain's properties: they operate in a fully automated way, they are distributed across the network, and they are permanent and tamper-proof (Beck & Müller-Bloch, 2017; Morabito, 2017).

2.3 Supply Chain meets Blockchain

Blockchain has the potential of improving processes and business models in supply chain management (Hakius & Petersen, 2017). Its trusted computing and auditability can serve other functions rather than money exchange (Nakasumi, 2017). Since no central authority is required, Blockchain can be used to transfer information in a fully automated and safe manner without the need of intermediaries. In this way, the transactions become faster and non-falsifiable, guaranteeing the traceability of the records all the way back to the originating party (Apte & Petrovsky, 2016). For illicit or counterfeit products, it becomes increasingly difficult to enter legitimate supply chains. Indeed, it becomes possible for end users to exactly verify who, where and by whom their product was made, impeding the expansion of a market for illegal and counterfeit products (Apte & Petrovsky, 2016).

With Blockchain, every stakeholder involved in the supply chain can have access to the same set of information that is included in the Blockchain, solving the problem of the opacity of the current supply chain system. Nevertheless, access control mechanisms can be used to protect the privacy of confidential data from unauthorized viewers (Imeri & Khadraoui, 2018).

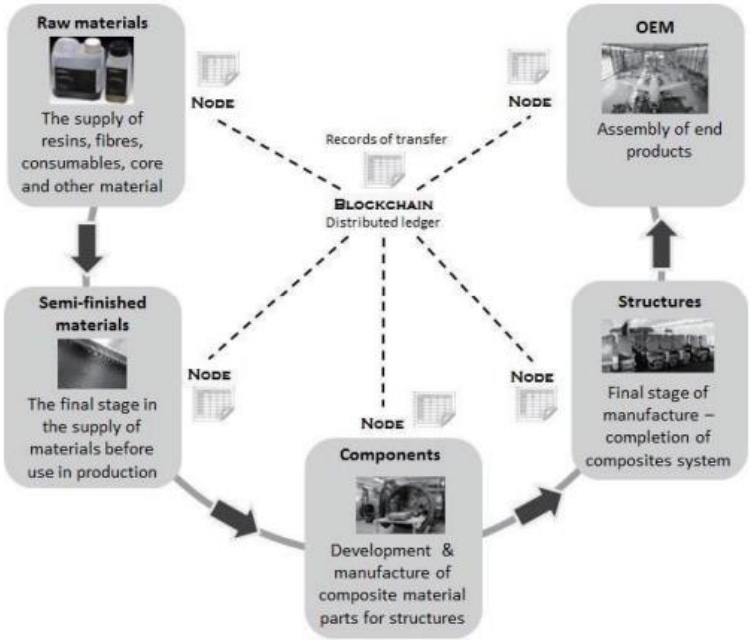

Figure 5. Blockchain in Supply Chain - Example from Mondragon et al. (2018)

These opportunities lead Blockchain to be applicable to several operations along the supply chain. For example, Miller (2018), in his research, states the opportunity of Blockchain to solve the problem of the lack of visibility of the shipment data. Blockchain would allow the increase of the transparency of the data related to products or components as the shipment moves through the supply chain (Miller, 2018). Moreover, the problem of lack of trust that affects the current supply chain system can be addressed by this technology. With Blockchain, the participants can share their data across a network of untrusted nodes, without the need of a trusted intermediary. It thus creates trust between the parties by eliminating the need for trust (Hakius & Petersen, 2017). Another example concerns the product traceability for food quality and safety that contributes to increase the customer confidence in the market system (Tse et al., 2017). Although all these benefits, Blockchain shows also some problems related, for example, to high costs and immaturity (Apte & Petrovsky, 2018; Tian, 2016). In this sense, Blockchain can still represent either a threat or an advantage. Nevertheless, in the literature, there is

a lack of comprehensive knowledge concerning the most important Blockchain characteristics in the supply chain domain. Moreover, as stated by Hackius and Petersen (2017), Blockchain in supply chain is not widespread: it is known only to some experts and, among them, only a small part pursues implementation plans. This research aims to investigate the reasons of this slow adoption, firstly understanding the most important characteristics of Blockchain in supply chain and, secondly, analyzing the factors that result to be determinant of the Blockchain adoption decision.

2.4 Summary

This chapter introduced the setting of this research. 2.1 described the main and different issues that affect the traditional supply chain context. Starting from these issues, in 2.2, the Blockchain solution was proposed and explained. In 2.3, a general overview of the potentialities of Blockchain in the supply chain domain was provided. Nevertheless, it was highlighted how the knowledge in this domain is quite fragmented. In the next chapter, the research design used to address the research questions is described.

3. Research Design

The aim of this research is to investigate the Blockchain applicability and use in the supply chain domain. For this purpose, the two research questions presented in Chapter 1 were elaborated. Since the final goal of this study is the development of a technology adoption model, the design science research methodology (DSRM) is followed (Peffers et al., 2007).

As introduced in Chapter 1, the DSRM process consists of six steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication. Moreover, the DSRM has different entry points: problem-centered initiation, objective-centered initiation, design and development-centered initiation, and client/context initiated (Peffers et al., 2007). This research starts with the identification and description of a problem. Therefore, the research enters the DSR process with a problem-centered initiation.

Figure 6 shows the six research steps of the DSRM performed in this study.

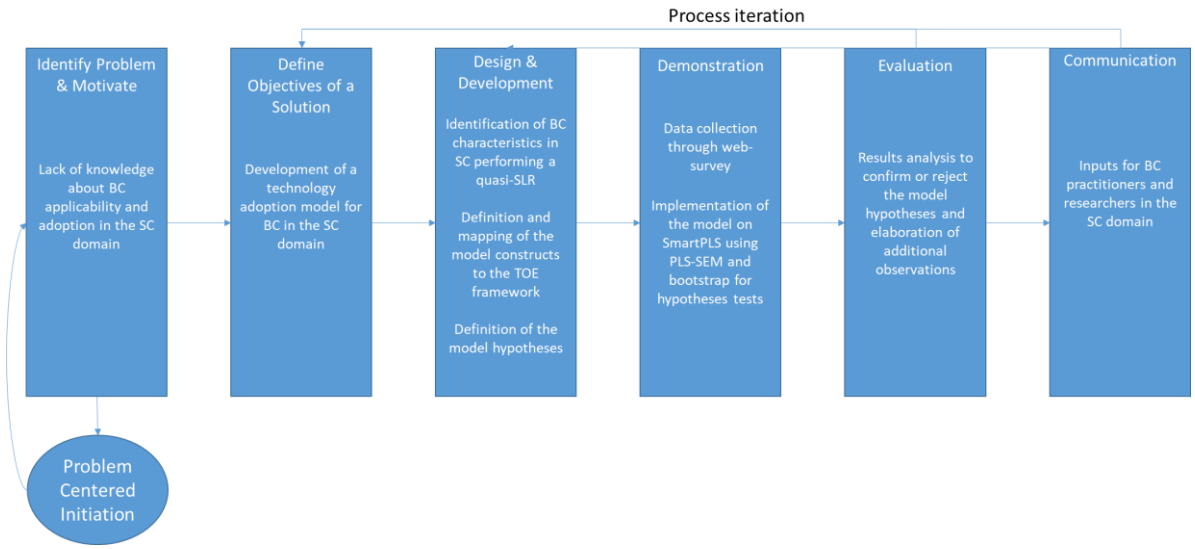

Figure 6. DSRM for Blockchain adoption model in the supply chain domain

Identify Problem and Motivate: supply chain is a domain that is facing a challenging moment due to the increasing complexity of its structure. In this scenario, Blockchain is a promising technology that aims to solve the supply chain criticalities. Nevertheless, within literature, the knowledge about the Blockchain possibilities in the supply chain domain is rather fragmented and sparse. Deepening in this context, there is a lack of understanding regarding the main Blockchain characteristics in the supply chain domain and their causal relationships with the intention of organizations to adopt the technology. Indeed, although the technology has been attracting the interest of a wide public, its adoption rate is limited. Nevertheless, there is a lack of empirical evidence regarding the adoption of this technology. Since adoption leads to diffusion, understanding its determinants is important to improve and adjust the development of the technology.

Define Objectives of a Solution: the objective of the research solution is to develop a technology adoption model that identifies the determinants of Blockchain adoption in the supply chain domain.

Design and Development: this phase was articulated in different parts. First, the main Blockchain use cases and related characteristics were collected from the literature. Because of a rather fragmented and scarce knowledge accumulation in this domain and the prevalence of grey literature, a quasi-SLR was performed. The output of the quasi-SLR gave an in-depth knowledge in the context of Blockchain

in supply chain (RQ1) and served as input for the development of the Blockchain adoption model (RQ2). The quasi-SLR showed a shortness of Blockchain risks and challenges that were judged fundamental to understand the slow Blockchain adoption rate. Therefore, a second screening of SLRs and extended reviews was performed. The individual characteristics were selected and merged into generic constructs that were used for the formulation of the hypotheses of the Blockchain adoption model. The reference model used in this research was the Technology Organization Environment framework (TOE) by Tornatzky and Fleischer (1990) (see *Figure 7*).

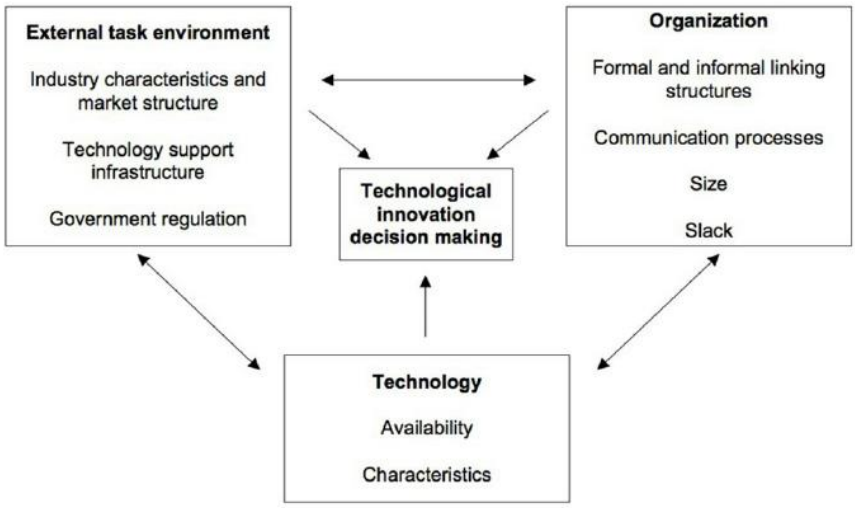

Figure 7. TOE framework from Tornatzky and Fleischer (1990)

The technology adoption models traditionally aim at understanding the factors that move a user from not having an innovation to having it (Tornatzky and Fleischer, 1990). Besides TOE, other frameworks exist in literature, like TAM (Technology Acceptance Model) by Davis (1985) and TPB (Theory of Planned Behavior) by Ajzen (1991). Nevertheless, these approaches focus their attention on the users and their perceptions about the usability of the technology (Lee, 2009). This research has a different goal that is to understand the perception of the technology from a company perspective. The TOE approach places innovation adoption within the context of organizational decision making (Tornatzky and Fleischer, 1990). In this sense, the TOE framework fitted better the research purpose. According to Tornatzky and Fleischer (1990), there are three elements that influence the adoption of a technological innovation: the technological context, the organizational context and the environmental context. The technological context refers to internal and external technologies that are relevant to the firm. Different characteristics of the technology can influence its adoption. The organizational context is defined in terms of features concerning the organization that can constraint or facilitate the adoption of the innovation. The environmental context represents the arena in which the organization conducts its business (Tornatzky & Fleischer, 1990). Previous works have extensively supported this model. Wang et al. (2010) used the TOE framework for understanding the determinants of RFID adoption in the manufacturing industry. Moreover, in their research, they mention numerous other studies that used TOE for understanding the adoption of technologies like EDI, Internet and E-commerce (Wang et al., 2010). On the same line, Ruivo et al. (2014) used the TOE framework to understand the determinants of the ERP use. Starting from these considerations, the TOE framework was judged as an adequate model for assessing the Blockchain adoption in the supply chain domain. Therefore, the constructs outlined were mapped to the Technology, Organization and Environment components, and the model hypotheses were formulated.

Demonstration: the survey was selected as an appropriate method of data collection for testing the hypotheses. Since the model was built based on the literature, the constructs used did not have validated measurement models. Therefore, specific multi-item scales were developed. For this reason, a first pilot test was conducted in order to guarantee the effectiveness of the survey. The pilot round involved the participation of four Blockchain and supply chain experts. Following the feedbacks received, the last changes were made to the survey, which was subsequently sent to organizations active in a supply chain context. The data gathered were processed using the software SmartPLS 3.0 (Ringle et al., 2015). PLS-SEM and bootstrapping were used for the hypotheses testing (Hair et al., 2014).

Evaluation: the results obtained were analyzed in this phase, leading to the confirmation or rejection of the model hypotheses. Moreover, additional observations about the model results were elaborated in this phase.

Communication: the audience of this research involves three main groups. First, the results of this study are valuable for Blockchain practitioners in the supply chain domain. Understanding the Blockchain perception from the surrounding business world can be helpful to improve the direction of the Blockchain development. Second, Blockchain researchers in the supply chain domain can know dispose of an organic collection of knowledge in this domain (RQ1), and they can use the developed adoption model (RQ2) as an input for further analyses and improvements. Lastly, the performed research resulted in this MSc thesis, which is publicly available on the TU/e repository for students and employees.

4. Blockchain use cases and characteristics (RQ1)

This chapter aims to gather the existing knowledge about the Blockchain applicability in the supply chain domain. To achieve this goal, a quasi-SLR was conducted to identify the main use cases and their related characteristics. Since the output of the quasi-SLR showed a shortness in terms of Blockchain challenges, it was integrated with an additional screening of Blockchain SLRs and extensive reviews from other domains. Lastly, the main characteristics were selected and merged into generic constructs.

Figure 8 shows the main steps performed to answer the first research question. In particular, the first three steps are described in this chapter, while the last one is addressed in Chapter 5.

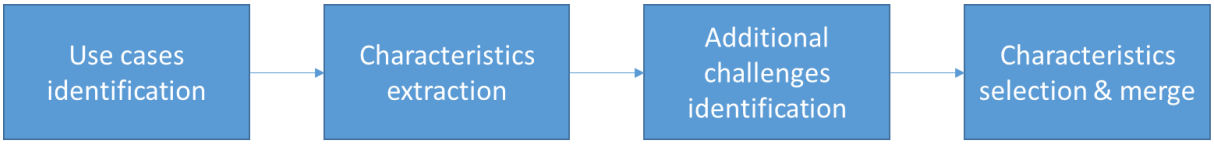

Figure 8. Research steps for RQ1

This chapter includes four main parts. In 4.1, the steps performed to execute the quasi-SLR are explained. In 4.2, the Blockchain use cases are described and the related characteristics are collected. In 4.3, a summary of the use cases and related characteristics about the Blockchain applicability in the supply chain domain is shown. In 4.4, the review of supply chain papers is integrated with the knowledge coming from generic Blockchain SLRs and extensive reviews. In 4.5 a summary of the whole chapter is provided.

4.1 Quasi-SLR

An SLR is generally undertaken in order to provide a thorough and unbiased summary of all existing information about a phenomenon (Kitchenham & Charters, 2007). Nevertheless, in this case, a full SLR would have not been exhaustive since there is a limited knowledge accumulation in this domain. Moreover, most of the papers about this topic is in the grey literature. For these reasons, a quasi-SLR was conducted following the guidelines from Kitchenham and Charters (2007). In particular, this quasi-SLR diverges from a standard SLR for two main reasons. Firstly, also grey literature was used. Secondly, due to the scarce knowledge accumulation, the keywords utilized in the review protocol were not used with the strict imposition of synonyms and Boolean relationships, which would have led to a small and limited number of results.

The main steps performed in this quasi-SLR are shown in *Figure 9*.

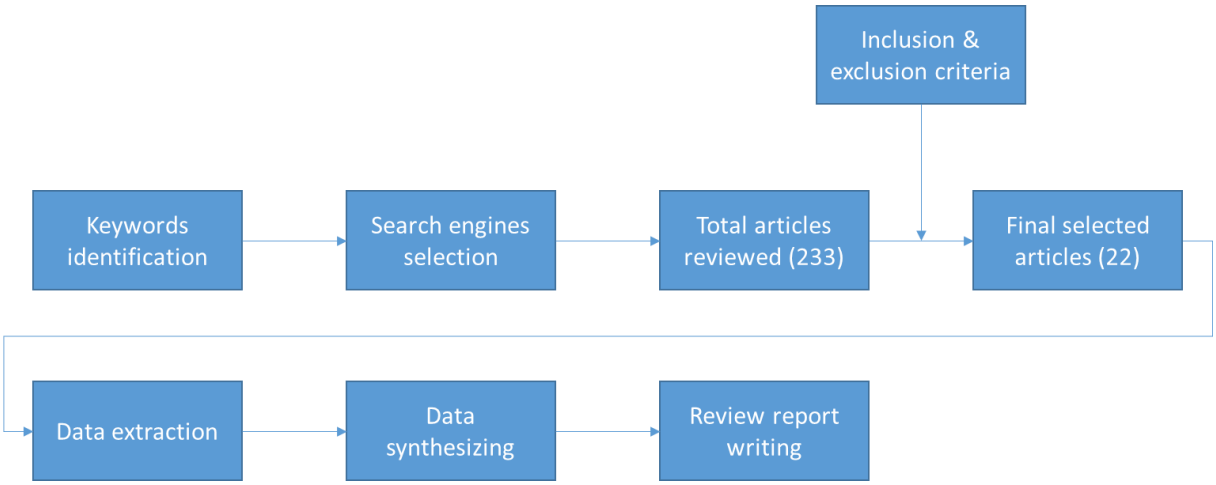

Figure 9. Quasi-SLR process

In particular, the keywords "Blockchain supply chain" were used for the review process. The search engines selected were Google Scholar, Scopus and IEEE. These databases were selected for their wide papers availability and for their relation to the fields of economics, informatics, science and technology. All the results from IEEE were analyzed (33 papers). The first 100 results from Google Scholar and the first 100 results from Scopus were inspected. Therefore, a total number of articles equal to 233 was reviewed. Then, some inclusion and exclusion criteria were established. First, access-ability criteria were used to measure if a study was available for additional assessments. Second, paper specification criteria measured if the meta-information of the study was satisfactory. Third, the content criteria measured whether the content of the study addressed the research question (Pourmirza et al., 2017). In this research, the following criteria were applied:

- Access-ability criterion 1.1: papers with full text availability were included;
- Access-ability criterion 1.2: papers in English language were included;
- Paper specification criterion 2.1: papers that were not duplicates were included;
- Paper specification criterion 2.2: papers that were not posters were included;
- Content inclusion criterion 3.1: papers that were related to applications of Blockchain in supply chain business processes were included;
- Content exclusion criterion 3.2: papers that focused on the domain of cryptocurrency were excluded;
- Content exclusion criterion 3.3: papers that focused on the analysis of Blockchain architecture or protocols were excluded.

Paper specification criteria about the publication date were not defined, since the topic of Blockchain in supply chain is rather new and all the available studies dated back at 2016 at most.

A final pool of 22 papers was available for the data extraction, which was performed in three steps. Firstly, the different use cases discussed in each paper were highlighted. Secondly, the knowledge coming from different papers about the same use case was merged. Thirdly, based on the analysis of the single use cases, the main characteristics were extracted. In particular, the following three data categories were collected for each use case:

- Blockchain inherent characteristics: highlighted as characteristics typical of the technology itself, regardless of the domain;
- Blockchain use cases: highlighted as supply chain processes or operations were Blockchain revealed its usefulness;

- Blockchain in-use characteristics: selected as results of the application of the Blockchain, and therefore of its inherent characteristics, to the use cases.

Lastly, the complete knowledge obtained from these steps was synthesized in a comprehensive model (paragraph 4.3).

4.2 Use-cases

Several studies analyzed the applicability of Blockchain in different supply chain processes. After having read the most relevant papers concerning the Blockchain applicability in the supply chain domain, the relative use cases were collected. In *Appendix B*, it is possible to find a table that connects each use case to the papers that mentioned it. From this procedure, 17 use cases were highlighted. To facilitate the reading process, the use cases were classified in the following groups:

- Identity management: use cases aimed at managing the digital identity of actors and products involved in the supply chain.
- Asset tracking: use cases aimed at improving the product traceability along the supply chain;
- Logistics: use cases aimed at improving the process of product flow along the supply chain;
- Quality management: use cases aimed at improving the process quality;
- Cross-organizational collaborations: use cases aimed at improving the process efficiency, quality and integration across organizations;
- Customer management: use cases aimed at improving and exploiting the customer experience.

In this analysis, the use of smart contracts is not considered on its own, but it is seen as a tool to achieve specific use cases.

4.2.1 Identity management

UC1 Digital identity

Blockchain-based identity and access management systems can be exploited to strengthen the security of IoT (Kshetri, 2017). Blockchain would allow products and actors to have their own digital profile. In particular, each product would have an information tag attached, which represents a unique digital cryptographic identifier that connects a physical product to its virtual identity. On the other hand, actors have their digital profile including the personal information and the association with products (Abeyratne & Monfared, 2016). Digital identity can use particular access authority that helps to preserve privacy from competitors along the supply chain. In particular, accessing data is managed by smart contracts that in turn use the digital identity in order to protect the secrecy of the data (Chen et al., 2017). This system allows to establish trust among participants of the global trade, which can facilitate the efficiency of product logistics flow and money transfers. The higher efficiency can consequently lead to lower transactional costs (Duan & Patel, 2018). According to Duan and Patel (2018) Blockchain in global trade can create self-sovereign,

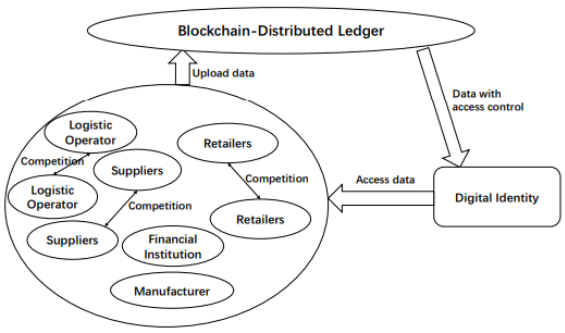

Figure 10. Digital Identity framework from Chen et al. (2017)

decentralized identity, ensuring more trust, control and security over the process of information exchange. In its introduction, Bocek et al. (2017) mention several companies that offer identity management services based on Blockchain, like Blockstack, UniquID, ShoCard and SolidX (Bocek et al., 2017).

Table 1. Digital identity-BC characteristics.

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Privacy	*Digital Identity*	Privacy
Trustworthiness		Digital trust
		Costs reduction
		Improvement of logistics performance
		Money transfer efficiency
		Time reduction
		Data control
		Data security
EXTRA TOOLS: IoT, Smart contracts		

4.2.2 Asset tracking

UC2 Product traceability

The most important use case that underlies all the following ones is product traceability. Casado-Vara et al. (2018) state that, differently from the linear model that characterizes the actual supply chain system, Blockchain introduces a new circular model in which all products can be traced with Blockchain (Casado-Vara, 2018).

A sector that has been extensively investigated in terms of product traceability is the food sector. This happens because the product safety is highly important in this domain and Blockchain can be helpful in the achievement of this quality. Caro et al. (2018), in their research, analyze the implementation of a traceability system for the agri-food supply chain management. They describe Blockchain as a digital technology that provides fault-tolerance, immutability, transparency, traceability, digital representation of physical assets and autonomous transaction executions. All these properties contribute to represent Blockchain as a potential solution to obtain tamper-proof stored records and the elimination of centralized third-party intermediary. In particular, they develop a farm-to-fork use case that wants to create a traceability scenario to promote the food traceability, from the agricultural production to the consumption process (Caro et al., 2018).

Another author who analyzed the applicability of Blockchain for the food traceability is Feng Tian. In particular, he conducted two studies (2016, 2017). In the first one, he built a model that combines Blockchain and RFID technology, stating that, thanks to this system, the food safety and quality can be enhanced, significantly reducing the losses during the logistics process. In the second one, he analyzed the applicability of Blockchain in the food safety domain, combining Internet of Things and HACCP. He defined this system as open, transparent, decentralized, trustless, reliable and secure. Tian (2017) explains that other technologies already exist that can trace products and operations. Nevertheless, the most relevant problem in these cases is how to ensure the trustworthiness of the data uploaded.

Indeed, there are usually some centralized organizations that take care of the data protection and security. However, this could generate information asymmetry between organizations and individuals, creating the risk for bribery that could lead to the threat for valuable information to be tampered with. Another potential risk of the traceability system in use highlighted by the author is the presence of a single point of failure (Tian, 2017). In this context, Blockchain can solve the opacity problem of the current system, storing the data in a transparent and shared ledger that can be accessed by all the members along the supply chain (Tian, 2017). Nevertheless, some relevant criticalities are also highlighted by Tian. The first one is scalability that, he states, is a primary urgent concern that needs to be solved (Tian, 2016). Moreover, he identifies the high costs encountered for the establishment of this kind of traceability system and the immaturity of this technology as major concerns of its applicability (Tian, 2017).

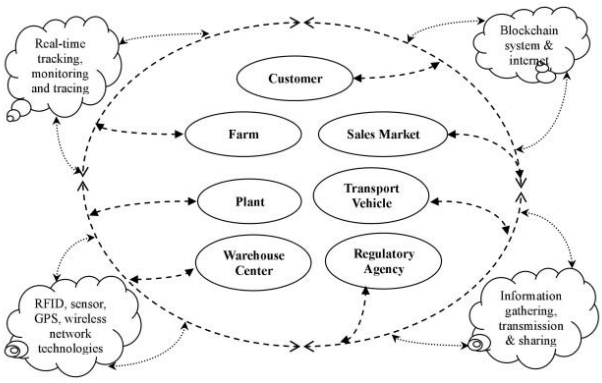

Figure 11. Traceability framework from Tian (2016)

A different sector is analyzed by Bocek et al. (2017). In particular, they examine the applicability of a Blockchain traceability system in the pharmaceutical supply chain domain. The tamper-proof characteristic of the data stored in the Blockchain is again highlighted as one of the most important properties. Moreover, the visibility of the data is seen as a way to guarantee a transparent information access from both organizations and consumers. Lastly, the use of smart contracts can establish digital trust, making the third-party intervention unnecessary and reducing the operational expenses and the data manipulation risks (Bocek et al., 2017).

Table 2. Product traceability-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Fault-tolerance	*Product traceability*	Product safety
Immutability		Traceability
Transparency		Costs reduction
Tamper-proof		Transactions automation
Reliability		Elimination of centralized third-party intermediaries
Security		Improvement of logistics performance
Openness		Process transparency
Trustworthiness		Easy information sharing
Decentralization		Data security
		Digital trust
		Customer engagement
		Scalability
		High costs
		Immaturity
EXTRA TOOLS: Smart contracts, RFID, IoT, sensors, wireless network technology		

UC3 Ownership traceability

Abeyratne and Monfared (2016) in their research analyze possible Blockchain applications in the manufacturing supply chain. In particular, the most interesting one concerns the usage of Blockchain to trace the ownership of the products along the chain. They propose that every time two parties sign a contract, data should be uploaded on the Blockchain and the status of the product profile should be automatically updated, showing who is the new stakeholder. This application allows the network to keep trace of an unquestionable record of ownership for each product (Abeyratne & Monfared, 2016). Using these records that are publicly available on the Blockchain, a potential buyer can easily check if the seller is the actual owner of the product and what is the origin of the product (Hackius & Petersen, 2017). An interesting research conducted by Toyoda et al. (2017) analyzes the usefulness of Blockchain in the post supply chain. Their research states that, using Blockchain in combination with RFID technology, it is possible to guarantee the ownership of the products also in the post supply chain phase. Indeed, even if the RFID tag of the product is cloned, the system developed by Toyoda et al. leverages the Blockchain's principle that anyone can check the proof of possession. Then, even if products have genuine RFID tags, if the seller does not possess their ownership, customers can decide to reject their purchase (Toyoda et al., 2017). Nevertheless, the performance capability of such system and the inadequacy of certain IT infrastructure can constitute a bottleneck for this kind of implementation (Abeyratne & Monfared, 2016).

Table 3. Ownership traceability-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Reliability	*Ownership traceability*	Product safety
Transparency		Customer engagement
		Easy information sharing
		Performance capability
		IT infrastructure inadequacy
EXTRA TOOLS: RFID		

UC4 Provenance

Customers, retailers and suppliers would be able to see the products' source, whether the products were produced through child labor or if any dangerous or hidden components are present; all these helping the decisions about the products (Chakrabarti & Chaudhuri, 2017). The origin and history information about the product can be directly checked from the Blockchain, without the need of intermediaries (Bocek et al., 2017). The transparent, reliable and secure environment increases also the information credibility of the whole system (Tian, 2016). Some provenance applications have been tested by companies like ProvChain. In their work, the collection, storage and validation of the data obtained good results in terms of tamper-proof records and user privacy (Caro et al., 2018). Another example explained by Bocek et al. (2017) is represented by Provenance. Provenance is a company that is making the supply chain transparent, using Blockchain to prove the product's authenticity and origin. In this way, a detailed description of who created and assembled the single parts is visible (Bocek et al., 2017).

Table 4. Provenance-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Provenance*	Process security
Reliability		Product safety
Security		Intermediaries minimization
Tamper-proof		Customer confidence
		Privacy protection
		Data visibility
EXTRA TOOLS: Not specified		

UC5 Product recalling & Responsible investigation

Thanks to the real-time information and data visibility, a precise recalling and responsible investigation can be facilitated. In this way, once unsafety incidents happen, the defective products and the responsible can be located immediately, reducing losses and hazards (Tian, 2016; Tian, 2017; Chakrabarti & Chaudhuri, 2017). Moreover, it helps the participants to find solutions in a short time, improving the efficiency of the supply chain (Tse et al., 2017). Lastly, the transactions can be linked to the users of vulnerable devices. In this way, Blockchain facilitates the tracking progress, that allows a fast intervention for addressing vulnerabilities and notify the owners (Kshetri, 2017). Moreover, in the retailers' case, the easy identification of the problem can lead to specific products recalling, instead of the recall of the entire product line (Kshetri, 2018).

Table 5. Product recalling & Responsible Investigation –BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Product recalling & Responsible Investigation*	Real-time information
		Loss reduction
		Time reduction
		Improvement of logistics performance
		Improvement of quality management
EXTRA TOOLS: Not specified		

UC6 Counterfeit Products Identification

Hackius and Petersen (2017) in their research highlight the identification of counterfeit products as one of the main use cases of Blockchain in supply chain. Indeed, they state that usually the origins of valuable items rely on paper certificates that can be lost or tampered with. In this context, some startups developed new certification methods based on Blockchain to ensure the identity of the products. Everledger, for example, is a startup that creates a new way to identify a diamond. Since its serial number can easily be cut, they determine the identity of a diamond by recording 40 data points that uniquely identify it. Then, saving this information on Blockchain, every buyer can easily determine if the seller is the actual owner of the diamond and if the product is original (Hackius & Petersen, 2017). In this way, the customer confidence about the product quality increases (Chakrabarti, Chaudhuri,

2017). The problem of fraud detection was also analyzed by Bocek et al. (2017), who describe numerous startups that are working on it. Other than Everledger, Blockverify operates in the pharmaceutical sector, storing the products private keys on the Blockchain. Verisart, instead, certifies documents and verifies artworks using Blockchain. Chronicled focuses on luxury items, providing the possibility to check the information of both buyers and sellers (Bocek et al., 2017).

Table 6. Counterfeit product identification-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Reliability	*Counterfeit products identification*	Product safety
Transparency		Customer confidence
Security		
EXTRA TOOLS: Not specified		

4.2.3 Logistics

UC7 Paperwork processing

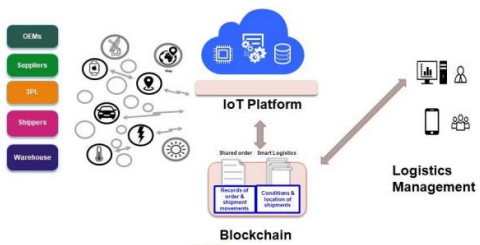

Figure 12. Paperwork processing framework from Miller (2018)

Tse et al. (2017) in their research highlight two main advantages in the use of Blockchain in supply chain processes. From a data perspective, Blockchain provides permanent records that cannot be tampered with. From a business perspective, its adoption can replace the traditional paper tracking systems and manual monitoring systems, preventing the inaccurate impact caused by the human work. Indeed, with Blockchain, the document verification could be performed automatically, eliminating also the need for centralized authorities (Tse et al., 2017). Another author who investigates the applicability of Blockchain together with IoT along the supply chain is Dennis Miller (2018). In his paper, he says that Blockchain is the first candidate to solve the supply chain visibility problem of shipment data for products and components information. Indeed, paperwork is usually misplaced or lost or it has to wait for a long time to be performed. Blockchain could be used to capture data from IoT devices and the transactions registered could then be used as proof of shipment or proof of delivery. In this way, the process time could be minimized and the predictions of the lead-time due to the materials flowing could be more accurate (Miller, 2018). Moreover, organizations can allocate just the right amount of resources to perform these activities (Kshetri, 2018). Lastly, Lu and Xu (2017) in their research, describe the use of smart contracts that codify the conditions defined in the agreements, so that they can automatically check and enforce the established conditions. In this way, they can enable automated regulatory-compliance checking (Lu & Xu, 2017).

Table 7. Paperwork processing-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Tamper-proof	*Paperwork processing*	Data accuracy
Permanency		Process automation
		Intermediaries minimization
		Data visibility
		Time reduction

		Resource optimization
		Improvement of logistics performance
EXTRA TOOLS: Smart contracts, IoT		

UC8 Transportation quality control

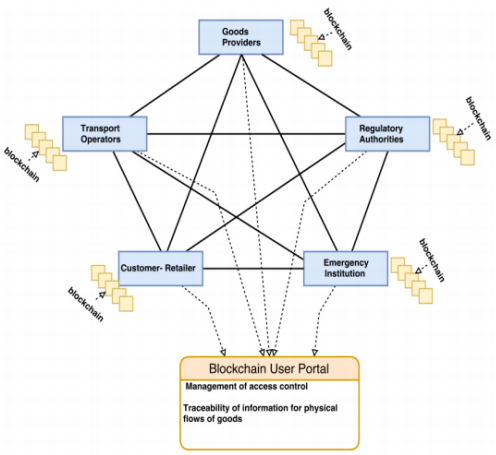

Figure 13. Information sharing framework in the transportation process from Imeri and Khadraoui (2018)

In the transportation process, time, temperature and tolerance are the key factors in ensuring the safety and quality of products. With Blockchain, real-time data can be uploaded in the system without any chance to be tampered with. Therefore, when values exceed the security standards, the different parties involved in the chain are aware of it (Tian, 2017). Moreover, smart contracts can regulate the consequent rejection of the product and payment back process, in case the required standards are not fulfilled (Bocek et al., 2017). According to Kshetri (2018), the use of Blockchain during the transportation process can provide accurate data for the analysis of the product quality. Indeed, stakeholders can check if the product was in the right place or if it waited in a location for a long time. Moreover, stores can exactly know the details regarding the arrival of a shipment, being therefore prepared to receive it (Kshetri, 2018). Another example in this context is described in the research of Imeri and Khadraoui (2018). They state that the Blockchain properties of immutability, data integrity, non-repudiation and transparency can improve the process of dangerous goods transportation. In particular, all the stakeholders involved in the process have the sets of information that is included in the Blockchain. Moreover, they can be connected without middle points of communication. Any attempt to change the data could be easily detected and blocked. Nevertheless, an access management system to confidential information can preserve the privacy of the data (Imeri & Khadraoui, 2018).

Table 8. Transportation quality control-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Tamper-proof	*Transportation quality control*	Real-time data
Transparency		Product safety
Integrity		Data accuracy
Non-repudiation		Data visibility
Immutability		Data security
		Process synchronization
		Improvement of quality management
EXTRA TOOLS: Smart contracts, RFID, GPS		

UC9 Distribution route calculation

Tian (2016, 2017) in his studies analyzes additional Blockchain functionalities in combination with technologies different from the RFID used for the product tracking. In particular, thanks to Blockchain and GPS sensors, an optimal distribution route can be calculated that can reduce the distribution time (Tian, 2016; Tian, 2017). Indeed, thanks to data transparency, transport business has the chance to optimize both duties in the storage and arrangements of people and trucks (Nakasumi, 2017). Chen et al. agree on this opinion, assessing that logistics providers can exploit the potentialities of smart contracts, using them to plan their routes and way of transportation intelligently. In this way, smart contracts can enhance the distribution making logistics plan based on the real-time quantities and positions of the products (Chen et al., 2017). Lastly, in case of components or products delay, the buyer would prefer to order substitutes, based on the expected delay time. Since this can work only in case of real-time and transparent information, Blockchain is a potential solution to achieve these goals (Nakasumi, 2017).

Table 9. Distribution route calculation-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Distribution route calculation*	Time reduction
		Resource optimization
		Improvement of logistics performance
		Process synchronization
		Real-time data
EXTRA TOOLS: Smart contracts, RFID, GPS		

UC10 Dynamic warehouse management

Warehouse management has, with Blockchain, the possibility to be performed in a dynamic way. In particular, using the data collected on the Blockchain, it is possible to dynamically establish which product has the priority to move out of the storage, enhancing the safeness and quality of the products. Moreover, with Blockchain, enterprises have the possibility to perform their market demand analysis, production and sales plan based on more accurate data information (Tian, 2016; Tian, 2017). Thanks to a dynamic warehouse management, the inventory level can be kept closer to the just-in-time practices (Miller, 2018). Indeed, Blockchain can be used to gather data related to customer buying pattern, order placement trends, etc. This data can then be used to forecast the location specific demands and suggested stock on hand that enhance the just-in-time inventory facility (Chakrabarti & Chaudhuri, 2017). Lastly, since all the values of production and sales are uploaded on the Blockchain, through the use of smart contract it is possible to have an automatic supplement for both manufacturers and retailers. This can reduce the supplement lead time and the loss of sales

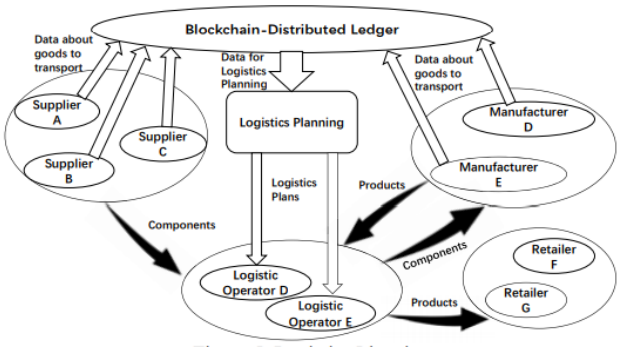

Figure 14. Logistics planning from Chen et al. (2017)

opportunity. Since the order is placed automatically, there are no ordering duties and, therefore, the operation costs decrease (Nakasumi, 2017).

Table 10. Dynamic warehouse management-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Dynamic warehouse management*	Product safety
		Data accuracy
		Improvement of logistics performance
		Time reduction
		Loss of sales reduction
		Costs reduction
		Process automation
EXTRA TOOLS: Smart contracts, RFID, IoT		

UC11 Departments management

Tse et al. in their research assess the usefulness of the adoption of this technology to collect statistics of various kinds that can then be reused to efficiently manage the different nodes or departments. In this way, the production can be more efficient, also reducing the amount of waste (Tse et al., 2017). Moreover, organizations along the supply chain have the opportunity to obtain an improved understanding of how their products are used further along the supply chain. This level of analysis can be utilized to improve their different organization's sectors like technology, marketing, production accounting and sales accounting. In this way, Blockchain can bring to a higher level of flexibility that leads organizations to adapt their operations to the changing competitive environment, providing products and services timely and cost effectively (Kshetri, 2018).

Table 11. Statistics collection-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Statistics collection*	Flexibility
		Resources optimization
		Waste reduction
		Data visibility
		Time reduction
		Cost efficiency
EXTRA TOOLS: Not specified		

4.2.4 Quality management

UC12 Process quality control

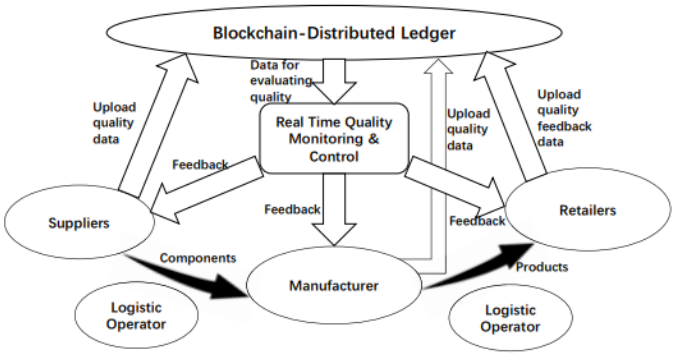

Figure 15. Quality monitoring and control frmework from Chen et al. (2017)

Chen et al., in their research (2017), analyze the applicability of Blockchain for the improvement of the supply chain quality management. This use case can be considered as an extension of the *Transportation Quality control* case, to any kind of processes. In particular, the authors highlight three main problems that affect the traditional centralized system: the self-interests of the members, the information asymmetry, the high costs and limitations of the processes. They believe that Blockchain can solve these issues thanks to its properties: trustworthiness, decentralization and traceability. These characteristics can improve the qualities of products and services together with the use of smart contracts. In particular, they propose a model in which the quality data collected during the production and inspection processes are uploaded and recorded on the Blockchain. Thanks to the real-time quality data, process and product quality can be evaluated using smart contracts and suppliers, manufacturers and retailers can be notified of the obtained results (Chen et al., 2017). Moreover, smart contacts can bring privacy protection to the system, also achieving several different functions with the Blockchain data. For example, in case of internal faults, the products are withdrawn; while in case of external faults, the different parties involved take the losses according to their quality contract (Chen et al., 2017).

Table 12. Quality management-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Decentralization	*Quality management*	Traceability
Trustworthiness		Product & service quality
		Real-time data
		Privacy protection
		Profits increase
		Process synchronization
		Improvement of quality management
EXTRA TOOLS: Smart contracts, IoT sensors		

4.2.5 Cross-organizational collaborations

UC13 B2B Integration

Korpela et al. (2017), in their research, describe the usefulness of Blockchain for business to business (B2B) integration between supply chain business partners. In this paper, the main advantages of Blockchain applications are the minimization of unnecessary third-party intermediaries, the security

and flexibility, creating a many-to-many integration model that can execute transactions rapidly and at a lower cost. Nevertheless, they highlight the necessity to reach a standardization of electronic documents before having the chance to implement this technology. With the definition of standards, then, it should be possible to use this technology to perform transactions and documents exchange quickly, reliably and at low cost. Another shortness of Blockchain implementation concerns the interoperability with the legacy systems, which is not offered by the Blockchain itself (Korpela et al., 2017). Moreover, with Blockchain, the possibility to have trustless networks becomes real. Indeed, using Blockchain, it is possible to execute transfers without the need to trust the other users. Without intermediaries and with the use of cryptography, transactions become faster and secure (Casado-Vara et al., 2018).

Table 13. B2B Integration-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Security	*B2B Integration*	Intermediaries minimization
Trustworthiness		Flexibility
		Time efficiency
		Cost efficiency
		Process security
		Digital trust
		Data security
		Lack of standards
		Lack of interoperability
EXTRA TOOLS: Not specified		

UC14 Supply chain synchronization

Blockchain allows storing data coming from different points in the same place, allowing a complete data collection process from multiple parties of the global supply chain (Duan & Patel, 2018). The collection and availability of "fresh" information, as defined by Nakasumi (2017), can bring to the whole supply chain network several benefits in terms of process synchronization. For example, suppliers and manufacturers can adjust their production acquiring real-time information from the others. Retailers can share information about their point of sales in real-time, reducing the supplement lead time and the loss of sales opportunity. Distributors can share their schedule and, in case of delay, adapt their plans based on the expected delay (Nakasumi, 2017). Indeed, as stated by ElMessiry and ElMessiry (2018) communication and coordination are vital in supply chain to meet the predetermined goals and timelines. The effective coordination of all parties involved in the supply chain brings to successful and smooth processes (ElMessiry and ElMessiry, 2018).

Table 14. Process synchronization - BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Supply chain synchronization*	Complete data collection
		Real-time data
		Costs reduction
		Market adaptation

		Time reduction
		Loss of sales reduction
		Easy information sharing
		Process synchronization
EXTRA TOOLS: Not specified		

4.2.6 Customer management

UC15 Customers applications

From a customer's point of view, it becomes possible to obtain products information related to the entire supply chain. Customers can obtain real-time information about the products they want to buy, by inspecting the traceability system. (Tian, 2016; Tian, 2017). In this way, customers can just walk through the records of the products, avoiding counterfeiting and increasing their confidence about the product quality (Chakrabarti & Chaudhuri, 2017). Duan and Patel in their research (2018) make the example of a mobile phone application. They state that, through the use of a mobile phone, customers can have the chance to scan the unique label of a product. This scan will show on the display the product information along the logistics steps in the global trade supply chain (Duan & Patel, 2018).

Table 15. Customers applications-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Customers applications*	Data visibility
		Real-time data
		Process efficiency
		Customer confidence
		Customer engagement
EXTRA TOOLS: Smartphone, labels		

UC16 Customer profiling

Blockchain is useful to gather information related to customers' buying patterns, order placement trends, etc. This data can then be used to evaluate reward points, cash back, personalized retail price and promotions, and to share with them customers targeted offers on real-time basis (Chakrabarti & Chaudhuri, 2017). Moreover, along the chain, all suppliers have access to the analysis and feedbacks of the customers about the products. Therefore, based on this data, they can adjust their production (Chen et al. 2017).

Table 16. Customer profiling-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Customer profiling*	Improvement of customer data analysis
		Market adaptation
EXTRA TOOLS: Not specified		

UC17 Loyalty programs

Blockchain technology can transform the current loyalty systems in smart ones. Storing the encrypted customer data, coupons and discounts could provide all the stores deeper analytics on customer records. Moreover, a smart loyalty system can allow customers to see all the loyalty information across multiple retailers in the same place (Chakrabarti & Chaudhuri, 2017).

Table 17. Loyalty programs-BC characteristics

BC INHERENT CHARACTERISTICS	USE CASE	BC IN-USE CHARACTERISTICS
Transparency	*Loyalty programs*	Improvement of customer data analysis
		Improvement of customers experience
EXTRA TOOLS: Not specified		

A summary of the characteristics highlighted in each use case is shown in *Appendix C*.

4.3 Summary of the use cases and characteristics

From the performed review, it is possible to summarize the main use cases and characteristics related to the Blockchain application in the supply chain domain. In particular, the Blockchain inherent characteristics applied to the supply chain use cases generate some specific in-use characteristics, as shown in *Figure 16*.

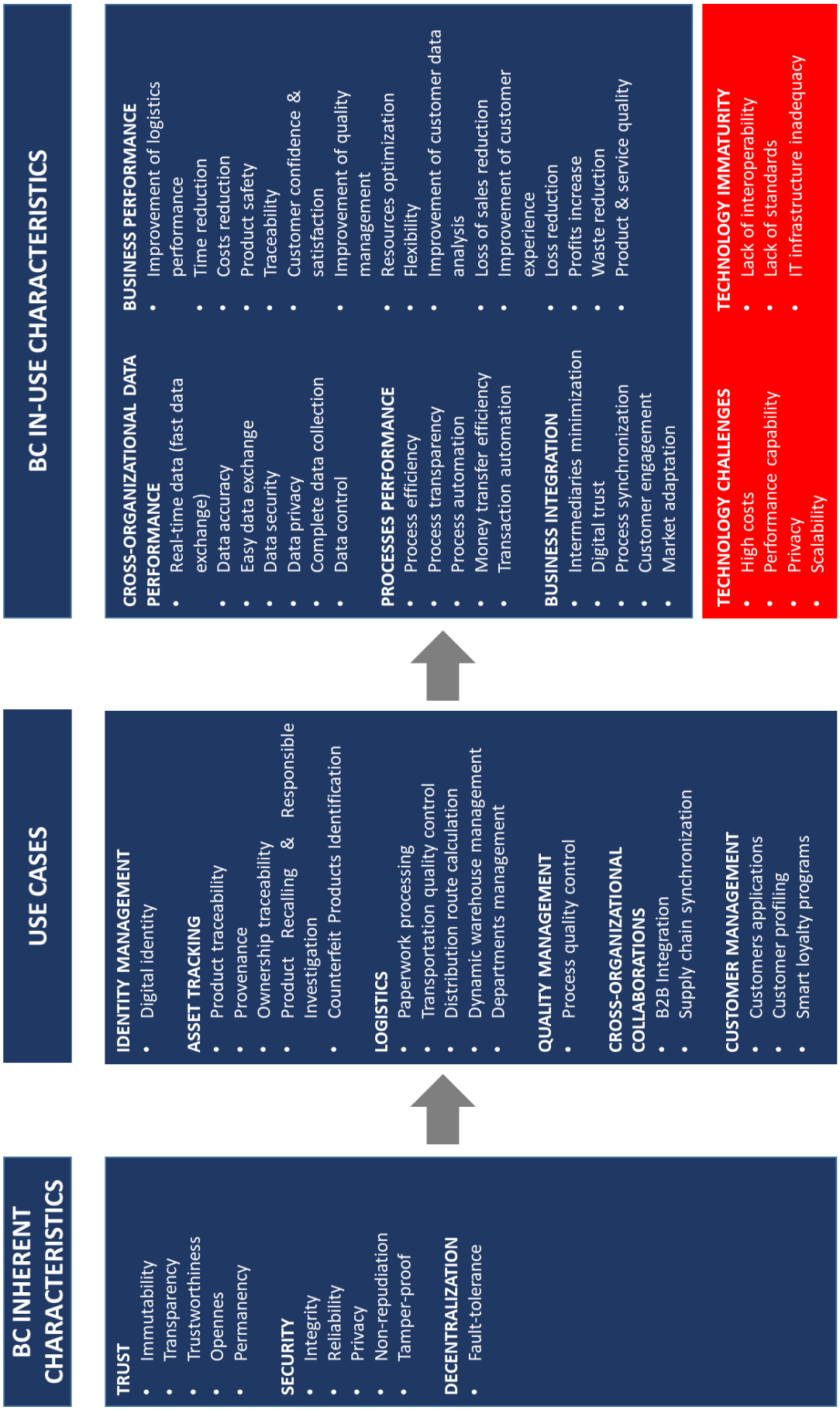

Figure 16. Blockchain use cases and characteristics in the supply chain domain (RQ1)

4.4 Additional factors

Before proceeding to build the Blockchain adoption model, a further step was needed. Indeed, the performed quasi-SLR showed one shortness: the discussion about potential risks and challenges related to the adoption of Blockchain was very limited. This is probably due to the publication bias that leads researchers to publish only positive results. Moreover, as it is possible to notice from the number and date of the papers analyzed, the research about the Blockchain applicability in this domain is rather recent. Therefore, it was executed an additional screening of SLRs and extensive reviews about Blockchain applications and challenges in different domains. In this way, it was possible to integrate the solid collection of advantages gathered in the quasi-SLR, with the experience coming from other domains about the main threats and challenges.

4.4.1 Security

Security is considered one of the major challenges and, many times, the primary topic investigated in studies about Blockchain applicability (Yli-Huumo et al., 2016). Indeed, even if security is often seen as one of the main strengths of this technology, many scholars still question it (Batubara et al., 2018). Batubara et al. in their review state that the main challenges that have been highlighted from the research concern cybersecurity issues and threats, and blind trust on the technology from general public, lawmakers and developers (Batubara et al., 2018). Other security challenges consist in the existence of dangerous attacks that can be harmful to the security of the system, like the verifier's dilemma, malleability attack, 51% attack, double-spending problem, race attack, Denial of Service (Batubara et al., 2018; Reyna et al., 2018; Sadhya & Sadhya, 2018). In particular, the most common one is the 51% attack, or majority attack. It happens when a Blockchain participant is able to control more than 51% of the mining power, which brings to the control of the consensus in the network (Reyna et al., 2018).

4.4.2 Privacy and anonymity

A key feature of Blockchain is transparency. Every information can be checked and traced until the very first transaction from each participant (Reyna et al., 2018). The public can see all information but without linking it to the respective identity, since pseudonyms are used for each identity (Yli-Huumo et al., 2016; Sadhya & Sadhya, 2018). Even though there is no direct relationship between the owner of the information and the identity, user privacy and anonymity can still be compromised by possible attacks (Reyna et al., 2018). In particular, some articles showed how, applying some practices, it was possible to map some Blockchain addresses to the respective IP addresses. For this reason, several studies analyzed possible solutions in order to increase the anonymity of Blockchain (Yli-Huumo et al., 2016). Indeed, legal institutions like governments or hospitals have to protect sensitive data from the public availability (Sadhya & Sadhya, 2018).

4.4.3 Legal and regulatory issues

Laws and regulatory support were found to be one of the main barriers for Blockchain adoption (Batubara et al., 2018). In order to guarantee that a user has legal certainty to establish the rights and obligations of the different parties in any agreement, clear laws and regulatory supports are needed. Indeed, to contribute to the diffusion of this technology, a proper legal framework in which it can be utilized should be developed (Batubara et al., 2018). Reyna et al. (2018), in their research, state that,

since Blockchain guarantees its work with the absence of a central authority, this could be both attractive and dangerous, if not properly regulated. Therefore, a first step in this direction could be the establishment of a common regulatory framework for Blockchain systems (Reyna et al., 2018). Sadhya and Sadhya (2018), in their research, affirm that the regulatory bodies did not reach the same evolution phase as the Blockchain technology, which is running ahead of it. Also Batubara et al. (2018) recognize this issue as an important barrier for the technology adoption. In particular, they call this problematic regulatory situation a "dilemma phase", stating that the development of a regulatory support could encourage more experimentations that could lead to find useful use cases for the technology (Sadhya & Sadhya, 2018).

4.4.4 Scalability

The other important characteristic recognized as a challenge from many studies is scalability. Sadhya and Sadhya (2018) explain the scalability problem using the Bitcoin example. They use this example because Bitcoin is the most known application of the Blockchain technology. In this case, the Blockchain technology is only able to conduct seven transactions per second at the maximum. This is a low number if compared with systems such as VISA, which is able to handle up to 4700 transactions per second. In this sense, Blockchain applications on a global scale need improvements from an architectural point of view (Sadhya & Sadhya, 2018). Reyna et al. (2018) also interrogate themselves about the scalability of the technology. They affirm that, as the size of the chain grows, nodes require more and more resources, reducing the system's capability to scale. In this process, they identify the choice of the consensus protocol used as an important determinant of the scalability of the system (Reyna et al., 2018). The restriction of the block size increases the delay of the consensus process, since only a restricted number of transactions can be confirmed each second. Nevertheless, increasing the block size would cause a delay in the block propagation procedure (Puthal et al., 2018). Although this problem has already been addressed by individual firms and industry consortia, a robust and final solution remains elusive (Underwood, 2016).

4.4.5 Interoperability and integration

Underwood (2016) names privacy, scalability and interoperability as the three major challenges of Blockchain. Challenges that he defines as pervasive across applications and not cleanly solved yet (Underwood, 2016). The interoperability problem concerns both interoperability between Blockchain technologies and interoperability with the legacy systems. In the first case, since several Blockchain technologies exist, a procedure could be developed to allow their cooperation (Underwood, 2016). On the other hand, Blockchain is a stand-alone system but it has to be implemented as a sub-system of an existing IT organizational infrastructure (Wang et al., 2016). Sadhya and Sadhya (2018) state that businesses have two options. They can either develop Blockchain solutions that can interoperate with the existing legacy systems, or they can transform them to be Blockchain compatible. Moreover, the integration in the existing businesses could be difficult, due to a diffuse lack of knowledge about the technology (Sadhya & Sadhya, 2018, Wang et al., 2016). In this context, Wang et al. (2016) recognize as one of the main issues the difficulty in executing a correct migration of the data into Blockchain.

4.5 Summary

This chapter aimed at answering the first research question, preparing the stage for the second one. In particular, in paragraph 4.1, the performed quasi-SLR was explained. In 4.2, several use cases of

Blockchain in the supply chain domain were described, showing the variety of the technology possibilities in this domain. In paragraph 4.3, a summary of the overall use cases and respective Blockchain inherent and in-use characteristics was shown. Lastly, in paragraph 4.4, the research in the supply chain domain was integrated with the Blockchain challenges highlighted in SLRs and extensive reviews. In this way, a wider and more comprehensive collection of characteristics related to the Blockchain applicability was available for the next phase. In the next chapter, the technology adoption model is developed.

5. Blockchain adoption model (RQ2)

The goal of this chapter is to answer the second research question: *What are the determinants of the adoption of Blockchain in the supply chain domain from a company perspective?*

In the first part of the thesis, several characteristics related to the Blockchain applicability were highlighted. Nevertheless, the perception from companies about what Blockchain is and can do could be different from what stated in the literature. Moreover, from the quasi-SLR, it was not clear how these characteristics could influence the intention to adopt the technology. Therefore, starting from the theory built in the previous chapter, a Blockchain adoption model was developed, in order to discover the determinants of the Blockchain adoption in the supply chain domain. The framework used for the Blockchain adoption model was the TOE (Technology, Organization, Environment) framework by Tornatzky and Fleischer (1990).

This chapter includes five main parts. In 5.1 the characteristics of Blockchain are selected and merged into more generic constructs. In 5.2 the research model and hypotheses are defined. In 5.3 the sampling methods and the instruments used to conduct the data analysis are described. In 5.4 the results are examined. In 5.5 the overall findings are discussed and in 5.6 a summary of the whole chapter is provided.

5.1 Model constructs identification

A wide range of factors was highlighted from the first review process and the second screening. Therefore, a selection was made considering the most recurring in-use characteristics. The choice of the in-use characteristics to be used for the technology adoption model was based on the following two criteria:

- The in-use characteristics should have recurred at least three times across the use cases;
- The challenges highlighted from the second screening were directly included since they came from multiple-papers reviews (see *Appendix C*).

From this process, 20 items were selected. Then, the single items were grouped into more generic constructs that were consequently used to build the adoption model. In particular, the items were grouped based on the similar contexts they were referring to. From the analysis of studies that implemented the TOE framework and from the quasi-SLR, an additional factor was found to be important in the Blockchain adoption decision: *Competitive pressure*. Kshetri (2018) in his research states that the extent of pressure faced by the firms to stay competitive is an important factor in Blockchain adoption. Indeed, the number and capabilities of related actors involved can exert pressures on other supply chain members to influence their adoption (Kshetri, 2018). Moreover, Blockchain has been mentioned in the mass media very frequently. This situation can bring to the development of a “Heard Behavior”, which is the phenomenon that consists in taking actions only because everyone else is doing the same (Sadhya and Sadhya, 2018). For these reasons, this construct was added to the Blockchain adoption model. The items and constructs chosen for the model are shown in *Table 18*.

Table 18. Model constructs and items

CONSTRUCTS	ITEMS
Technology risks (TER)	Data Security (TER_1)
	Data Privacy (TER_2)
	Scalability (TER_3)
Business Performance (BUP)	Product safety (BUP_1)
	Process quality (BUP_2)
	Time efficiency (BUP_3)
	Cost reduction (BUP_4)
	Resource optimization (BUP_5)
	Improvement of logistics performance (BUP_6)
	Customer confidence & satisfaction (BUP_7)
Technology & regulation immaturity (TRI)	Interoperability (TRI_1)
	Integration (TRI_2)
	Regulations (TRI_3)
Business Integration (BUI)	Intermediaries minimization (BUI_1)
	Digital trust (BUI_2)
	Process synchronization (BUI_3)
	Customers engagement (BUI_4)
Cross-organizational data performance (CDP)	Fast data exchange (CDP_1)
	Accurate data (CDP_2)
	Easy data exchange (CDP_3)
Competitive pressure (COP)	Competitors pressure (COP_1)
	Partners pressure (COP_2)
	General market pressure (COP_3)
Intention to adopt Blockchain (IAB)	Level of adoption (IAB_1)

The chosen constructs were mapped to the TOE framework (*Figure 17*). As described by Tornatzky and Fleischer (1990), the technology context refers to the characteristics of the technology that can influence its adoption. Therefore, '*Technology risks'* is mapped to this context. On the other hand, the organizational context is defined in terms of characteristics of the organization that can facilitate or undermine the adoption of the innovation (Tornatzky & Fleischer, 1990). Therefore, *'Business performance'* and *'Technology and regulation* immaturity' are mapped to this context, investigating the relative advantage that the organization can achieve exploiting the innovative technology and its readiness to implement it. Lastly, the environmental context represents the arena in which the organization operates (Tornatzky & Fleischer, 1990). Therefore, all the factors related to external dependences or interconnections are mapped to this context. In particular, the latter are *'Business integration'*, *'Cross-organizational data performance'* and '*Competitive pressure'*.

Figure 17. Factors mapped to TOE

5.2 Research model and hypotheses

As anticipated, this research model includes factors related to the technological, organizational and environmental contexts as determinants of technology adoption. *Figure 18* shows the six constructs that were considered predictors of Blockchain adoption. These factors were examined as direct or indirect responsible of the adoption decision.

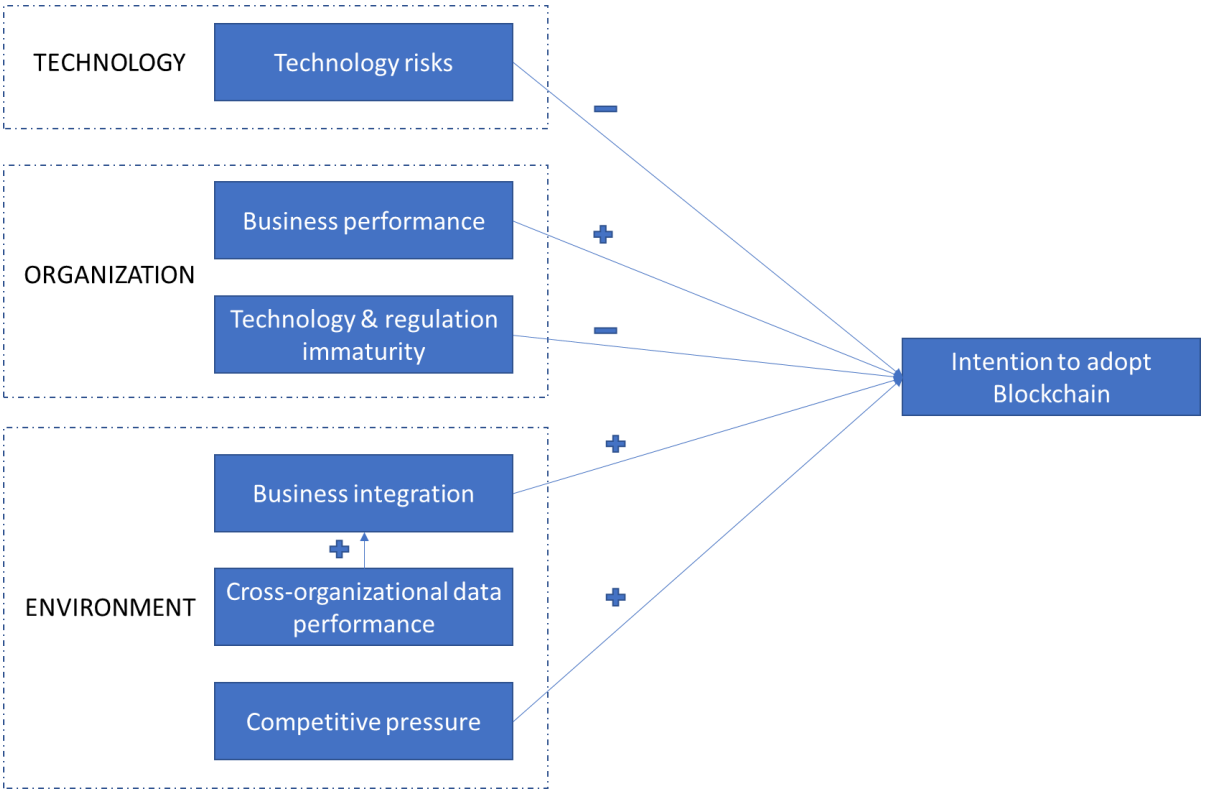

Figure 18. Conceptual model of the adoption of Blockchain in the supply chain domain

5.2.1 Technological context

Technology risks is a factor that refers to the perceived risks related to the implementation of the technology. As assessed by Abramova and Böhme (2016) in their research concerning Bitcoin adoption, the perceived risk is more likely to negatively influence the users' readiness to use a new technology. In this case, as highlighted from the literature, the research refers to this factor in terms of security risk, privacy risk and scalability risk. In particular, Batubara et al. (2018) highlight the most important problem of Blockchain as the blind trust on the technology. Moreover, some possible attacks still question the absolute security of Blockchain (Batubara et al., 2018). The privacy risk is also an

important threat because, even if the identities are protected by pseudonyms, the information is transparent, and some possible attacks could still reveal the IP addresses of the owners (Reyna et al., 2018). Lastly, Blockchain scalability is considered an important challenge for its applications in large networks (Sadhya & Sadhya, 2018). Therefore, the following hypothesis is formulated:

> *H_1:* Firms that perceive high Blockchain technology risks are less likely to adopt it.

5.2.2 Organizational context

Business performance refers to the advantages that Blockchain can bring to company operations. As stated by Low et al. (2011), the advantages that derive from the innovative technology are important determinants of its adoption decision. In the case of Blockchain in supply chain, the literature highlighted several relevant benefits. Thanks to the possibility of Blockchain to trace products, the quality and safety of the products themselves increase (Tian, 2017). Moreover, the automatic document verification can diminish the paper work, reducing the time needed to perform the different operations, the number of resources allocated and, therefore, the overall costs (Tse et al., 2017). Furthermore, the Blockchain data availability can enhance a more dynamic way to manage the warehouses, with inventory levels close to the just-in-time practices (Miller, 2018). Therefore, the following hypothesis is formulated:

> *H_2:* Firms that perceive that Blockchain can improve the business performance are more likely to adopt it.

Technology and regulation immaturity refers to the inability of organizations to receive and integrate the new technology. As highlighted in the literature, organizations suffer from an interoperability problem that undermines the adoption of the technology. Indeed, IT systems are not ready to integrate the new technology; moreover, there is a lack of interoperability solutions between different Blockchain technologies (Underwood, 2016). Furthermore, organizations suffer from a lack of regulations that complicates the integration of this technology in the organizational context. Indeed, as stated by Sadhya and Sadhya (2018), the Blockchain technology is running ahead of the regulatory bodies. These regulatory issues can constitute an important barrier for the technology adoption (Batubara et al., 2018). Therefore, since the organizational readiness is assumed to be a positive determinant of innovative technologies adoption (Low & Chen, 2011), the following hypothesis is formulated:

> *H_3:* Firms that perceive a high technology and regulation immaturity are less likely to adopt Blockchain.

5.2.3 Environmental context

Business integration is a factor that refers to the ability of Blockchain to establish close interconnections between different organizations. As noticed from the literature, supply chain suffers from several problems that derive from the complexity of its fragmented structure (Nakasumi, 2017). In this context, Blockchain can solve this huge challenge, because the transparency of the data and the tamper-proof feature of the technology allow trustless collaborations without the need of trusted third parties. As stated by Bocek et al., 2017, the origin and history information about the products can be directly verified from the Blockchain, without the need of intermediaries. The same happens for the automatic document verification that removes the need for a central authority (Tse et al., 2017). This

decentralized approach allows a synchronization of the parties involved in the supply chain that facilitates the smoothness of the processes (ElMessiry and ElMessiry, 2018). Moreover, giving to customers the opportunity to check by themselves the reliability of products and services, there is a higher level of engagement of the customer party (Tian, 2016). Therefore, the following hypothesis is formulated:

> *H_4:* Firms that perceive Blockchain as able to perform a supply chain business integration are more likely to adopt it.

Cross-organizational data performance refers to the degree to which Blockchain is perceived to facilitate and optimize the exchange of information across the network participants. Blockchain has the chance to provide real-time data to organizations and in a more accurate way. Indeed, thanks to the process automation, the human error problem is overcome and the delay problem due to long waiting time for information to be processed could be solved (Tse et al., 2017). This data performance deeply facilitates the coordination and integration of operations across organizations. As stated by Nakasumi (2017), the collection and availability of "fresh" information brings to the whole supply chain network several benefits in terms of process synchronization. Moreover, the new way of sharing data can replace the traditional systems, leading to the elimination of centralized authorities (Tse et al., 2017). Lastly, the real-time and easy mechanisms of information sharing let customers walk through the records of the products, easily acquiring all their information (Chakrabarti & Chaudhuri, 2017). Therefore, the following hypothesis is formulated:

> *H_5:* The perceived Blockchain cross-organizational data performance is positively associated with the perceived Blockchain capacity to perform a supply chain business integration.

Competitive pressure is an important construct that is mentioned in numerous adoption studies (Wang et al., 2010; Low and Chen, 2011; Ruivo et al., 2014). It is defined as the degree of pressure that an organization feels from its competitors (Ruivo et al., 2014). Indeed, as the market competition increases, organizations perceive a higher pressure to adopt innovative technologies in order to enhance their competitive advantage (Wang et al., 2010). In the case of Blockchain in supply chain, Kshetri (2018) defined the pressure faced by the firms to stay competitive as an important factor in Blockchain adoption. On the same line, Sadhya and Sadhya (2018) mention a "Heard Behavior" that leads organizations to act only because everyone else is doing the same. Therefore, the following hypothesis is formulated:

> *H_6:* Firms that perceive a higher competitive pressure are more likely to adopt Blockchain.

5.3 Sampling and instrument

A web-survey was used to collect the data (the complete survey is shown in *Appendix D*). The constructs were operationalized based on the performed literature review. Before submitting the survey, a feedback process was conducted in order to assess the survey quality and validity. This process involved the participation of TU/e Professors and company employees who were both Blockchain and supply chain experts (for their profiles see *Appendix A*). From the elaboration of these feedbacks, the final version of the survey was created.

The questionnaire is composed by two main parts:

1. Collection of demographic characteristics (like company age, number of employees, etc.) and respondents characteristics (experience in the supply chain domain, experience in their company, level of Blockchain knowledge, etc.);
2. Evaluation of the seven constructs through 24 survey items, measured by a five-point Likert scale.

Questionnaires were sent in November and December 2018 to companies active in the supply chain domain. From the data collection process, 73 valid responses were returned.

The Kolmogorov-Smirnov test (K-S test) was executed to test the normality of the data. The results, shown in *Appendix F*, revealed that none of the items was normally distributed. Given the non-normality of the data and the small sample size, a PLS-SEM was conducted to empirically assess the constructs relationships (Hair et al., 2011).

PLS-SEM is a causal modelling approach that focuses on maximizing the explained variance of the dependent latent constructs. It has two components: the structural model and the measurement model. The structural model, or inner model, shows the relationships between the latent constructs. The measurement model, or outer model, shows the unidirectional predictive relationships between the latent constructs and their associated observed indicators (Hair et al., 2011).

The PLS was used as implemented in the software SmartPLS 3.0 (Ringle et al., 2015). For additional descriptive analyses, SPSS Statistics and Tableau software were used (IBM Corp. Released 2015, Tableau [Computer Software]).

5.3.1 PLS Requirements satisfaction

As stated by Chin (1998), the PLS requires a sample size that is equal to the largest of two measures: (i) ten times the maximum number of formative indicators per construct or (ii) ten times the maximum number of independent latent variables pointing to a dependent variable. In this case, only the *Technology and regulation immaturity* was a formative construct and it had three items. Since *Intention to adopt Blockchain* had six independent variables pointing to it, the second rule was considered as constraint. Based on this statement, the threshold for this research model was equal to 60 respondents. Since the number of responses received for this research (73) was higher than the threshold, the sample size was considered to be acceptable.

5.4 Results

The results were analyzed in two main parts: in 5.4.1 the descriptive statistics of the data were outlined, and in 5.4.2 the hypotheses were tested.

5.4.1 Descriptive statistics

In total, 73 valid responses were received. In this paragraph, the characteristics of the sample are described. In *Figure 19*, the number of responses per country and their percentage coverage are shown. The highest response rate was collected from The Netherlands (39 responses). This happened because the main channels that were used to distribute the survey were located in the Netherlands. The second state that appears in the graph is Italy (13 responses), followed by several other countries (USA, Germany, etc.), whose number of responses per country was 4 or less.

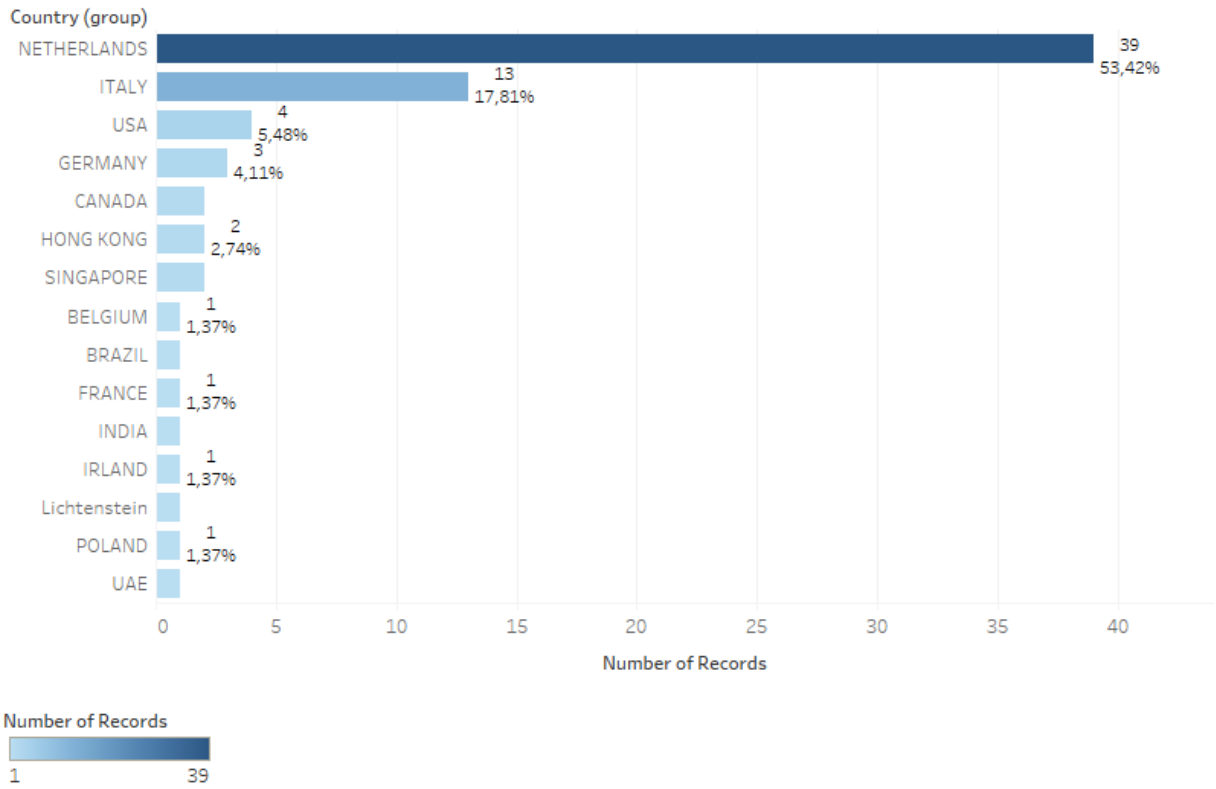

Figure 19. Responses per country

The following chart (*Figure 20*) shows that the majority of companies that filled in the survey were multinational (84.72%), while only the 15.28% were national companies.

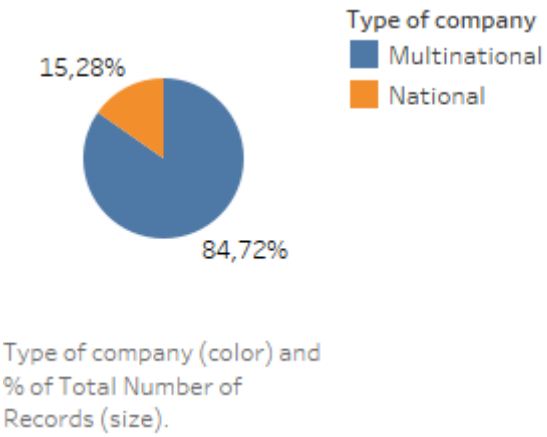

Figure 20. Type of company

In *Figure 21*, it is possible to see a clear disparity between the number of responses received from manufacturing companies and the other types. The responses received from manufacturers accounted for almost half of the total number (46.38%), while on the second place there are consultancy companies (9.59%). The single response rate of the other industry types was less than 5%, with a number of responses per industry type that was between 1 and 3.

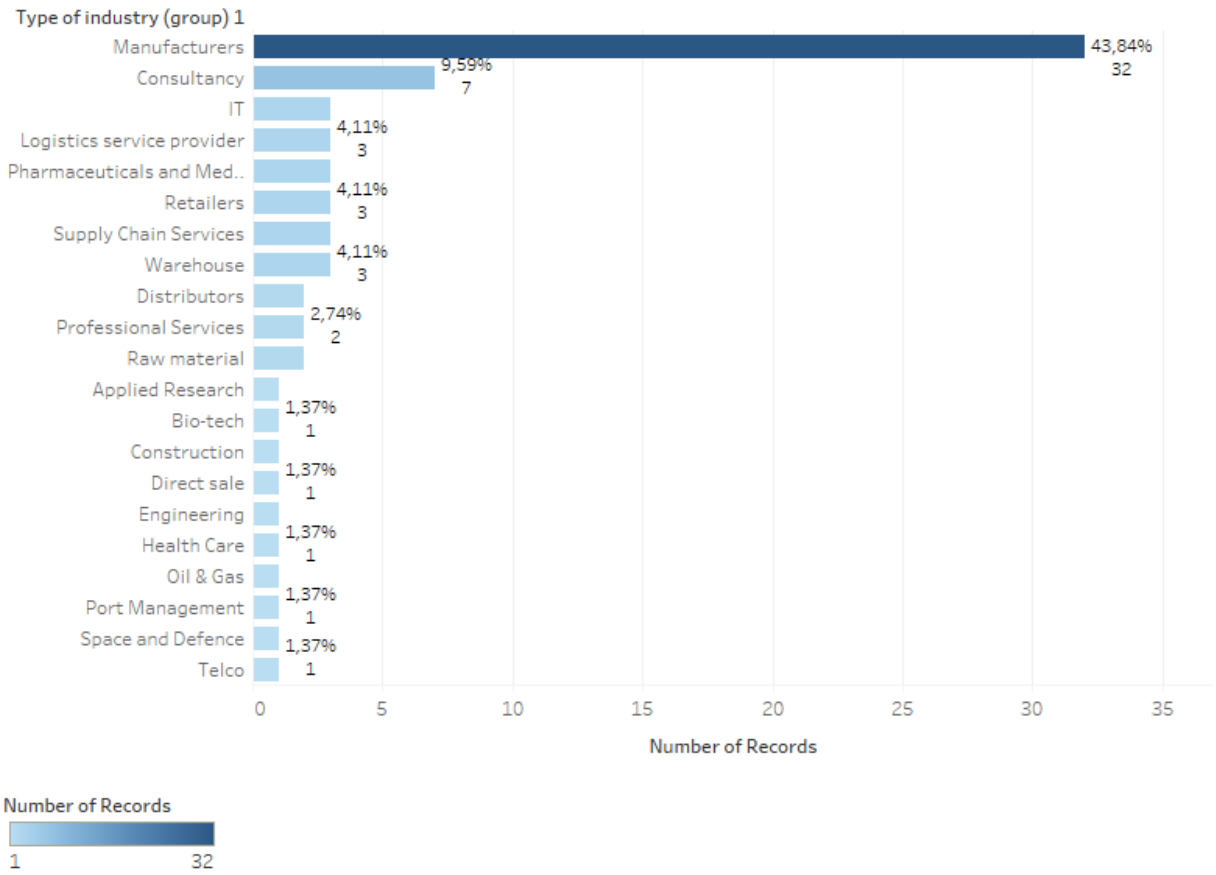

Figure 21. Type of industry

As it is possible to see in *Figure 22*, the main roles of the survey respondents were 'Middle or Low Manager', who answered the 38.36% of the surveys received, and 'Vice President', who appeared in 28.77% of the responses. These two main roles are followed by 'Operations Worker' (13.70%). The other roles showed a percentage that was lower than 5%. Moreover, as shown in *Figure 23*, most of the respondents were Blockchain practitioners or experts.

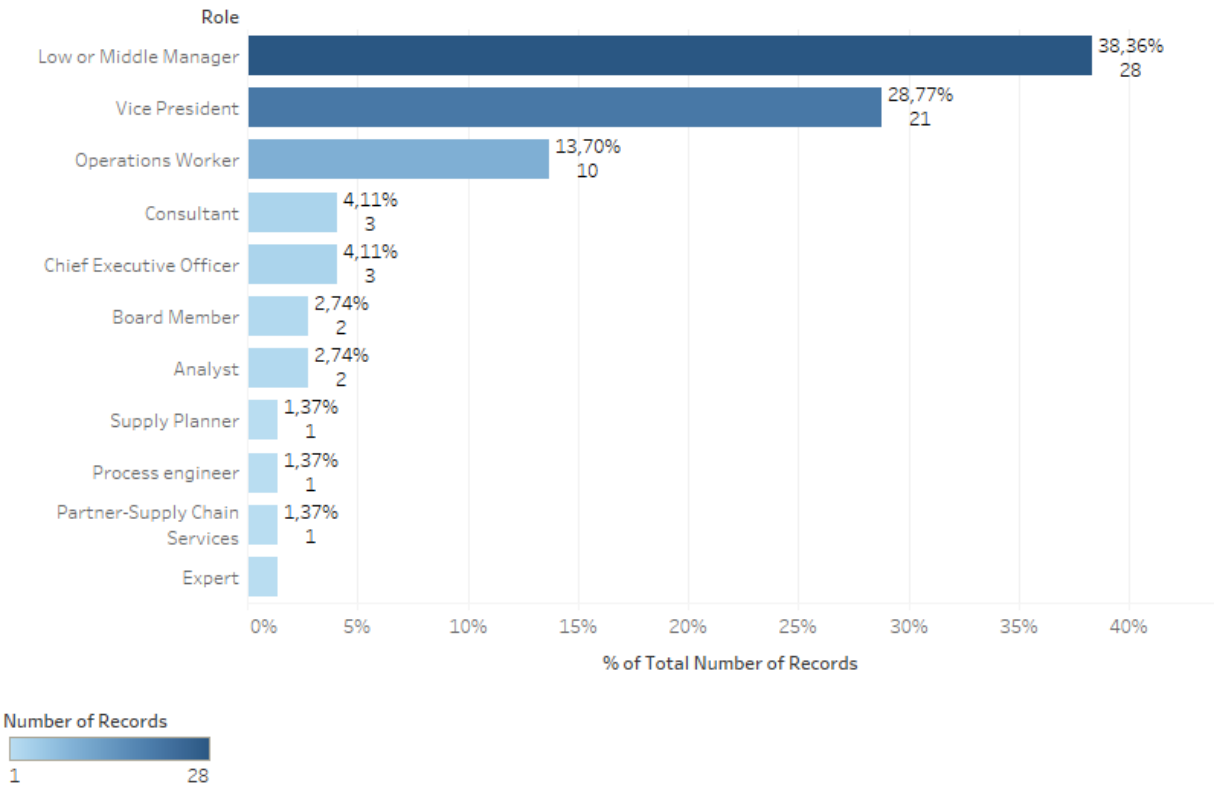

Figure 22. Role of respondents

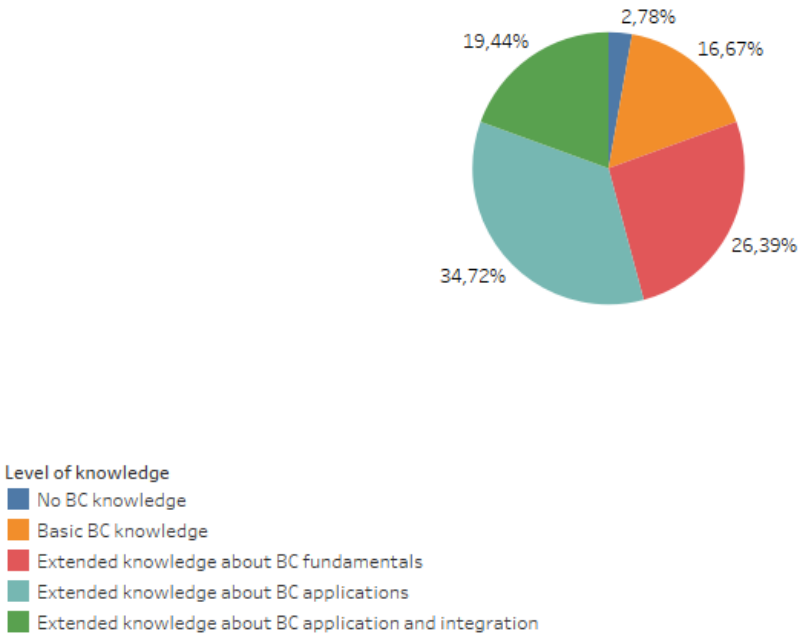

Figure 23. Level of Blockchain knowledge of respondents

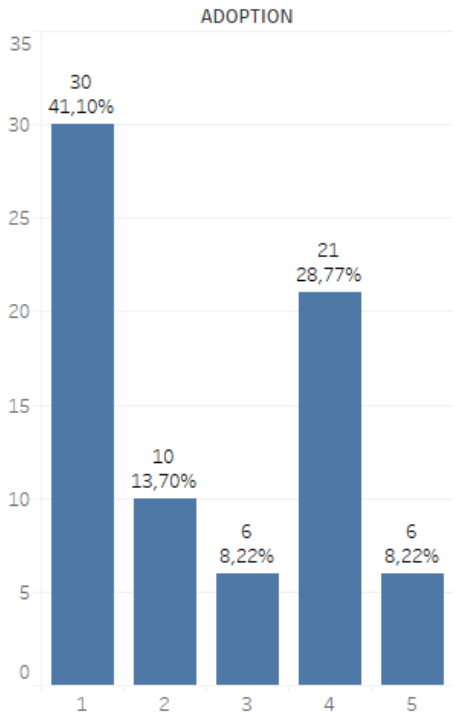

Figure 24. Adoption level

In *Figure 24,* an overall view of the entire sample shows that about 41% of respondents works in a company that has no plan for Blockchain adoption. The second highest percentage is almost at the opposite of the scale. About 29% of respondents works in a company that is developing proofs of concept or pilot implementations of Blockchain. On the third place, there are companies that have plans to adopt Blockchain in the long term (13.70%). Lastly, the same amount of respondents (8.22%) either has plans to adopt Blockchain in the short term, or they already have running Blockchain solutions.

In *Figure 25*, a visualization of the single items is shown. The different colors refer to the different survey scores (from 1 to 5). The length of each color bar depends on the frequency of the different scores per item. The scores equal to 5 (Strongly Agree) and 4 (Agree) were the most frequent ones. An exception was highlighted in the last three cases (items related to *Competitive pressure*). For these cases, the scores equal to 3 (Neither agree nor disagree) and 2 (Disagree) were the most frequent ones. Additional statistics about the single items are available in *Appendix E*.

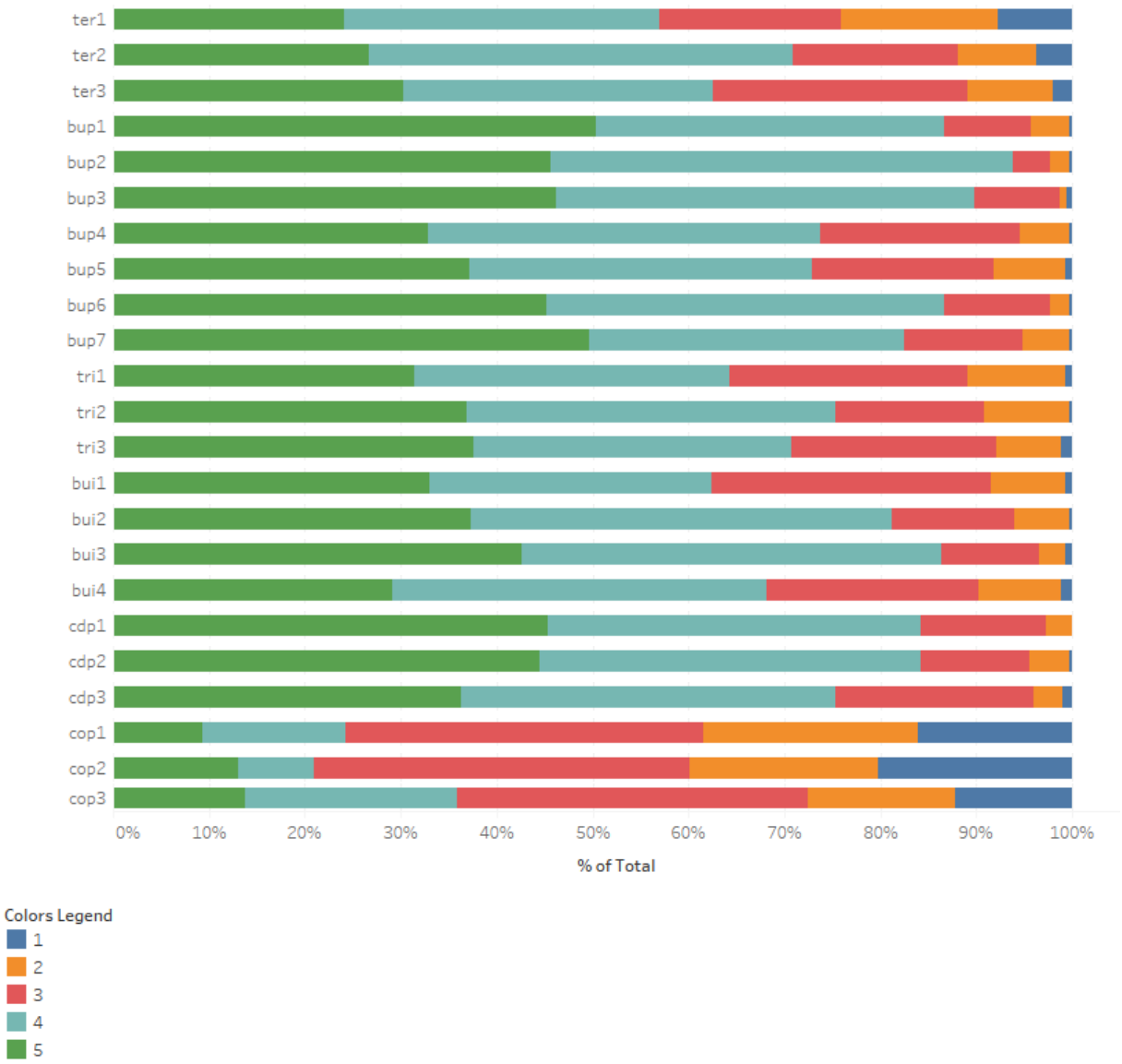

Figure 25. Items visualization

5.4.2 Hypotheses testing

The hypotheses testing required some preliminary steps in order to assess the reliability of items and constructs. Afterwards, the significance of the hypotheses was examined. In *Table 19*, an overview of the six hypotheses is provided.

Table 19. Hypotheses overview

Hypotheses	
H_1	Firms that perceive that Blockchain is affected by technology risks are less likely to adopt it
H_2	Firms that perceive that Blockchain can improve the business performance are more likely to adopt it
H_3	Firms that perceive a high technology and regulation immaturity are less likely to adopt Blockchain
H_4	Firms that perceive Blockchain as able to perform a supply chain business integration are more likely to adopt it

H_5	The perceived Blockchain cross-organizational data performance is positively associated with the perceived Blockchain capacity to perform a supply chain business integration.
H_6	Firms that perceive a higher competitive pressure are more likely to adopt Blockchain

5.4.2.1 Reflective measurement model

The measurement model (also called the outer model) is aimed at understanding the relationships between the constructs and their items. For the reflective indicators, it is assessed by analyzing the indicators reliability and the constructs reliability (Hair et al., 2011).

5.4.3.1.1 Indicators reliability

In this stage, the indicators reliability was analyzed, by evaluating the factor loadings. These coefficients are interpreted as indicators of validity of the observed variables, showing how well they measure the latent variables (Perry, 1996). Factor loadings of 0.5 or higher with a p-value lower than 0.05 are considered to be acceptable (Lee, 2009; Perry, 1996). *Table 20* shows that the item *Resources (BUP_5)* was the only one with a factor loading lower than 0.5 and p-value higher than 0.05.

Table 20. PLS factor loadings

	TER	BUP	BUI	CDP	COP	IAB	p-value
TER_1	0.861						0.000
TER_2	0.820						0.000
TER_3	0.599						0.001
BUP_1		0.849					0.006
BUP_2		0.773					0.002
BUP_3		0.734					0.002
BUP_4		0.665					0.005
BUP_5		0.387					0.204
BUP_6		0.576					0.024
BUP_7		0.803					0.005
BUI_1			0.700				0.000
BUI_2			0.821				0.000
BUI_3			0.793				0.000
BUI_4			0.792				0.000
CDP_1				0.774			0.000
CDP_2				0.731			0.000
CDP_3				0.793			0.000
COP_1					0.916		0.000
COP_2					0.850		0.000
COP_3					0.881		0.000
IAB_1						1.000	0.000

5.4.3.1.2 Constructs reliability

This step focused on the constructs. Following the guidelines from Hair et al. (2013), the constructs reliability of reflective indicators was assessed by evaluating the following coefficients: internal consistency reliability, convergent validity and discriminant validity.

Internal consistent reliability

Internal consistency reliability was examined through the analysis of Cronbach's Alpha (α) that should range between 0.6 and 1 (Hair et al., 2014) and through the analysis of the composite reliability (CR) indicator that should be 0.7 or higher (Hair et al., 2013). *Table 22* shows that all constructs respect these criteria.

Convergent validity

Convergent validity was assessed through the average variance extracted (AVE) that should be 0.5 or higher (Hair et al., 2013). *Table 21* shows that all of the AVEs satisfy this requirement. In particular, *Business performance* is only slightly under the threshold, therefore it is considered to be acceptable.

Table 21. Reliability measures of the latent variables

	Items	α	CR	AVE
TER	3	0.644	0.809	0.591
BUP	7	0.885	0.865	0.489
BUI	4	0.783	0.859	0.605
CDP	3	0.651	0.810	0.587
COP	3	0.865	0.913	0.779
IAB	1	1.000	1.000	1.000

Discriminant validity

In order to assess the discriminant validity, the Fornell-Larcker criterion results are reported and analysed (Hair et al., 2013). This criterion evaluates whether the constructs are truly different from each other or some of them can be combined to form a single dimension (Perry, 1996). The criterion is respected if, looking at the Fornell-Larcker values (*Table 22*), each latent construct is higher than its squared correlations with any other construct (Hair et al., 2011). As evident from the table, the requirement was satisfied.

Table 22. Fornell-Larcker criterion analysis

	TER	BUP	BUI	CDP	COP	IAB
TER	**0.769**					
BUP	-0.119	**0.699**				
BUI	-0.072	0.594	**0.778**			
CDP	-0.117	0.591	0.726	**0.766**		
COP	0.065	0.311	0.341	0.192	**0.883**	
IAB	-0.345	0.268	0.145	0.021	0.277	**1.000**

5.4.2.2 Formative measurement model

The analysis of the measurement model in case of formative items is generally executed through the analysis of items weights and significance, and the multicollinearity assessment (Hair et al., 2011).

Weights and significance analysis

The significance of the items was examined using bootstrapping (Hair et al., 2011). The values shown in *Table 23* were all above the threshold of 0.05. Therefore, the items were all significant. Nevertheless, a negative loading is shown for the item TRI_1. This could indicate a criticality. In these cases, the multicollinearity assessment should be executed. If they are not collinear, they should be included in the analysis (Cenfetelli & Bassellier, 2009).

Table 23. Significance analysis

Items	Weights	p-value
TRI_1	-0.748	0.040
TRI_2	0.636	0.035
TRI_3	0.616	0.046

Multicollinearity assessment

The multicollinearity (VIF) expresses the extent to which an indicator in the analysis can be explained by other indicators. As this value increases, it becomes difficult to establish the effect of the single indicators because of their strong inter-relationships (Hair et al., 2014). The threshold defined by Hair et al. (2011) is a VIF < 5. As shown in *Table 24*, all the items had values that were below the threshold.

Table 24. Multicollinearity assessment

Items	VIF
TRI_1	1.270
TRI_2	1.476
TRI_3	1.459

5.4.2.3 Structural model

The structural model (also called inner model) aimed at understanding the relationships between the constructs. The bootstrapping was used to assess the significance of indicators' coefficients and path coefficients (Hair et al., 2011). A minimum number of bootstrapping equal to 5000 was set as threshold by Hair et al. (2011). After running the Smart-PLS algorithm with 5000 bootstrapping, the results shown in *Figure 26* were obtained. In particular, the arrows of the inner model show the path coefficients with p-values between brackets. The arrows of the outer model show the factor loadings with p-values between brackets.

Path coefficients

No significant relationships were highlighted between Business *Performance* and *Business Integration* with the *Intention to adopt Blockchain* (p-values equal to 0.787, 0.799 respectively). Therefore, H_2 and H_4 were rejected. On the other hand, *Technology risks* and *Technology and regulation immaturity* showed significant negative relationships with the *Intention to adopt Blockchain* (β_1=-0.215, p-value = 0.028**; β_3=-0.329, p-value = 0.035**); *Cross-organizational data performance* showed a positive

relationship with *Business integration* (β_5=0.726, p-value = 0.000*); *Competitive pressure* showed a positive relationship with the *Intention to adopt Blockchain* (β_6=0.217, p-value = 0.027**). Therefore, H_1, H_3, H_5 and H_6 were supported.

Adjusted R^2

The explanatory power of the structural model is usually evaluated based on the significance of the coefficient of determination (adjusted R^2 value) and the path coefficients (Abramova & Bhome, 2016). As described by Hair et al. (2014) in their book, the R^2 represents the proportion of the variance of the dependent variable that is explained by its independent variables. The adjusted R^2 is a modified measure of the coefficient of determination. While the R^2 tends to rise if the number of independent variables increases, the adjusted R^2 can fall if the degrees of freedom become too small or if the added variables have little explanatory power (Hair et al., 2014). This is a value between 0 and 1. The highest the value, the better the prediction of the dependent variable (Hair et al., 2014). As shown in *Table 25*, the adoption model roughly explains the 26% of the variance of *Intention to adopt Blockchain*. In this case, the adjusted R^2 value is rather weak (Hair et al., 2011). A different value is registered in terms of explained variance of *Business integration*. Indeed, in this case, the adjusted R^2 is equal to 52%. Therefore, it has an explanatory power between moderate and substantial, as indicated by Hair et al. (2011).

Effect size

The effect size is defined by Hair et al. (2014) as the estimation of the degree to which the phenomenon that is studied exists in the population. This measure could be weak (0.02), moderate (0.15) or strong (0.35) (Hair et al., 2013). *Table 25* shows a strong effect size for *Cross-organizational data performance,* a moderate effect size for *Technology risks*, *Business performance*, *Technology and regulation immaturity*, and *Competitive pressure*, and a weak effect size for *Business integration*.

Q^2

The Q^2 expresses the predictive relevance of the independent variables for the dependent variable under consideration (Hair et al., 2011). A value greater than zero is indicative of predictive relevance (Hair et al., 2013). *Table 25* reveals a Q^2 related to *Intention to adopt Blockchain* equal to 0.207. On the same line, the Q^2 related to *Business integration* is equal to 0.275.

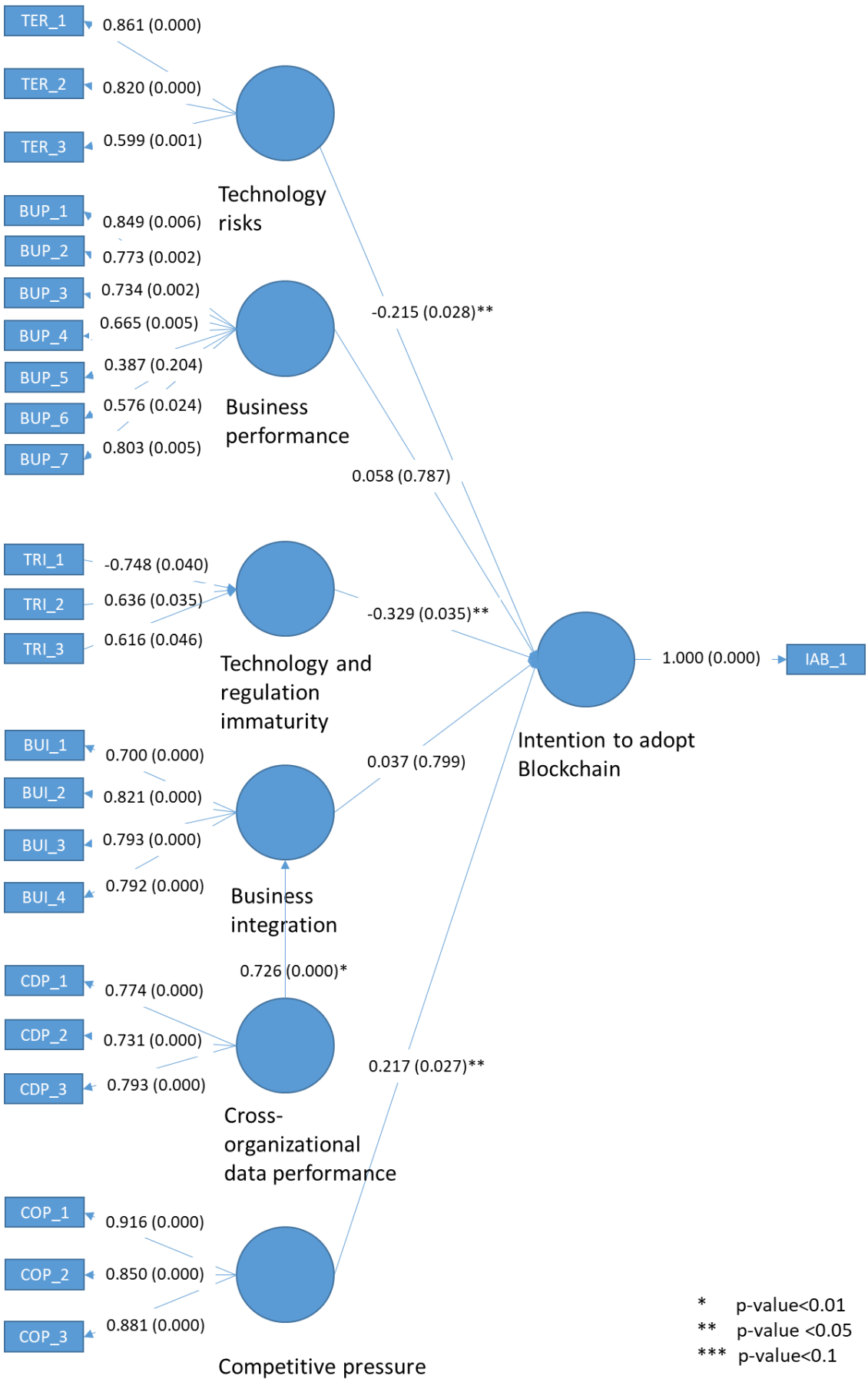

Figure 26. PLS-SEM model

Table 25. Effect sizes

Construct	Effect size (f^2)	Adjusted R^2 value	Q^2 value
TER	0.053		
BUP	0.003		
TRI	0.106		
BUI	0.001	0.520	0.275
CDP	1.112		
COP	0.056		
IAB		0.255	0.207

5.5 Discussion

In this paragraph, the results are discussed in order to address the second research question:

What are the determinants of the adoption of Blockchain in the supply chain domain from a company perspective?

In this chapter, a Blockchain adoption model was created to assess which factors are determinants of the companies' adoption decision. The chosen factors were: *Technology risks*, from a technological perspective; *Business performance* and *Technology and regulation immaturity* from an organizational perspective; *Business integration*, *Cross-organizational data performance* and *Competitive pressure* from an environmental perspective. For each of these constructs, hypotheses were formulated regarding their relationships with the *Intention to adopt Blockchain*. Results showed that some hypotheses were supported and some other were rejected with different significance levels (*Table 26*).

Table 26. Hypotheses results

	Hypotheses	Result
H_1	Firms that perceive high Blockchain technology risks are less likely to adopt it.	Supported**
H_2	Firms that perceive that Blockchain can improve the business performance are more likely to adopt it	Rejected
H_3	Firms that perceive a high technology and regulation immaturity are less likely to adopt Blockchain	Supported**
H_4	Firms that perceive Blockchain as able to perform a supply chain business integration are more likely to adopt it	Rejected
H_5	The perceived Blockchain cross-organizational data performance is positively associated with the perceived Blockchain capacity to perform a supply chain business integration.	Supported*
H_6	Firms that perceive a higher competitive pressure are more likely to adopt Blockchain	Supported**

A significant negative relationship was found between the perceived *Technology risks* and the *Intention to adopt Blockchain*. This means that the perceived technology risks contribute to the refuse of the companies to adopt Blockchain, and that issues like data security, privacy and scalability, need to be considered as obstacles to the diffusion of this technology. Therefore, the findings of Abramova and Böhme (2016) concerning the negative influence of the perceived risks on the users' readiness to use a new technology are extended also to a company perspective.

Business performance did not reveal any significant relationship with the *Intention to adopt Blockchain*. Indeed, the high value mean related to this construct showed how the advantages that this technology

can bring in terms of company performance are clear to both adopters and non-adopters. In this case, the statement formulated by Low et al. (2011), about the importance of the advantages of an innovative technology in its adoption decision still holds. Nevertheless, also the non-adopters seem to be aware of the Blockchain opportunities. In particular, for the single items responses per adoption level, see *Appendix G*. Therefore, *Business Performance* was not highlighted as a determinant of the Blockchain adoption decision.

A significant negative relationship was found between the perceived *Technology and regulation immaturity* and the *Intention to adopt Blockchain*. This means that the interoperability issues, the technology integration difficulties and the regulatory uncertainty represent a barrier for the adoption of this technology. Starting from the statement formulate by Low and Chen (2011), who assessed that the organizational readiness is assumed to be a positive determinant of innovative technologies adoption, it is possible also to claim that the organizational immaturity is a negative determinant of innovative technologies adoption.

As for the case of *Business performance*, the advantages related to the supply chain integration are known and confirmed also from non-adopters (*Appendix G*). Therefore, *Business integration* is not determinant of the Blockchain adoption decision.

Cross-organizational data performance showed a strong significant relationship with the perceived *Business integration*. This means that the perception of having a faster, easier and more accurate data exchange process strongly influences the perception of Blockchain improvements in terms of supply chain integration.

The last hypothesis that was supported was about the relationship between the perceived *Competitive pressure* and the *Intention to adopt Blockchain*. The results showed that companies that feel a higher competitive pressure from either competitors, partners or the market environment are more likely to adopt the new technology. Therefore, confirming the statement of Kshetri (2018), the competitive pressure faced by the firms is an important factor in Blockchain adoption.

5.6 Summary

In this chapter, a Blockchain adoption model for the supply chain domain was developed and tested. In particular, in 5.1, six model constructs were identified. In 5.2, after mapping the constructs to the TOE framework, the adoption model was built and six hypotheses were defined. In 5.3 the survey process and the software used for the data analysis were described. In 5.4 the data analysis was provided and in 5.5 the overall findings about the confirmation or rejection of the hypotheses were explained. In the next chapter, the conclusions and limitations of the whole research are discussed. Moreover, some recommendations about future research and practical implications are elaborated.

6. Conclusions

This research constitutes a first attempt to apply the TOE (Technology Organization Environment) framework to the study of Blockchain adoption in the supply chain domain. Indeed, although the Blockchain possibilities in this domain are numerous and various, the adoption of this technology is still reluctant. Therefore, this research was aimed at understanding the determinants of the adoption decision. In this way, it could give a contribution encouraging corrective actions for the future technology development and promotion in this domain.

To achieve this goal, a quasi-SLR (Systematic literature review) was performed collecting the Blockchain use cases, and the relative characteristics in terms of inherent and in-use properties. This review showed how Blockchain can bring improvements such as process quality and efficiency, supply chain integration and synchronization, and customer satisfaction. In this regard, a map of the main Blockchain use-cases and characteristics was drawn. Moreover, an additional screening revealed how challenges like security, scalability or interoperability undermine the development of this technology. Therefore, both benefits and threats characterize the Blockchain applicability.

Deepening the performed analysis, it was investigated how these characteristics are causal related with the intention to adopt the technology. In this regard, six hypotheses were formulated about the likelihood that the different perception of Blockchain characteristics could influence the Blockchain adoption decision. From the obtained results, it was discovered that the perceived technology risks, technology and regulation immaturity, and competitive pressure are indeed determinants of the Blockchain adoption decision. Therefore, firms that perceive a higher level of technology risks, and technology and regulation immaturity are less likely to adopt Blockchain. While firms that perceive a higher competitive pressure from competitors, partners or the external market environment are more likely to adopt it. Moreover, a positive influence was highlighted between the cross-organizational data performance and business integration. Therefore, a strong relationship connects these two dimensions. On the other hand, the hypotheses regarding the positive relationships between business performance and business integration with the intention to adopt Blockchain were rejected. Interestingly, from an additional data analysis, it was shown how the advantages related to these two dimensions are recognized from both adopters and non-adopters.

In conclusion, the Blockchain risks and challenges represent the main obstacles to the diffusion of this technology. Indeed, since the advantages and opportunities of this technology are recognized from every adoption level, it is possible to assess that they are not decisive in the adoption decision. In contrast, the resolutions of issues like privacy, scalability or technology integration could be determinant to encourage the technology adoption.

6.1 Limitations and future research

The first limitation concerns the relative newness of the topic, i.e. Blockchain application in the supply chain domain, which was reflected in the restricted number of studies available for the review. This is also the reason why an additional screening was conducted on generic SLRs and extensive reviews about Blockchain. However, this screening, did not provide challenges specific to the supply chain domain. Therefore, there was a shortness in the level of detail of the limitations used in the adoption model.

A second limitation concerns the number of received responses. A wider group of participants could have improved the precision of the study. Moreover, the sample used for the data collection was heterogeneous in nature. As it was shown in the descriptive statistics, there were some disparities

between the number of responses per different categories. In particular, the demographic analysis revealed a heterogeneous sample in terms of country and type of industry. Indeed, about half of the responses were received from the Netherlands, while the rest was spread across 14 other countries. The same reasoning applies to the number of responses received from manufacturing companies, compared to the number received from the other 20 industry types. An additional limitation related to the used sample concerns the respondents' profile. Indeed, a more effective analysis could have been obtained limiting the answers to company participants that cover decisional roles. Due to the difficulty of this particular requirement's satisfaction, the survey was submitted without the imposition of this limitation, but asking company employees to answer the questionnaire based on their own company perspective.

Future work could address the limitations of this research in different ways. Firstly, it is possible to include all the findings coming from new studies that day by day are being published. To give a practical example, in the last five months the number of results in IEEE has doubled (from 33 to 69). A wider number of available studies on this topic can bring to a more complete and specific analysis. For example, highlighting challenges related specifically to the supply chain domain could improve the proposed model of Blockchain applicability in supply chain. Consequently, the choice of the constructs could be more accurate, improving the overall analysis of Blockchain adoption.

Secondly, the involvement of a larger and more representative sample of participants could provide better results. A more homogenous sample, whose participants are from one country or are equally spread on different countries, could improve the quality of the analysis. Indeed, countries with different levels of technology innovation could have different perceptions about the Blockchain possibilities. Moreover, including in the study only participants that cover decisional roles within supply chain companies (like CEOs) could improve its precision and reliability.

Another follow-up of this analysis could be to include the investigation of possible moderator factors that were not considered in this research.

6.2 Practical implications

The findings of this research can be helpful to business practitioners in the supply chain domain for two main purposes.

First, companies that want to approach this technology, or simply understand its possibilities, can now dispose of a clear and explicative table of (i) the inherent Blockchain characteristics, (ii) the main use-cases where Blockchain can be applicable and useful, (iii) the main advantages and challenges connected with these applications. This table can be helpful for people who do not know or only have limited knowledge about the properties and possibilities of this technology in the domain of the supply chain.

Second, the Blockchain adoption model developed in the second part of the research provides useful insights to practitioners involved in the implementation and deployment of this technology. For them, it could be useful to understand what the perceived Blockchain strengths and weaknesses are in the surrounding business environment. In this way, they can have the possibility to take more targeted measures to lead organizations to interface with this technology. For example, a factor that is already argument of debate in literature is the technology security. The results of this study show how the different opinions of adopters and non-adopters represent a clear determinant of the technology adoption decision. In this sense, Blockchain practitioners should be more explicative about the security of Blockchain, for example developing proofs of concept that clearly show the Blockchain security strengths and that can be widely tested from the clients. On the same line, the solutions adopted to

overcome the problems of privacy and scalability should be clearly presented. From the point of view of the immaturity of organizations to integrate the new technology, the research findings were supported in the adoption model analysis. Therefore, feasible solutions should be provided to possible adopters in terms of (i) interoperability of the technology with the existing IT systems, (ii) integration through training courses in order to form Blockchain companies' experts, (iii) demonstration of the compatibility of the Blockchain solutions with the existing regulatory environment. Lastly, the awareness that external companies are adopting the technology seems to be a determinant of the companies' decision to adopt Blockchain. Therefore, sharing the experiences of other companies that successfully implemented Blockchain could be helpful to encourage organizations to approach this new technology.

References

Abeyratne, S. A., & Monfared, R. P. (2016). Blockchain ready manufacturing supply chain using distributed ledger.

Abramova, S., & Böhme, R. (2016). Perceived benefit and risk as multidimensional determinants of bitcoin use: a quantitative exploratory study.

Ajzen, I. (1991). The theory of planned behavior. Organizational behavior and human decision processes, 50(2), 179-211.

Apte, S., & Petrovsky, N. (2016). Will blockchain technology revolutionize excipient supply chain management?. Journal of Excipients and Food Chemicals, 7(3), 910.

Batubara, F. R., Ubacht, J., & Janssen, M. (2018, May). Challenges of blockchain technology adoption for e-government: a systematic literature review. In Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age (p. 76). ACM.

Beck, R., & Müller-Bloch, C. (2017). Blockchain as radical innovation: a framework for engaging with distributed ledgers as incumbent organization.

Benton, M. C., & Radziwill, N. M. (2017). Quality and Innovation with Blockchain Technology. arXiv preprint arXiv:1710.04130.

Bocek, T., Rodrigues, B. B., Strasser, T., & Stiller, B. (2017, May). Blockchains everywhere-a use-case of blockchains in the pharma supply-chain. In Integrated Network and Service Management (IM), 2017 IFIP/IEEE Symposium on (pp. 772-777). IEEE.

Canaday, H. (2017, October 26). Blockchain In MRO Could Happen Sooner Than You Think. Retrieved from https://www.mro-network.com/big-data/blockchain-mro-could-happen-sooner-you-think

Caro, M. P., Ali, M. S., Vecchio, M., & Giaffreda, R. (2018, May). Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. In IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany), 2018 (pp. 1-4). IEEE.

Casado-Vara, R., Prieto, J., De la Prieta, F., & Corchado, J. M. (2018). How blockchain improves the supply chain: case study alimentary supply chain. Procedia computer science, 134, 393-398.

Casey, M. J. and P. Wong (2017). Global Supply Chains Are About to Get Better, Thanks to Blockchain.

Cenfetelli, R. T., & Bassellier, G. (2009). Interpretation of formative measurement in information systems research. MIS quarterly, 689-707.

Chakrabarti, A., & Chaudhuri, A. K. (2017). Blockchain and its scope in retail. International Research Journal of Engineering and Technology, 4.

Chen, S., Shi, R., Ren, Z., Yan, J., Shi, Y., & Zhang, J. (2017, November). A Blockchain-based supply chain quality management framework. In e-Business Engineering (ICEBE), 2017 IEEE 14th International Conference on (pp. 172-176). IEEE.

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. Modern methods for business research, 295(2), 295-336.

Crosby, M., Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). Blockchain technology: Beyond bitcoin. Applied Innovation, 2, 6-10.

Davis, F. D. (1985). A technology acceptance model for empirically testing new end-user information systems: Theory and results (Doctoral dissertation, Massachusetts Institute of Technology).

Duan, J., & Patel, M. (2018, June). Blockchain in Global Trade. In International Conference on Blockchain (pp. 293-296). Springer, Cham.

ElMessiry, M., & ElMessiry, A. (2018, June). Blockchain Framework for Textile Supply Chain Management. In International Conference on Blockchain (pp. 213-227). Springer, Cham.

Fassott, G., Henseler, J., & Coelho, P. S. (2016). Testing moderating effects in PLS path models with composite variables. Industrial management & data systems, 116(9), 1887-1900.

Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics. Journal of marketing research, 382-388.

Francisco, K., & Swanson, D. (2018). The supply chain has no clothes: technology adoption of blockchain for supply chain transparency. Logistics, 2(1), 2.

Hackius, N., & Petersen, M. (2017). Blockchain in logistics and supply chain: trick or treat?. In Proceedings of the Hamburg International Conference of Logistics (HICL) (pp. 3-18). epubli.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). Multivariate data analysis.

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. Journal of Marketing theory and Practice, 19(2), 139-152.

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance.

Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. Harvard Business Review, 95(1), 118-127.

IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Imeri, A., & Khadraoui, D. (2018, February). The security and traceability of shared information in the process of transportation of dangerous goods. In New Technologies, Mobility and Security (NTMS), 2018 9th IFIP International Conference on (pp. 1-5). IEEE.

Kamble, S., Gunasekaran, A., & Arha, H. (2018). Understanding the Blockchain technology adoption in supply chains-Indian context. International Journal of Production Research, 1-25.

Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering. EBSE Technical Report, 2007(1), 1-57.

Korpela, K., Hallikas, J., & Dahlberg, T. (2017, January). Digital supply chain transformation toward blockchain integration. In proceedings of the 50th Hawaii international conference on system sciences.

Kshetri, N. (2017). Can blockchain strengthen the internet of things?. IT Professional, 19(4), 68-72.

Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. International Journal of Information Management, 39, 80-89.

Lee, M. C. (2009). Factors influencing the adoption of internet banking: An integration of TAM and TPB with perceived risk and perceived benefit. Electronic commerce research and applications, 8(3), 130-141.

Low, C., Chen, Y., & Wu, M. (2011). Understanding the determinants of cloud computing adoption. Industrial management & data systems, 111(7), 1006-1023.

Lu, Q., & Xu, X. (2017). Adaptable blockchain-based systems: a case study for product traceability. IEEE Software, 34(6), 21-27.

Mattila, J., Seppälä, T., & Holmström, J. (2016). Product-centric information management: A case study of a shared platform with blockchain technology.

Miller, D. (2018). Blockchain and the Internet of Things in the Industrial Sector. IT Professional, 20(3), 15-18.

Mondragon, A. E. C., Mondragon, C. E. C., & Coronado, E. S. (2018, April). Exploring the applicability of blockchain technology to enhance manufacturing supply chains in the composite materials industry. In 2018 IEEE International Conference on Applied System Invention (ICASI) (pp. 1300-1303). IEEE.

Moon, T. K. (1996). The expectation-maximization algorithm. IEEE Signal processing magazine, 13(6), 47-60.

Morabito, V. (2017). Business Innovation Through Blockchain. Cham: Springer International Publishing.

Mudliar, K., Parekh, H., & Bhavathankar, P. (2018, February). A comprehensive integration of national identity with blockchain technology. In 2018 International Conference on Communication information and Computing Technology (ICCICT) (pp. 1-6). IEEE.

Nakasumi, M. (2017, July). Information sharing for supply chain management based on block chain technology. In Business Informatics (CBI), 2017 IEEE 19th Conference on (Vol. 1, pp. 140-149). IEEE.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. Journal of management information systems, 24(3), 45-77.

Perry, J. L. (1996). Measuring public service motivation: An assessment of construct reliability and validity. Journal of public administration research and theory, 6(1), 5-22.

Pourmirza, S., Peters, S., Dijkman, R., & Grefen, P. (2017). A systematic literature review on the architecture of business process management systems. Information Systems, 66, 43-58.

Puthal, D., Malik, N., Mohanty, S. P., Kougianos, E., & Das, G. (2018). Everything You Wanted to Know About the Blockchain: Its Promise, Components, Processes, and Problems. IEEE Consumer Electronics Magazine, 7(4), 6-14.

Reyna, A., Martín, C., Chen, J., Soler, E., & Díaz, M. (2018). On blockchain and its integration with IoT. Challenges and opportunities. Future Generation Computer Systems.

Ringle, Christian M., Wende, Sven, & Becker, Jan-Michael. (2015). SmartPLS 3. Bönningstedt: SmartPLS. Retrieved from http://www.smartpls.com

Ruivo, P., Oliveira, T., & Neto, M. (2014). Examine ERP post-implementation stages of use and value: Empirical evidence from Portuguese SMEs. International Journal of Accounting Information Systems, 15(2), 166-184.

Sadhya, V., & Sadhya, H. (2018). Barriers to Adoption of Blockchain Technology.

Swan, M. (2015). Blockchain: Blueprint for a new economy. " O'Reilly Media, Inc.".

Tableau [Computer software]. (n.d.).

Tian, F. (2016, June). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In Service Systems and Service Management (ICSSSM), 2016 13th International Conference on (pp. 1-6). IEEE.

Tian, F. (2017, June). A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In Service Systems and Service Management (ICSSSM), 2017 International Conference on (pp. 1-6). IEEE.

Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Lexington Mass.: D.C. Heath.

Toyoda, K., Mathiopoulos, P. T., Sasase, I., & Ohtsuki, T. (2017). A novel blockchain-based product ownership management system (POMS) for anti-counterfeits in the post supply chain. IEEE Access, 5, 17465-17477.

Tse, D., Zhang, B., Yang, Y., Cheng, C., & Mu, H. (2017, December). Blockchain application in food supply information security. In Industrial Engineering and Engineering Management (IEEM), 2017 IEEE International Conference (pp. 1357-1361). IEEE.

Underwood, S. (2016). Blockchain beyond bitcoin. Communications of the ACM, 59(11), 15-17.

Wang, H., Chen, K., & Xu, D. (2016). A maturity model for blockchain adoption. Financial Innovation, 2(1), 12.

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.

Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where is current research on blockchain technology?—a systematic review. PloS one, 11(10), e0163477.

APPENDIX A - Feedback process

Table 27. Experts profile

NAME	ROLE
Wout Hofman	Senior Advisor, specialized in the logistics sector, now focusing on Blockchain for logistics at TNO.
Paul Grefen	Full Professor and Chair of Information System Architecture in the School of Industrial Engineering at Eindhoven University of Technology, active in the Blockchain research domain.
Willem L. van Jaarsveld	Tenure-track Assistant Professor at Eindhoven University of Technology, active in the Blockchain research domain.
Arun Chockalingam	Assistant Professor at the Eindhoven University of Technology. He is part of the Supply Chain and Finance Lab. Together with other members in this lab, he is exploring how Supply Chain Finance could leverage new technologies such as Blockchain to address problems related to developing sustainable supply chains.

APPENDIX B - Use cases identification

Table 28. Use cases per paper

		PAPERS																					
		Caro et al. (2018)	*Tian (2016)*	*Tian (2017)*	*Xie et al. (2017)*	*Bocek et al. (2017)*	*Abeyratne and Monfared (2016)*	*Toyoda et al. (2017)*	*Kshetri (2017)*	*Chen et al. (2017)*	*Chakrabarti & Chaudhuri (2017)*	*Tse et al. (2017)*	*Miller (2018)*	*Lu and Xu (2017)*	*Nakasumi (2017)*	*Korpela et al. (2017)*	*Duan & Patel (2018)*	*ElMessiry & ElMessiry (2018)*	*Casado-Vara et al. (2018)*	*Kshetri (2018)*	*Apte & Petrovsky (2016).*	*Imeri & Khadraoui (2018)*	*Hackius & Petersen (2017)*
USE CASES	Product traceability	X	X	X	X	X	X							X			X	X	X	X			
	Ownership traceability			X			X	X															X
	Digital identity			X		X	X		X	X							X			X			
	Provenance	X	X			X					X									X			
	Paperwork processing											X	X	X						X			
	Distribution route calculation		X	X						X					X								
	Product recalling & responsible investigation		X	X					X		X	X						X		X			
	Counterfeit products identification					X															X		X
	Dynamic warehouse management		X	X							X		X		X								
	Transportation quality control			X		X													X	X		X	
	Departments management						X					X								X			
	Quality management									X		X											
	B2B integration															X	X		X				
	Process synchronization														X		X	X					
	Customer engagement		X	X			X				X	X					X						
	Customer profiling									X	X												
	Smart loyalty programs										X												

APPENDIX C - Blockchain characteristics

Table 29. Inherent characteristics per use case

	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9	UC10	UC11	UC12	UC13	UC14	UC15	UC16	UC17
Fault-tolerance	X																
Immutability	X						X										
Transparency	X		X	X	X	X	X	X		X	X			X	X	X	X
Tamper-proof	X			X			X		X								
Reliability	X		X	X		X											
Security	X			X		X							X				
Openness	X																
Trustworthiness	X	X										X	X				
Privacy		X															
Integrity							X										
Non-repudiation							X										
Permanency									X								
Decentralization	X											X					

Table 30. In use characteristics per use case: advantages in black; challenges in red; selected survey items in bold

	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9	UC10	UC11	UC12	UC13	UC14	UC15	UC16	UC17	SLRs	SURVEY ITEM
Improvement of logistics performance	X	X			X		X	X	X	X		X							YES
Time reduction	X				X		X		X	X	X		X	X					YES
Costs reduction	X	X								X	X		X	X					YES
Product safety		X	X	X		X		X		X									YES
Real-time data (fast data exchange)					X			X	X			X		X	X				YES
Data security	X	X						X					X						YES
Intermediaries minimization		X		X			X						X						YES
Customer confidence & satisfaction				X		X									X				YES
Customer engagement		X	X												X				YES
Data accuracy							X	X		X									YES
Digital trust	X	X											X						YES
Easy data exchange		X	X											X					YES
Improvement of quality management					X			X				X							YES
Privacy	X			X								X							YES
Process synchronization								X	X			X		X					YES
Resources optimization							X		X		X								YES
Flexibility											X		X						NO
Improvement of customer data analysis																X	X		NO
Loss of sales reduction										X				X					NO
Market adaptation														X		X			NO
Process automation							X			X									NO
Traceability		X										X							NO
Complete data collection														X					NO
Data control	X																		NO
Improvement of customer experience																	X		NO
Loss reduction					X														NO
Money transfer efficiency	X																		NO
Process efficiency															X				NO
Process transparency		X																	NO
Product & service quality												X							NO
Profits increase												X							NO
Transaction automation		X																	NO
Waste reduction											X								NO
Data security																		X	YES
High costs		X																	NO
Immaturity		X																	NO
Difficult integration (IT inadequacy)		X																X	YES
Lack of interoperability													X					X	YES
Lack of standards													X						NO
Performance capability		X																	NO
Privacy																		X	YES
Regulatory issues																		X	YES
Scalability		X																X	YES

APPENDIX D - Survey

Blockchain adoption in Supply Chain

Hi, my name is Maria. I am a Master student of Operations Management & Logistics at Eindhoven University of Technology. I am conducting a research about the adoption of Blockchain in Supply Chain and I would kindly ask you to participate in this survey in order to contribute to this research.

Whether your company adopted Blockchain or not, whether you have technical knowledge, or you have barely heard about this technology, it does not matter! Your opinion is very important for this research.

This survey requires only 5-10 MINUTES of your time.

All data provided will be kept in the strictest confidentiality and will be treated in a completely anonymous way.

If you are interested in the research results, at the end of the survey you can provide your e-mail. If you do so, we will send you the outcome of this survey, which can give you interesting insights regarding the current Blockchain situation in Supply Chain.

Thank you!

NEXT

Page 1 of 7

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Blockchain adoption in Supply Chain

WELCOME!

Dear Participant,

Thank you for participating in this survey. We will ask you to rate some statements related to the implementation of Blockchain in Supply Chain, based on the degree they apply for your company. Please answer every question freely, to the best of your knowledge and taking YOUR COMPANY PERSPECTIVE.

If you have any questions, please contact Maria Cioffi at m.c.cioffi@student.tue.nl

In advance, I really would like to thank you for your contribution to this research.

BACK NEXT

Page 2 of 7

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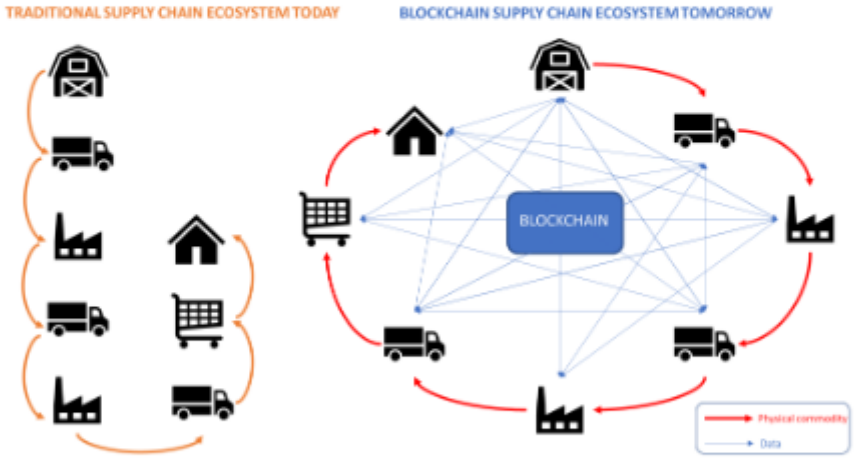
Let's remember what Blockchain is...

A Blockchain is a distributed ledger where all the transactions executed among the network's participants can be recorded. The transactions are transparent, highly encrypted and stored across many computers. Thanks to this structure, Blockchain is not controlled by any central authority, but the whole network controls it. Nevertheless, this self-regulation process requires time and can reduce the overall scalability of the system.

In the picture below, it is shown how Blockchain could be implemented for Supply Chain collaborations, connecting all the links of the chain (from the raw material provider to the customer) with a transparent and shared ledger. This ledger offers visibility of the products information and their related processes.



BACK NEXT

Page 3 of 7

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Blockchain adoption in Supply Chain

*Required

What do you think about Blockchain?

Fill in the survey based on how far you agree or disagree with the statements.

PLEASE, KEEP IN MIND THE FOLLOWING SCALE!

(1)Strongly Disagree; (2)Disagree; (3)Neither Agree nor Disagree; (4)Agree; (5)Strongly Agree

Blockchain adoption in my company will increase the data security risks *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Blockchain adoption will increase the challenges for the privacy protection of my company's transactions *

1	2	3	4	5
○	○	○	○	○

The scalability challenge of Blockchain constitutes an important barrier for its adoption in my company *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will increase our products safety providing access to our products' historical information *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will lead to a better proactive quality management by providing a transparent information exchange process *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will improve the time-efficiency of my company's operations by providing real-time data availability and automating processes like document registration *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will improve the cost-efficiency of my company's operations by providing real-time data visibility and enabling process automation *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will optimize the allocation of resources by providing data from different departments *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will improve the performance of my logistics operations by providing real-time data availability *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will increase the degree of customer confidence and satisfaction providing deeper insights about the product's provenance and history *

1	2	3	4	5
○	○	○	○	○

The lack of Blockchain interoperability standards is an adoption concern for my company *

1	2	3	4	5
○	○	○	○	○

The development of Blockchain integration capability (consultants, training providers, skilled IT experts, etc.) is difficult *

1	2	3	4	5
○	○	○	○	○

The lack of strong Blockchain regulations is an adoption concern for my company *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will help my company reduce the number of undesired intermediaries *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will facilitate my company collaborations with business partners offering the chance to directly cooperate with them by establishing digital trust *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will improve the process synchronization with our business partners by providing data visibility *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will help my company business to foster the customers' engagement in our trade system *

1	2	3	4	5
○	○	○	○	○

Blockchain adoption will accelerate the information sharing process with our business partners by providing real-time data availability *

1	2	3	4	5
○	○	○	○	○

Blockchain's automatic transactions will reduce the number of human errors by providing more accurate data to my company *

1	2	3	4	5
○	○	○	○	○

The data transparency provided by Blockchain will facilitate the acquisition of information from our business partners *

1	2	3	4	5
○	○	○	○	○

My company experiences pressure from its competitors to implement Blockchain *

1	2	3	4	5
○	○	○	○	○

My company experiences pressure from its business partners to implement Blockchain *

1	2	3	4	5
○	○	○	○	○

My company experiences pressure from the surrounding business environment (customers, media, marketing, etc.) to implement Blockchain *

1	2	3	4	5
○	○	○	○	○

Define your level of Blockchain adoption *

- ○ We already have Blockchain integrated solutions running
- ○ We are exploring the technology by proof of concept or pilot implementations
- ○ We intend to adopt Blockchain in the short term (1-2 years)
- ○ We intend to adopt Blockchain in the longer term (>2 years)
- ○ We do not have plans for adopting Blockchain

Blockchain adoption in Supply Chain

*Required

Background information

Country of residence *

Your answer

Name of the company (to aggregate results)

Your answer

Your company is *

- National
- Multinational

Type of industry *

- Raw material providers
- Distributors
- Manufacturers
- Warehouses
- Retailers
- Public Domain
- Other:

Company age *

- < 5 years
- 5 - 10 years
- 11 - 30 years
- Over 30 years

Number of employees *

- < 50
- 50 - 249
- > 249

What is your function in the organization? *

- Operations management
- Logistics
- Supply Chain
- Procurement
- IT
- Finance
- Service
- Quality
- Other:

What is your role in the organization? *

- ◯ Board Member
- ◯ Chief Executive Officer
- ◯ Vice President or Director or Executive Manager
- ◯ Middle or Low Manager
- ◯ Operations Worker
- ◯ Other: _____

Please indicate your working experience in the current organization (in years) *

Your answer

Please indicate your experience in the Supply Chain domain (in years) *

Your answer

How confident are you in regards to representing your company perspective for Technology Adoption? *

	1	2	3	4	5	
Zero confident	◯	◯	◯	◯	◯	Very confident

What is your level of knowledge of Blockchain? *

- ◯ I don't have any kind of knowledge about Blockchain.
- ◯ I only know the basic principles of Blockchain
- ◯ I know what Blockchain is, but I have limited knowledge about its possible applications
- ◯ I know about possible Blockchain applications, but I have limited knowledge about its integration
- ◯ I have a good level of Blockchain applications and integration knowledge

Please mark the following innovative technologies that you have an integration experience with

- ☐ I do not have any previous experience
- ☐ RFID
- ☐ IoT
- ☐ Big Data
- ☐ Analytics
- ☐ Cloud
- ☐ Other:

BACK NEXT Page 5 of 7

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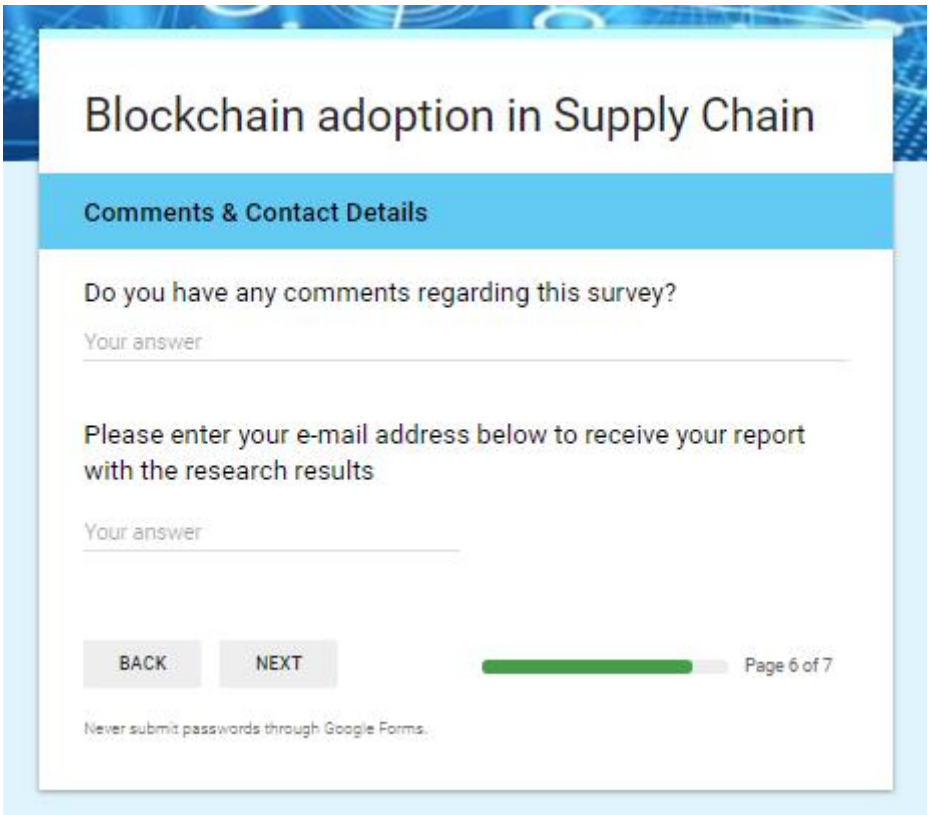
Blockchain adoption in Supply Chain
Comments & Contact Details
Do you have any comments regarding this survey?
Your answer
Please enter your e-mail address below to receive your report with the research results
Your answer
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Page 6 of 7
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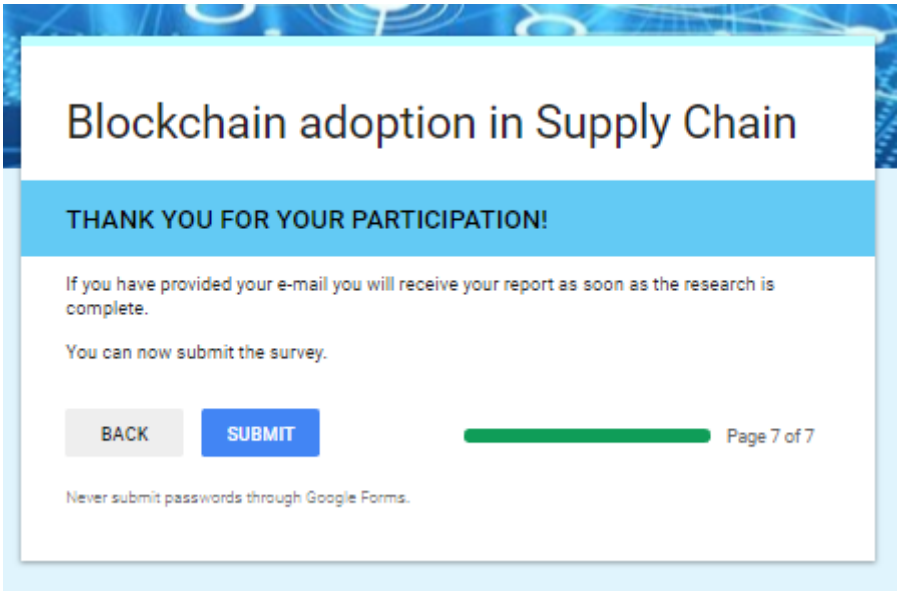
Blockchain adoption in Supply Chain
THANK YOU FOR YOUR PARTICIPATION!
If you have provided your e-mail you will receive your report as soon as the research is complete.
You can now submit the survey.
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SUBMIT
Page 7 of 7
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APPENDIX E – Descriptive statistics items

Table 31. Descriptive statistics per item

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ter_1	73	1	5	2,84	1,375	,107	,281	-1,265	,555
ter_2	73	1	5	3,34	1,272	-,511	,281	-,781	,555
ter_3	73	1	5	3,40	1,175	-,300	,281	-,684	,555
bup_1	73	1	5	4,08	,997	-1,034	,281	,493	,555
bup_2	73	1	5	4,21	,833	-1,445	,281	3,034	,555
bup_3	73	1	5	4,15	,892	-1,390	,281	2,793	,555
bup_4	73	1	5	3,75	,983	-,473	,281	-,326	,555
bup_5	73	1	5	3,68	1,104	-,486	,281	-,606	,555
bup_6	73	1	5	4,10	,900	-1,015	,281	1,095	,555
bup_7	73	1	5	4,00	1,041	-,836	,281	-,119	,555
tri_1	73	1	5	3,49	1,107	-,203	,281	-,848	,555
tri_2	73	1	5	3,71	1,086	-,467	,281	-,787	,555
tri_3	73	1	5	3,64	1,135	-,485	,281	-,549	,555
bui_1	73	1	5	3,53	1,081	-,192	,281	-,706	,555
bui_2	73	1	5	3,86	1,004	-,732	,281	-,083	,555
bui_3	73	1	5	4,01	,979	-1,124	,281	1,228	,555
bui_4	73	1	5	3,52	1,107	-,401	,281	-,570	,555
cdp_1	73	2	5	4,08	,878	-,669	,281	-,280	,555
cdp_2	73	1	5	4,00	,986	-,894	,281	,289	,555
cdp_3	73	1	5	3,78	1,044	-,748	,281	,312	,555
cop_1	73	1	5	2,21	1,142	,618	,281	-,396	,555
cop_2	73	1	5	2,10	1,169	,829	,281	-,037	,555
cop_3	73	1	5	2,48	1,248	,334	,281	-,873	,555
iab_1	73	1,0	5,0	2,493	1,4731	,295	,281	-1,541	,555
Valid N (listwise)	73								

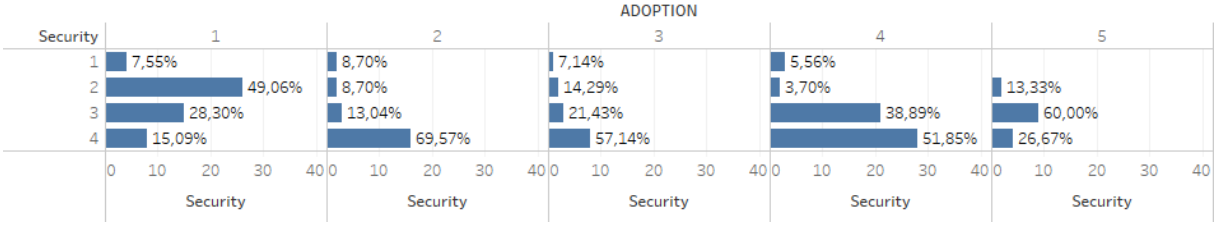
APPENDIX F – Normality tests

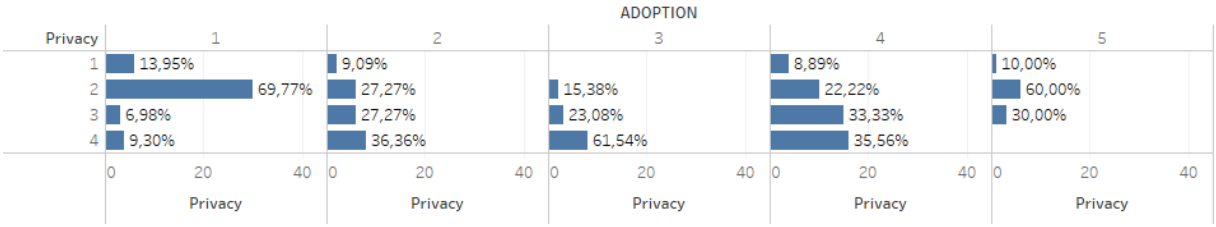
Table 32. Normality tests

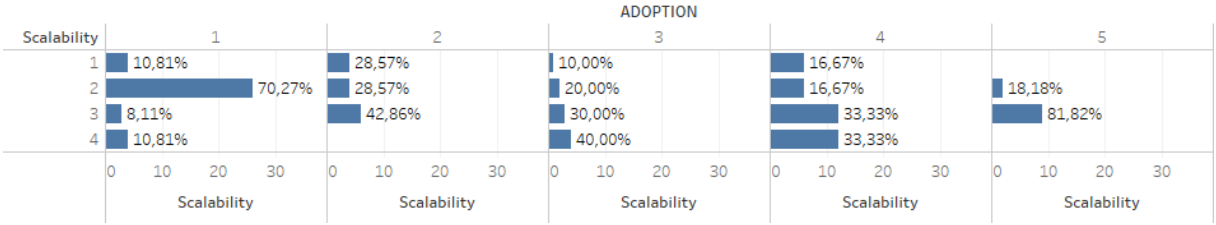
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
ter_1	,180	73	,000	,891	73	,000
ter_2	,245	73	,000	,881	73	,000
ter_3	,175	73	,000	,905	73	,000
bup_1	,248	73	,000	,810	73	,000
bup_2	,293	73	,000	,751	73	,000
bup_3	,269	73	,000	,778	73	,000
bup_4	,229	73	,000	,881	73	,000
bup_5	,215	73	,000	,883	73	,000
bup_6	,252	73	,000	,819	73	,000
bup_7	,229	73	,000	,831	73	,000
tri_1	,183	73	,000	,899	73	,000
tri_2	,235	73	,000	,871	73	,000
tri_3	,199	73	,000	,886	73	,000
bui_1	,196	73	,000	,896	73	,000
bui_2	,267	73	,000	,854	73	,000
bui_3	,275	73	,000	,817	73	,000
bui_4	,215	73	,000	,899	73	,000
cdp_1	,230	73	,000	,830	73	,000
cdp_2	,253	73	,000	,834	73	,000
cdp_3	,227	73	,000	,866	73	,000
cop_1	,211	73	,000	,858	73	,000
cop_2	,250	73	,000	,820	73	,000
cop_3	,183	73	,000	,881	73	,000
iab_1	,256	73	,000	,807	73	,000

APPENDIX G – Single items responses per adoption level

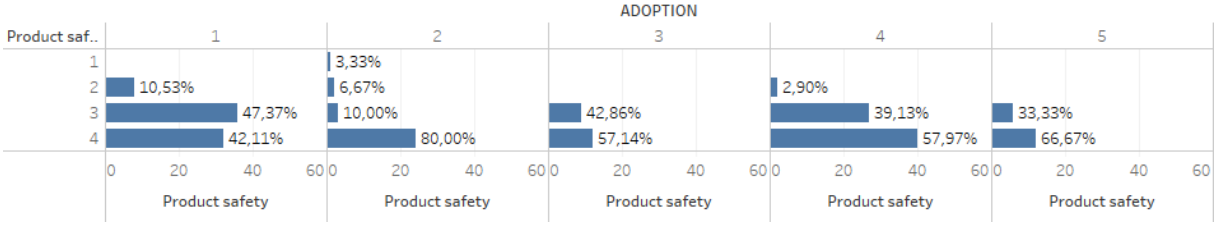
Technology risks

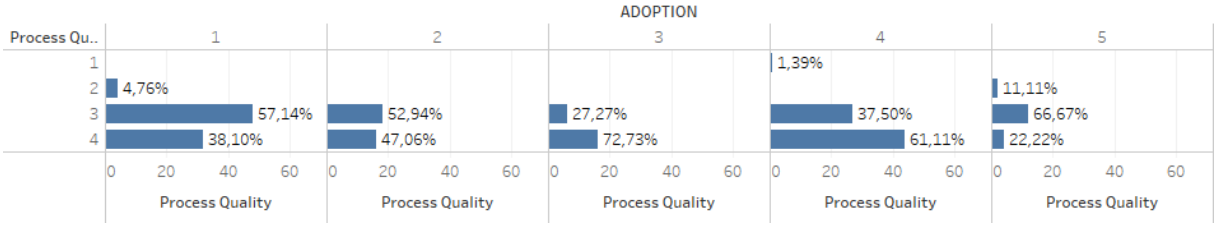


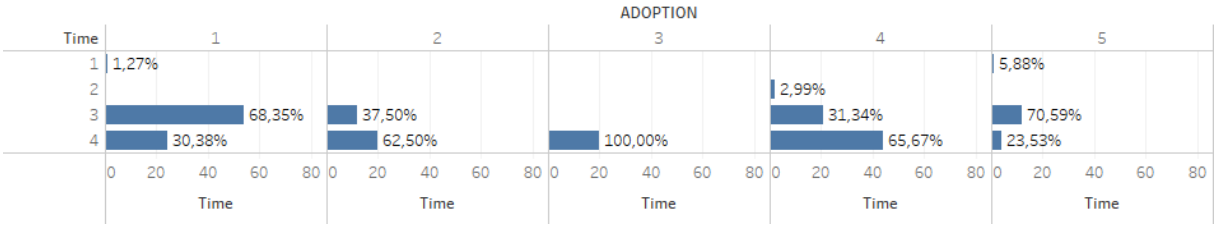


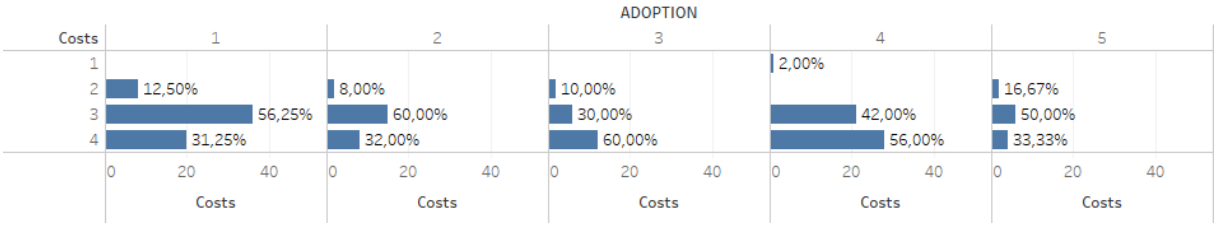


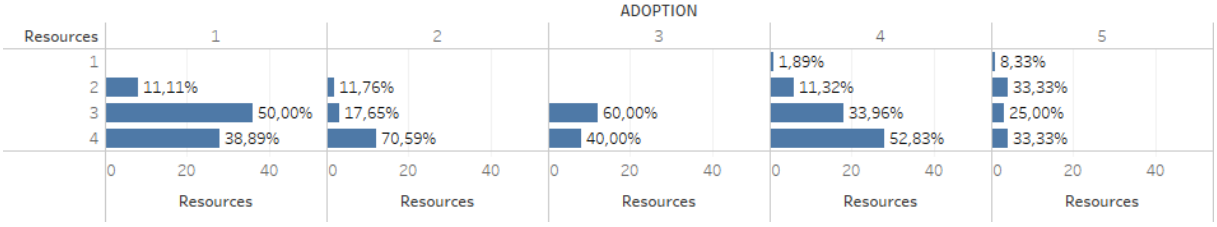
Business performance

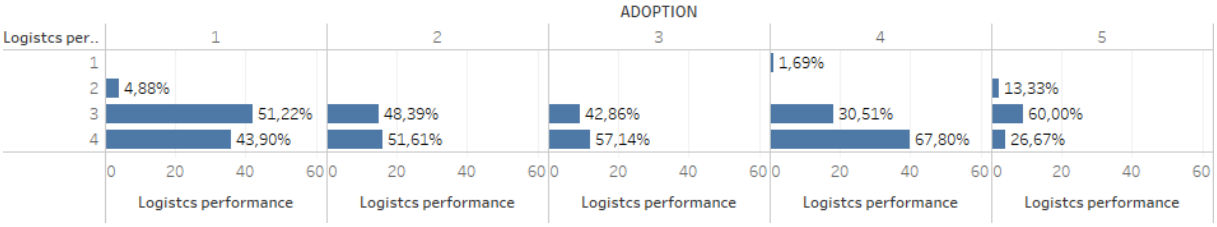


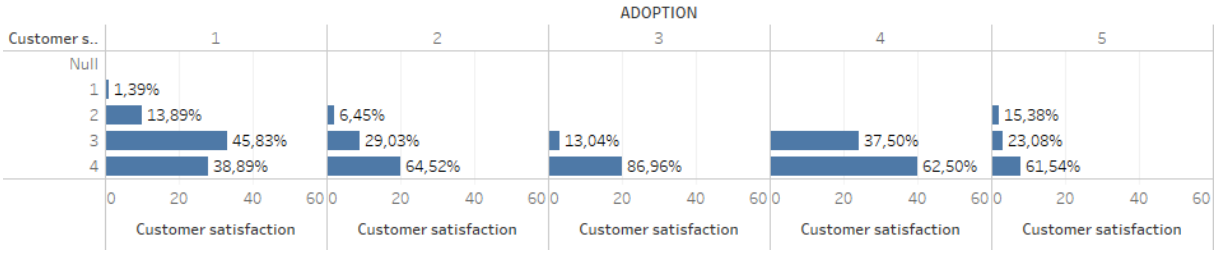




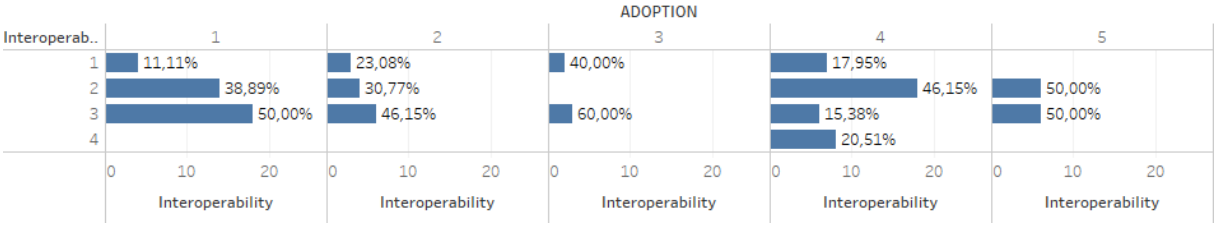


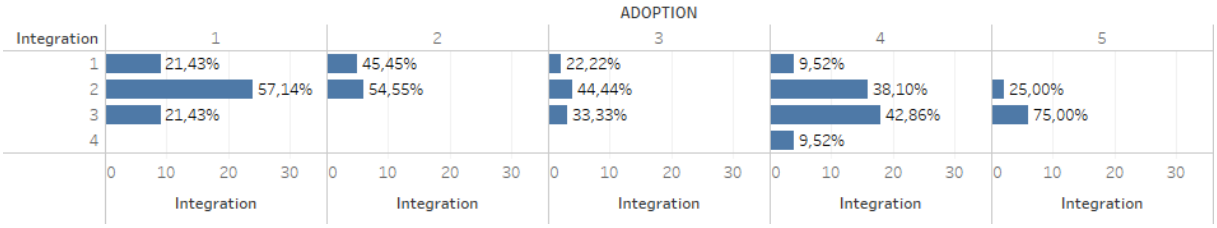


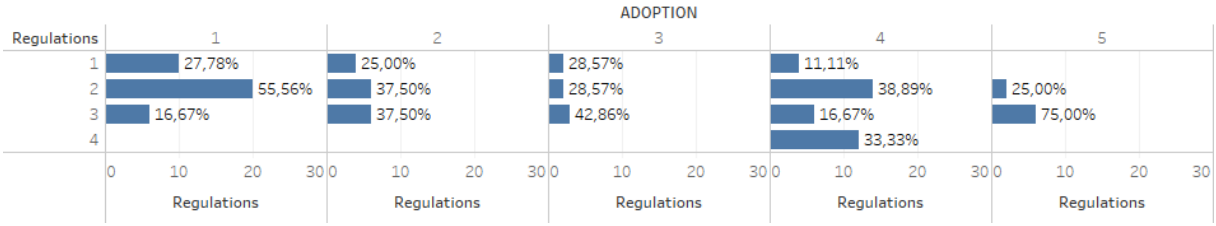




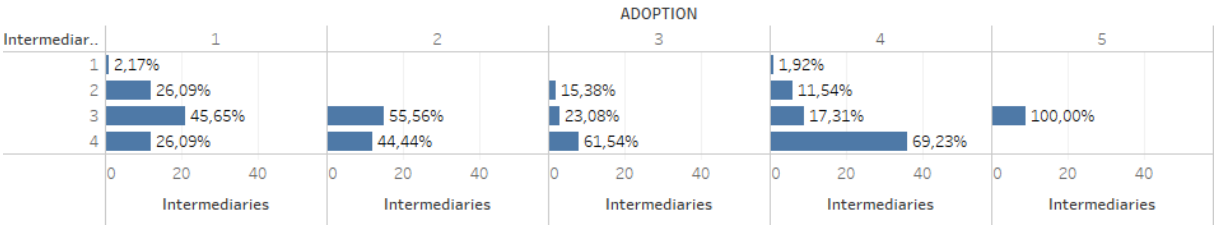
Technology and regulation immaturity

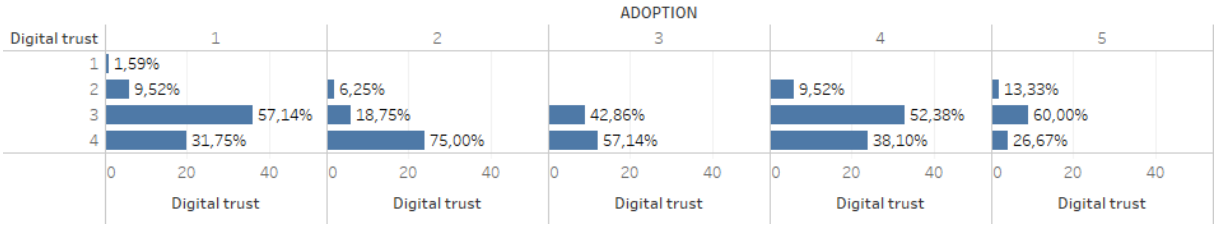


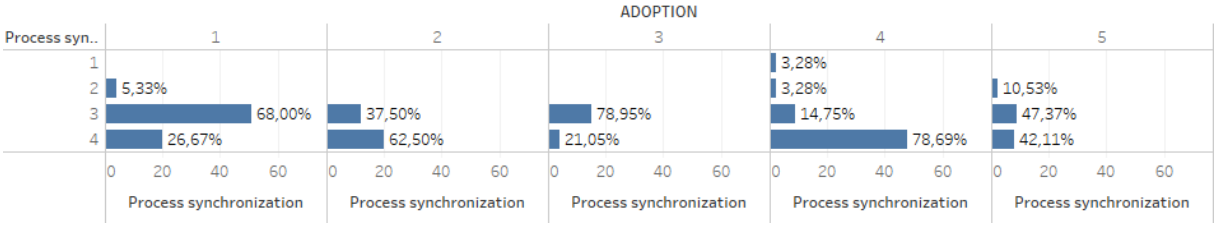


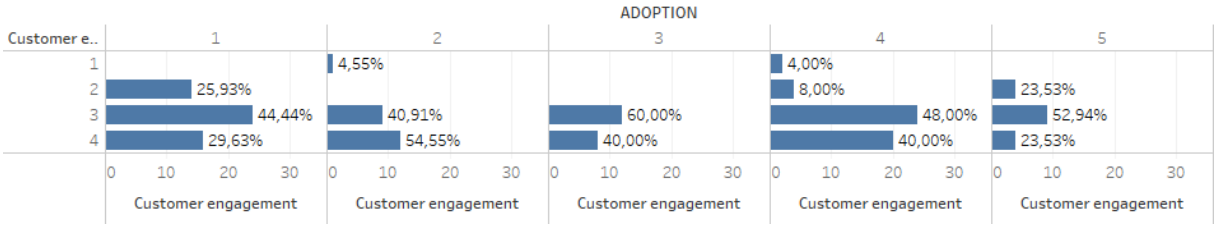


Business integration

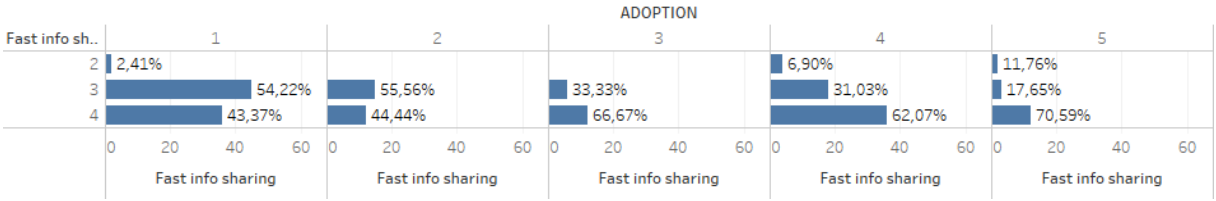


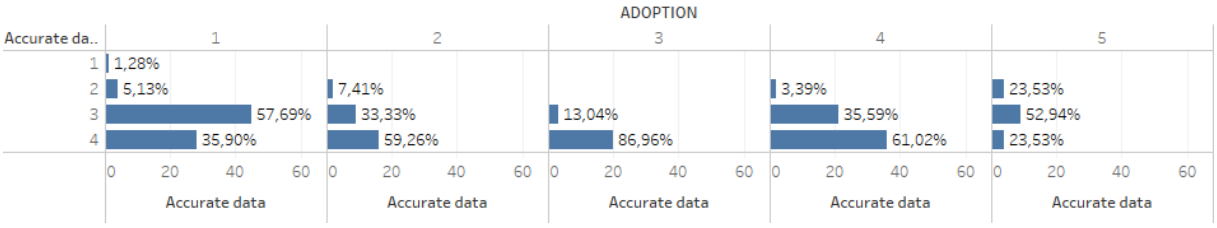


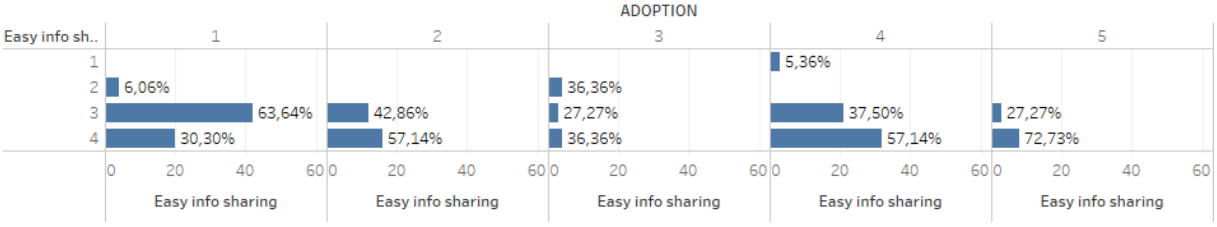




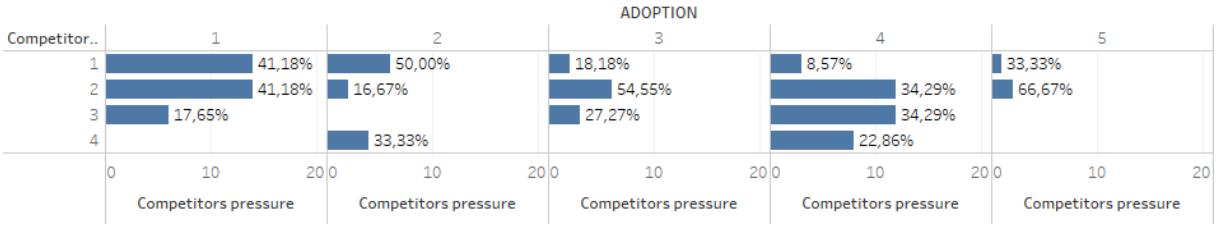
Cross-organizational data performance

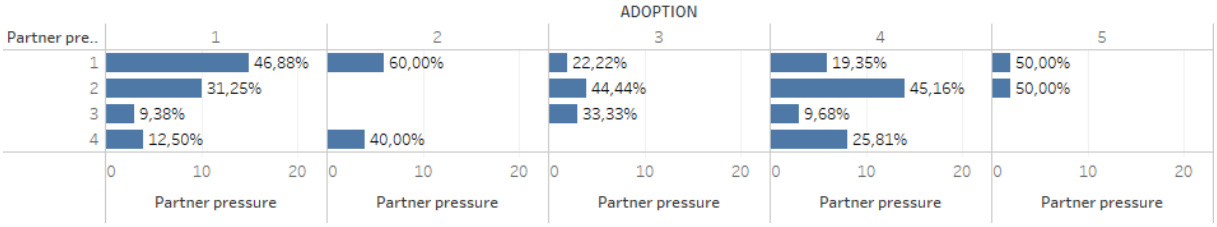


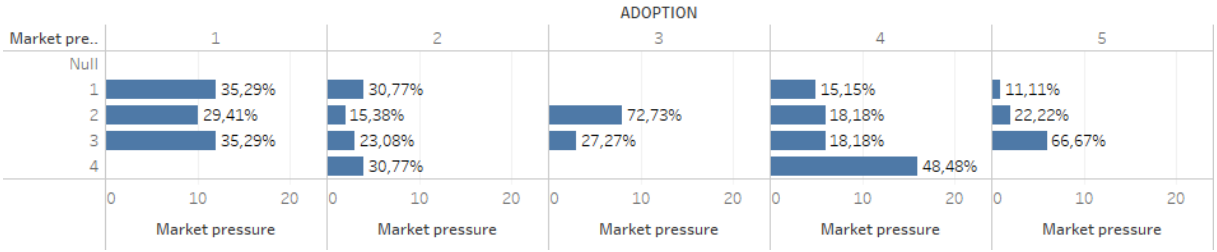




Competitive pressure







APPENDIX H – Correlation matrix

Table 33. Pearson correlation matrix

	ter_1	ter_2	ter_3	bup_1	bup_2	bup_3	bup_4	bup_5	bup_6	bup_7	tri_1	tri_2	tri_3	bui_1	bui_2	bui_3	bui_4	cdp_1	cdp_2	cdp_3	cop_1	cop_2	cop_3	iab_1
ter_1	1	,637**	,204	-,102	-,043	-,115	-,133	,075	-,099	-,243*	,027	,321**	,265*	-,164	-,137	-,298*	-,053	-,299*	-,041	-,161	,084	-,206	-,075	-,330**
ter_2	,637**	1	,289*	-,176	-,107	-,181	-,132	-,199	-,102	-,283*	,105	,404**	,230	-,084	-,180	-,149	-,128	-,125	-,144	-,100	,152	-,069	,000	-,210
ter_3	,204	,289*	1	,256*	,142	,035	,026	,151	,305**	,182	,392**	,417**	,482**	,104	,223	,261*	,287*	,183	,132	,072	,135	,063	,200	-,227
bup_1	-,102	-,176	,256*	1	,565**	,470**	,432**	,339**	,409**	,536**	,303**	-,080	,051	,242*	,469**	,412**	,364**	,230	,269*	,378**	,290*	,267*	,236*	,246*
bup_2	-,043	-,107	,142	,565**	1	,780**	,691**	,494**	,678**	,465**	,386**	,036	,093	,200	,416**	,474**	,395**	,471**	,558**	,436**	,130	,136	,131	,109
bup_3	-,115	-,181	,035	,470**	,780**	1	,692**	,444**	,518**	,464**	,289*	-,026	-,083	,175	,271*	,411**	,341**	,445**	,442**	,289*	,078	,186	,096	,091
bup_4	-,133	-,132	,026	,432**	,691**	,692**	1	,580**	,608**	,448**	,101	-,093	,007	,309**	,373**	,494**	,375**	,507**	,487**	,407**	,169	,263*	,120	,085
bup_5	,075	-,199	,151	,339**	,494**	,444**	,580**	1	,520**	,399**	,163	,004	,153	,131	,374**	,248*	,432**	,242*	,485**	,265*	,096	-,009	,020	-,100
bup_6	-,099	-,102	,305**	,409**	,678**	,518**	,608**	,520**	1	,460**	,398**	,227	,238*	,146	,414**	,519**	,507**	,675**	,423**	,436**	,183	,189	,008	-,005
bup_7	-,243*	-,283*	,182	,536**	,465**	,464**	,448**	,399**	,460**	1	,265*	-,037	,047	,247*	,399**	,504**	,458**	,395**	,447**	,332**	,222	,297*	,246*	,226
tri_1	,027	,105	,392**	,303**	,386**	,289*	,101	,163	,398**	,265*	1	,408**	,396**	,276*	,211	,147	,309**	,243*	,293*	,311**	,215	,124	,208	,113
tri_2	,321**	,404**	,417**	-,080	,036	-,026	-,093	,004	,227	-,037	,408**	1	,524**	,085	,065	,043	,265*	,054	,169	,164	,127	,066	,011	-,301**
tri_3	,265*	,230	,482**	,051	,093	-,083	,007	,153	,238*	,047	,396**	,524**	1	,248*	,164	,179	,304**	,169	,248*	,203	-,039	-,110	,024	-,301**
bui_1	-,164	-,084	,104	,242*	,200	,175	,309**	,131	,146	,247*	,276*	,085	,248*	1	,516**	,334**	,438**	,173	,326**	,536**	,225	,333**	,374**	,181
bui_2	-,137	-,180	,223	,469**	,416**	,271*	,373**	,374**	,414**	,399**	,211	,065	,164	,516**	1	,553**	,540**	,344**	,351**	,408**	,182	,189	,230*	,121
bui_3	-,298*	-,149	,261*	,412**	,474**	,411**	,494**	,248*	,519**	,504**	,147	,043	,179	,334**	,553**	1	,468**	,661**	,389**	,506**	,060	,230	,222	,072
bui_4	-,053	-,128	,287*	,364**	,395**	,341**	,375**	,432**	,507**	,458**	,309**	,265*	,304**	,438**	,540**	,468**	1	,413**	,420**	,509**	,343**	,294*	,289*	,096
cdp_1	-,299*	-,125	,183	,230	,471**	,445**	,507**	,242*	,675**	,395**	,243*	,054	,169	,173	,344**	,661**	,413**	1	,417**	,384**	,011	,141	-,011	-,010
cdp_2	-,041	-,144	,132	,269*	,558**	,442**	,487**	,485**	,423**	,447**	,293*	,169	,248*	,326**	,351**	,389**	,420**	,417**	1	,351**	,000	,108	,034	,067
cdp_3	-,161	-,100	,072	,378**	,436**	,289*	,407**	,265*	,436**	,332**	,311**	,164	,203	,536**	,408**	,506**	,509**	,384**	,351**	1	,283*	,370**	,263*	-,001
cop_1	,084	,152	,135	,290*	,130	,078	,169	,096	,183	,222	,215	,127	-,039	,225	,182	,060	,343**	,011	,000	,283*	1	,693**	,651**	,302**
cop_2	-,206	-,069	,063	,267*	,136	,186	,263*	-,009	,189	,297*	,124	,066	-,110	,333**	,189	,230	,294*	,141	,108	,370**	,693**	1	,701**	,134
cop_3	-,075	,000	,200	,236*	,131	,096	,120	,020	,008	,246*	,208	,011	,024	,374**	,230*	,222	,289*	-,011	,034	,263*	,651**	,701**	1	,240*
iab_1	-,330**	-,210	-,227	,246*	,109	,091	,085	-,100	-,005	,226	,113	-,301**	-,301**	,181	,121	,072	,096	-,010	,067	-,001	,302**	,134	,240*	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX I – Covariance matrix

Table 34. Covariance matrix

	ter_1	ter_2	ter_3	bup_1	bup_2	bup_3	bup_4	bup_5	bup_6	bup_7	tri_1	tri_2	tri_3	bui_1	bui_2	bui_3	bui_4	cdp_1	cdp_2	cdp_3	cop_1	cop_2	cop_3	iab_1
ter_1	1,889	1,113	,330	-,139	-,049	-,142	-,180	,114	-,123	-,347	,041	,480	,413	-,244	-,189	-,400	-,080	-,361	-,056	-,231	,131	-,331	-,128	-,668
ter_2	1,113	1,617	,432	-,223	-,113	-,205	-,164	-,279	-,117	-,375	,148	,558	,332	-,116	-,230	-,185	-,181	-,140	-,181	-,132	,220	-,103	,000	-,393
ter_3	,330	,432	1,382	,300	,139	,037	,030	,196	,322	,222	,510	,533	,643	,132	,264	,300	,374	,189	,153	,088	,181	,086	,293	-,393
bup_1	-,139	-,223	,300	,993	,469	,418	,423	,373	,367	,556	,334	-,087	,057	,261	,470	,402	,401	,201	,264	,393	,330	,311	,293	,362
bup_2	-,049	-,113	,139	,469	,693	,580	,565	,455	,508	,403	,356	,032	,088	,180	,348	,386	,364	,344	,458	,379	,124	,133	,136	,133
bup_3	-,142	-,205	,037	,418	,580	,796	,607	,437	,416	,431	,286	-,025	-,084	,168	,243	,359	,337	,349	,389	,270	,080	,194	,107	,119
bup_4	-,180	-,164	,030	,423	,565	,607	,966	,630	,538	,458	,109	-,100	,008	,328	,369	,476	,408	,437	,472	,417	,190	,302	,148	,123
bup_5	,114	-,279	,196	,373	,455	,437	,630	1,219	,517	,458	,199	,005	,192	,157	,415	,268	,527	,235	,528	,305	,121	-,011	,028	-,162
bup_6	-,123	-,117	,322	,367	,508	,416	,538	,517	,810	,431	,396	,222	,243	,143	,374	,457	,505	,534	,375	,410	,188	,199	,009	-,006
bup_7	-,347	-,375	,222	,556	,403	,431	,458	,458	,431	1,083	,306	-,042	,056	,278	,417	,514	,528	,361	,458	,361	,264	,361	,319	,347
tri_1	,041	,148	,510	,334	,356	,286	,109	,199	,396	,306	1,226	,491	,498	,330	,235	,160	,379	,237	,319	,360	,272	,160	,288	,184
tri_2	,480	,558	,533	-,087	,032	-,025	-,100	,005	,222	-,042	,491	1,180	,646	,100	,071	,046	,318	,052	,181	,186	,157	,084	,015	-,481
tri_3	,413	,332	,643	,057	,088	-,084	,008	,192	,243	,056	,498	,646	1,288	,304	,187	,199	,382	,169	,278	,240	-,051	-,146	,034	-,502
bui_1	-,244	-,116	,132	,261	,180	,168	,328	,157	,143	,278	,330	,100	,304	1,169	,560	,354	,524	,164	,347	,605	,278	,420	,504	,288
bui_2	-,189	-,230	,264	,470	,348	,243	,369	,415	,374	,417	,235	,071	,187	,560	1,009	,544	,600	,303	,347	,428	,209	,222	,289	,180
bui_3	-,400	-,185	,300	,402	,386	,359	,476	,268	,457	,514	,160	,046	,199	,354	,544	,958	,507	,568	,375	,517	,067	,263	,271	,104
bui_4	-,080	-,181	,374	,401	,364	,337	,408	,527	,505	,528	,379	,318	,382	,524	,600	,507	1,225	,401	,458	,588	,433	,380	,400	,156
cdp_1	-,361	-,140	,189	,201	,344	,349	,437	,235	,534	,361	,237	,052	,169	,164	,303	,568	,401	,771	,361	,352	,011	,145	-,012	-,013
cdp_2	-,056	-,181	,153	,264	,458	,389	,472	,528	,375	,458	,319	,181	,278	,347	,347	,375	,458	,361	,972	,361	,000	,125	,042	,097
cdp_3	-,231	-,132	,088	,393	,379	,270	,417	,305	,410	,361	,360	,186	,240	,605	,428	,517	,588	,352	,361	1,090	,337	,452	,343	-,002
cop_1	,131	,220	,181	,330	,124	,080	,190	,121	,188	,264	,272	,157	-,051	,278	,209	,067	,433	,011	,000	,337	1,304	,924	,928	,508
cop_2	-,331	-,103	,086	,311	,133	,194	,302	-,011	,199	,361	,160	,084	-,146	,420	,222	,263	,380	,145	,125	,452	,924	1,366	1,023	,230
cop_3	-,128	,000	,293	,293	,136	,107	,148	,028	,009	,319	,288	,015	,034	,504	,289	,271	,400	-,012	,042	,343	,928	1,023	1,559	,441
iab_1	-,668	-,393	-,393	,362	,133	,119	,123	-,162	-,006	,347	,184	-,481	-,502	,288	,180	,104	,156	-,013	,097	-,002	,508	,230	,441	2,170