MSc Program
Engineering Management

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Blockchain Technology Adoption for Supply Chain Management in Austria

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
Dr. Larry Stapleton

Hermann Gabriel, Bsc.

11779536

Vienna, 24.03.2023

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Affidavit

I, **HERMANN GABRIEL, BSC.**, hereby declare

1. that I am the sole author of the present Master's Thesis, "BLOCKCHAIN TECHNOLOGY ADOPTION FOR SUPPLY CHAIN MANAGEMENT IN AUSTRIA", 84 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

This master's thesis presents a comprehensive study of blockchain technology adoption for supply chain management in Austria. The thesis includes three literature reviews: one on blockchain technology, another on its application to supply chain management, and a third on blockchain adoption studies and theories. Based on the findings from the literature reviews, a new approach for studying blockchain adoption was developed. Our adoption framework is based on a processual approach that includes Neo-Institutional Theory and the Technology-Organization-Environment (TOE) framework. It was tested in a preliminary study consistsing of interviews with Austrian organizational managers.

The development of this new framework was necessary due to the structure of the Austrian economy, which consists of a majority of small and medium-sized enterprises (SMEs). As discovered during the literature review, existing literature on blockchain technology adoption for supply chain management does not adequately address the role of SMEs in this process. The main idea of our framework is to focus on the inter-organizational environment and use the supply chain as the unit of analysis rather than the individual company, which allows for a better evaluation of the situation and expectations of organizations about the adoption of blockchain technology for supply chain management.

The findings of the study showed the importance of taking the structure of the supply chain into account when studying blockchain adoption in this context and therefore indicate the validity of the developed framework. Furthermore, the findings provide valuable insights into the current situation of the adoption process of blockchain technology for supply chain management in Austrian organizations. In addition, the findings suggest that future blockchain technology adoption studies for supply chain management should be separated based on different adoption scenarios and differentiate between developing and participating companies in the blockchain solution. This approach will provide a more useful understanding of the factors that influence the adoption of blockchain technology in the supply chain management field. Finally, the results of this thesis indicate that, at the current moment, it should be of high importance for Austrian policymakers to support those companies that might be facing a mandatory adoption of blockchain technology for supply chain management, demanded by other participants in their supply chain.

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1 Introduction

1.1 Context and Background

The context for this thesis is provided by recent developments and trends in *blockchain technology* as well as *supply chain management*. In this section, we will briefly summarize these trends in order to give the reader an idea of how these two distinct topics evolved towards their current form, which makes it worth exploring their combination.

Since 2008, when the first application of blockchain technology in the form of the cryptocurrency *Bitcoin* was developed, blockchain technology has come a long way. Since then, blockchain technology has progressed from a single-purpose tool to an entire ecosystem consisting of various blockchain platforms that enable the development of specialized applications for the use of blockchain across industries and functions. The advances enabling the use of blockchain technology for enterprises consist of improvements in scalability, speed, and energy consumption. As a result, numerous platforms for enterprise use have emerged (Henry and Pawczuk, 2021).

According to a report by Deloitte in 2021:

> *"The current state of blockchain and other DLT platforms is not unlike that of internet in 1997: clunky, with an inadequate user interface, but with lots of possibility for enterprise applications. Like the internet, they're helping businesses and organizations streamline business processes and operations and drive value through the creation of new digital business models." (Henry and Pawczuk, 2021)*

Many enterprises realize this trend, and according to Deloitte's *2021 Global Blockchain Survey* 80% of the participants expect that their industry will see new revenue streams from blockchain (Pawczuk et al., 2021). One of the identified enterprise operations that could benefit a lot from blockchain is supply chain management.

Supply chain management evolved from classical logistics based on the idea of incorporating all participants in the supply chain into operations. According to Odile Panciatici[1]: "*The future of industry will be collaborative and cooperative*." (IBM, 2021) Therefore, information exchange and trust between all participants of a supply chain

[1] Vice President of Blockchain Projects, Renault Group

must be established (Le-Boucher, 2021). With improvements in information technologies, the goal of an efficient live supply chain could finally be achieved and blockchain technology could potentially be one of the missing pieces.

Today we can already see implementations of blockchain technology in supply chain management. For example, 10 out of 50 companies on the *Forbes Blockchain 50 List 2022* can be considered to be connected to this type of application (Paz, 2022). Therefore, we are able to analyze the benefits of the combination of blockchain and supply chain management using real-world case studies. However, these studies are mainly focused on the adoption of blockchain technology for supply chain management by large enterprises and not on the role of small and medium-sized enterprises in this potentially revolutionary shift in supply chain management.

1.2 Problem Statement

In the previous section, the current state of blockchain technology was compared to the early stages of the Internet. From 1997 onwards, we could observe how companies, that realized the benefits of the Internet early enough and found solutions for their problems based on the new technological possibilities, gained a competitive advantage. On the contrary, many companies failed to integrate the Internet and consequently could not keep up with the changing markets.

The overarching goal of this master's thesis is to investigate to what extent such a threat exists for blockchain technology and its applications in supply chain management. Due to the scope of this thesis, we have chosen to evaluate the adoption process of blockchain technology for supply chain management for Austrian enterprises. In addition, we would like to draw conclusions based on the findings of this thesis for strategic measures for Austria and Austrian enterprises, which we think will aid in mitigating this risk of being left behind and potentially yield a competitive advantage.

The problem tackled in this thesis can be separated into different aspects. At first we have to identify the general benefits of blockchain technology for supply chain management, which requires gaining knowledge about both of these areas. This topic has been researched intensively, and the potential benefits have been described theoretically throughout literature in recent years. Nowadays, we are already starting to see implementations and solutions in various industries (Raja Santhi and Muthuswamy, 2022). However, we assume that for the risk of being left behind the adoption of the technology is more relevant than the theoretic backgrounds. Therefore, the problem can be translated into a blockchain technology adoption question with the aim of evaluating the current situation and identifying major barriers to adoption.

Since the Austrian industry consists mainly of small and medium-sized enterprises (SMEs) (Bundesministerium - Arbeit und Wirtschaft, 2022), our ambition for studying blockchain adoption for supply chain management in Austria is inherently connected to the role of SMEs within this process. However, most of the literature, case studies, and adoption frameworks are targeted at the adoption on a large organizational scale. Consequently, the role of SMEs is unclear and was identified as a knowledge gap. With this thesis, we would like to help bridge this gap by suggesting a different approach for studying blockchain adoption for supply chain management, which we think can help incorporate SMEs in the study of the adoption process. Besides literature research, we will conduct guided interviews with Austrian organizations in order to identify hindrances and risks for the adoption of blockchain for SCM and validate our suggested adoption framework.

1.3 Motivation - Why is it important?

According to Deloitte's *2021 Global Blockchain Survey*, many enterprises believe that blockchain technology has the potential to be a disruptive technology for supply chain management (Pawczuk et al., 2021).We are beginning to see blockchain implementations and solutions to real-world problems that have the potential to significantly increase efficiency and lower supply chain management costs (Raja Santhi and Muthuswamy, 2022). This indicates a potential revolution for how supply chains can be managed. As with most innovative technologies, we expect the existence of an early-mover advantage. Consequently, it is important to explore the role of SMEs in this revolution as well as identify to what degree they are able to participate and take actions on their own without depending on large enterprises.

As a result, we anticipate this thesis will be of special interest to SMEs as we study their involvement in the adoption of this technology. This study's findings can help SMEs analyze their own situations more accurately by identifying crucial factors and hindrances to the adoption of blockchain technology for supply chain management. This understanding enables them to actively prepare for a variety of future scenarios. However, larger corporations should also be interested in this issue. SMEs may be part of their supply chains, and if they wish to implement their own blockchain solutions, they must be aware of the challenges their partners may experience.

In addition, we also offer a different method for evaluating the adoption of blockchain technology for supply chain management, in this thesis, so it may also be of interest to researchers. They may decide to employ this framework for future research in other regions or test it even further. The model that we will offer should be particularly useful to firms that intend to analyze their own supply chains for blockchain implementation.

This subject should also be of great interest to the Austrian government, given that we intend to evaluate the risks for Austrian organizations in this potential disruption of business operations. More than 99 percent of all businesses in Austria are small and medium-sized enterprises (Bundesministerium - Arbeit und Wirtschaft, 2022). Thus, identifying opportunities for them to gain a competitive advantage should be a priority for nations with such industrial structures. In addition, we will provide calls-for-action for the government that might aid Austrian organizations in the adoption process and can serve as a foundation for future efforts.

Finally, the personal motivation for this thesis derives from a large interest in blockchain technologies, which have already been part of the research for my bachelor's thesis, where the potential conflict between quantum computing and cryptocurrencies was explored. Since then, my attention has shifted from a sole focus on cryptocurrencies to the entire ecosystem of blockchain technologies. Personally, I see the implementation of blockchain technology for business reasons as being more promising and realizable than the objectives of cryptocurrencies. Consequently, it seemed obvious to me that the focus of my thesis should be on the enterprise use of blockchain technology. The integration with supply chain management followed naturally, since it is one of the most well-known applications of blockchain technology and aligns well with the topics covered in my master‘s studies in engineering management.

1.4 Research Objectives and Research Questions

The aim of this thesis is to research the benefits and adoption of blockchain technology for supply chain management. Furthermore, we want to identify the role of SMEs and evaluate the implied risks, barriers, and possibilities of this potential technological transformation.

A literature review will be conducted in order to identify the broad benefits of blockchain technology for supply chain management. At first, the focus will be on understanding blockchain and supply chain management individually in order to later evaluate the possibilities of combining the two. Therefore, we analyze the literature on this topic, consisting of theoretical and empirical work pieces, case studies, and adoption studies, with the purpose of answering the following research question:

Research Question 1. *What are the benefits of blockchain technology for supply chain management?*

Since this is a question regarding the technology itself, we believe these benefits are general. To make a strategic case for Austria, however, our second research question focuses on assessing the current situation in this region:

Research Question 2. *What is the present state and future ambition of Austrian organizations regarding the adoption of blockchain for supply chain management?*

As previously mentioned, the majority of the research examines this problem from the perspective of large businesses. However, the majority of Austrian industries are comprised of small and medium-sized enterprises, thus it is of interest to determine if there exist any differences in the context of employing blockchain technology for supply chain management. As a result, we want to answer the following question:

Research Question 3. *How does the adoption-process of blockchain technology for supply chain management differ for Austrian SMEs compared to larger organizations?*

In order to better understand the adoption process of blockchain technology for supply chain management in Austria, we have to dive deeper into the barriers, enablers, and difficulties for Austrian organizations. Thus, the fourth research question is:

Research Question 4. *What are the difficulties, enablers and barriers for blockchain adoption for supply chain management for Austrian organizations?*

We believe that by addressing the first four research questions, we will be able to provide valuable insights on how Austrian firms may be assisted in the future in terms of blockchain technology for supply chain management. Therefore, we would like to conclude the thesis by finding answers to the following question:

Research Question 5. *What calls-for-action, in the context of blockchain adoption for supply chain management, can be made for policymakers and organizations in Austria.*

1.5 Blockchain in Austria

We want to briefly explain how blockchain technology is fostered in Austria at the moment. We have identified that there are several agencies in Austria that tackle this topic. On the one hand, there are research groups at a number of Austrian academic institutions (for example, the Technical University of Vienna and the University of Vienna), many of which are members of the *ABC Research - Austrian Blockchain Center*, a collaborative initiative for *application-oriented research.* This research center is partly funded by the national initiative *COMET (Competence Center for Excellent Technologies)* (Austrian Blockchain Center, 2023).

On the other hand, a more implementation-focused approach is supported by *AUSTRIAPRO*, which is an agency of the Austrian Economic Chamber. *AUSTRIAPRO* is an *"association for the promotion of electronic data transmission in business transactions"*, which has a distinct working group for the use of blockchain technology for supply chain management. This group works on finding best practices, identifying use cases, and developing certain blockchain solutions.Furthermore, *AUSTRIAPRO* and *ABC Research* work together on developing and maintaining a blockchain that can be used for deploying different solutions supporting Austrian businesses, as well as a *Test-Lab* where new blockchain solutions for businesses could be tested in a secure environment (Wirtschafskammer Österreich, 2023).

1.6 Chapter Summary and Thesis Outline

In this chapter, we have defined the overall aim of this thesis. We started in Section 1.1 by providing a broad background on the two main topics, which are blockchain technology and supply chain management. However, in order to increase our understanding of the problems, introduced in Section 1.2, it is important to dive deeper into these topics. Consequently, we will explore blockchain technologies in Chapter 2 in more detail. The aim of this chapter is to give the reader an idea of what blockchain technology is (Section 2.1), what the building blocks of the technology are (Section 2.2), and how it works (Section 2.3). From there, we will continue with explaining the key features (Section 2.4) as well as differentiating between different blockchain types (Section 2.5). Finally, Section 2.6 provides some examples of the technology's various use-cases.

In Chapter 3, we start by explaining what supply chain management is (Section 3.1) and how it works (Section 3.2). These two chapters provide us with a framework, allowing us to explore blockchain applications for supply chain management in Section 3.3. In this section, we can use the knowledge gained in the previous chapters to understand the value of the combination of blockchain technology and supply chain management. Finally, we make the leap from what was explained in the previous chapters to the gap of knowledge we identified in Section 3.6.

The gained understanding for blockchain technology and supply chain management allows us to better analyze the problem statement and ultimately the research questions. In order to answer the research questions, we will have a look at technology adoption in Chapter 4. We will explore existing frameworks and previous studies about blockchain adoption in supply chain management. Finally, in Section 4.3, we will present our framework for studying blockchain adoption. The methodology for the empirical part of the thesis will be explained in Chapter 5. The findings of the empirical study will be presented in Chapter 6 and further discussed in Chapter 7.

2 Literature Review 1: Blockchain Technology

In order for the reader to understand the potential benefits of blockchain technology for supply chain management, we first want to provide a concise introduction to the fundamentals of the technology. Therefore, a literature review was performed and is summarized in this chapter.

In Section 2.1, we begin by defining blockchain technology and describing its position in the technology ecosystem. In sections 2.2 and 2.3, we introduce the building blocks and provide a general description of how a blockchain operates, respectively. After a summary of blockchain's key characteristics in Section 2.4, we introduce different types of blockchain networks in Section 2.5. In order to give the reader a sense of the various areas where blockchain technology may prove useful, the chapter concludes with examples of blockchain technology applications.

2.1 What is Blockchain Technology?

Over the last decade, blockchain has grown to be one of the most disruptive technologies of our time (Gray, 2021). Due to the complicated nature of blockchain technology, a lot of the hype and interest in the technology were compromised by speculation, false promises, and misinformation.

However, if we break blockchain technology down to its core, it is a technology that can be used for storing data. As the name suggests, the data is stored in connected blocks that are secured via cryptographic methods. The design of blockchain technology enables data entries stored within the blockchain to be *transparent, secure, and immutable* without the need for a trusted third party (Rehmani, 2021).

Blockchain technology evolved from earlier concepts for the creation of digital currencies such as Adam Back's *Hashcash* (1997), Wei Dan's *B-Money* (1998), or Nick Szabo's *Bit Gold* (2005) (Lantz and Cawrey, 2020). The first application of the technology that we refer to as blockchain today was proposed by Satoshi Nakamoto[2] in 2008. She published a paper called "*Bitcoin: A Peer-to-Peer Electronic Cash System*", often referred to as the *Bitcoin whitepaper*, in which she described the concept for a cryptocurrency called *Bitcoin*. She used the technology in order to solve the so-called

[2]Satoshi Nakamoto is a pseudonymous person or group used by the authors of Bitcoin whitepaper. For this thesis we assume, without further knowledge or intentions that Satoshi Nakamoto was female.

double-spending problem, which was the greatest obstacle to the creation of a properly working digital currency without the involvement of a middleman (Nakamoto, 2008).

Since 2008, the technology has undergone significant development and now exists in a variety of forms and implementations, enabling its use in different industries for purposes other than digital currency. Section 2.6 will go over additional use cases.

Blockchain technology is usually categorized as a decentralized implementation of *distributed ledger technology* (DLT). In blockchain technology, there are numerous methods for managing data. For the purpose of this thesis, we focus on the implementation, where the data is stored in a linked list of blocks, which is generally referred to as *blockchain*. Alternatively, data could be stored in tree-like structures, which are referred to as *directed acyclic graphs* (DAG) (Rehmani, 2021). However, exploring DAG and other DLTs is outside the scope of this thesis.

In the context of DLTs, blockchain can be defined in the following way:

> *"(...) blockchain as a distributed ledger technology can be used to store transactions securely with tamper resistance. Blockchain can be defined as a peer-to-peer (P2P) network, which consists of multiple numbers of nodes linked with each other in the form of blocks in a distributed manner, it can be used for carrying out transactions and storing records securely using digital signatures, distributed ledger technology, and cryptography."* (Tanwar, 2022, pg. 1)

Analyzing this definition, we can see that blockchain is defined as a network with various participants, called *nodes*. The transactions between these nodes are stored in the form of *blocks* in a *distributed (digital) ledger*. The ledger can be imagined as the database, where all the transactions are stored [3] (Rehmani, 2021). In addition, the network has a *peer-to-peer* (P2P) architecture, which further determines the distributed network's properties. This implies that the ledger is not stored centrally but that each node has its own copy and is able to interact and conduct transactions directly with every other node, without the need for a central authority to mediate the transaction. If every node can independently select what to add to her copy of the ledger, we refer to the system as decentralized (Tanwar, 2022). Different network types are illustrated in

[3] However, this is only a picture for better understanding blockchain, becuase blockchains and databases have different properties (Rehmani, 2021).

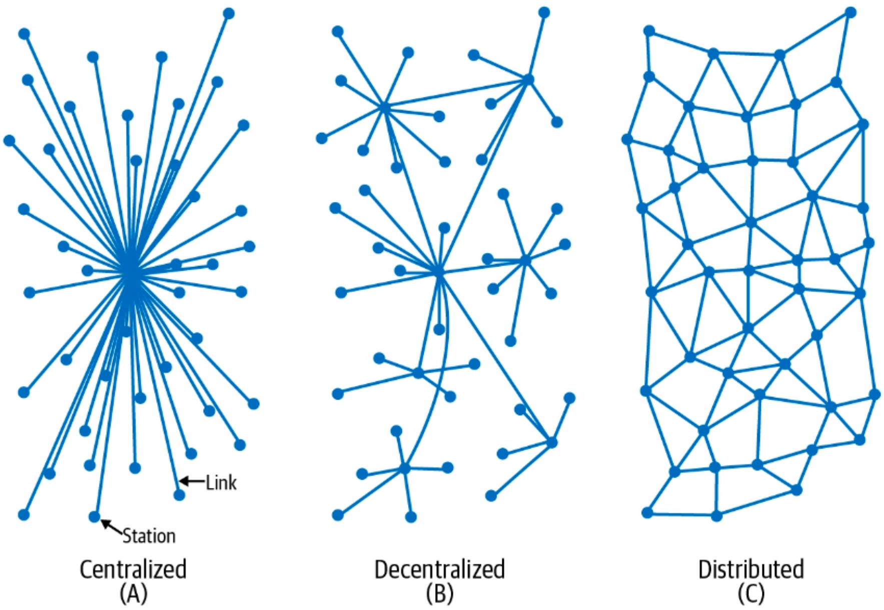


Figure 1: Centralized, Decentralized and Distributed Networks (Lantz and Cawrey, 2020, pg. 13)

Figure 1.

2.2 Building Blocks of Blockchain Technology

2.2.1 Cryptography

In a blockchain network, information has to be broadcasted between nodes through the Internet. In order to ensure the integrity of the shared information in an insecure network, like the Internet, further cryptographic methods are required (Rawal et al., 2022). Thus, cryptographic *hashes* and *digital signatures* are heavily used and can be considered building blocks for blockchain technology (Puthal et al., 2018b).

Hashes

A hash is a random-looking, fixed-size string created by cryptographic hash functions. The two most common hash functions used in blockchain technology are *SHA-256* (for Bitcoin) and *Keccak-256* (for Ethereum) (Lantz and Cawrey, 2020). They are functions that can take any type of data as input (*message*) and return a string (*hash value* or *message digest*) with length of 256 bits.

A cryptographic hash function is a so-called *one-way or trap-door function*, which implies that the computation is very easy in one direction but not feasible in the opposite

SHA256(“a”) = `ca978112ca1bbdcafac231b39a23dc4da786eff8147c4e72b9807785afee48bb`

SHA256(“b”) = `3e23e8160039594a33894f6564e1b1348bbd7a0088d42c4acb73eeaed59c009d`

Figure 2: Hash values for the two inputs “a” and “b”.

direction[4]. Thus, from the hash value, it is not possible to compute the original message. Furthermore, cryptographic hash functions are considered to be *deterministic* and *collision-resistant*. This means that the same input always returns the same hash value, but two different inputs cannot point to the same hash value. Therefore, a slight change in the message leads to an entirely different message digest (Lantz and Cawrey, 2020). This behavior of hash functions is illustrated in Figure 2, where the hash values for the letters ”a” and ”b” are shown.

These characteristics distinguish the hash function as a valuable tool for blockchain technology, where it may be used to generate addresses, ensure data integrity, and link blocks (Rawal et al., 2022). The latter is accomplished by using the hash value that encrypts the preceding block’s information as part of the input for the hash value of the subsequent block. Consequently, due to the nature of hash functions, modifying the data of a block necessitates simultaneously modifying the data of all future blocks.

Digital Signatures

A digital signature is a string with a fixed lengths[5], that contains information about the original document being signed, the signatory, as well as metadata about the algorithm used to generate the signature. They are used in blockchain technologies for ensuring information *integrity, authentication, non-copyability, and traceability* (Rawal et al., 2022).

In blockchain technologies, digital signatures are generated by making use of *asymmetric* or *public-key cryptography* in order to sign transactions. This implies that each node holds two keys. A public key that may be shared with anyone and a private key that only the node knows. The private key, however, cannot be recovered from knowledge of the public key (Rawal et al., 2022).

[4]this is not proven, but so far no collisions have been found.
[5]However the lengths of the string depends on the algorithm.

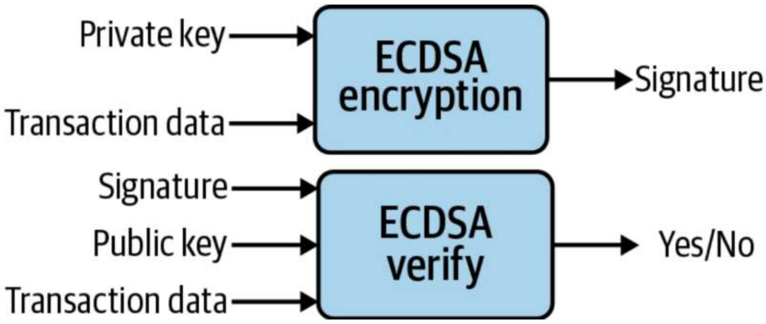


Figure 3: Concept of the ECDSA (Lantz and Cawrey, 2020, pg. 54 f.)

The most common algorithm used to generate digital signatures in blockchain technology is the *Elliptic Curve Digital Signature Algorithm* (ECDSA). In order to generate a digital signature, the transaction data is hashed using a cryptographic hash function (e.g. SHA-256). Afterwards, the hash value is encrypted using the node's private key, which generates the digital signature. Every other node can verify the signature by using the transaction data, the public key, and the signature. This is illustrated in Figure 3. Consequently, everyone in the network can check the integrity and validity of transactions independently by using publicly available data and the verification algorithm (Lantz and Cawrey, 2020; Rawal et al., 2022).

2.2.2 Transactions and Blocks

The information and content of transactions and blocks vary significantly with different implementations of blockchain technology. Nevertheless, we try to give an illustrative picture in this section, which is valid for most blockchains but would need to be further specified for individual applications. In our general picture, we define transactions in the following way:

> *"A transaction in blockchain can be defined as the smallest unit of a task in a blockchain network."* (Rawal et al., 2022, pg.103)

Each transaction includes information on the *sender, the recipient, and the transaction's subject*. However, the subject depends on the particular application of the blockchain. When using blockchain as a cryptocurrency, for instance, the subject is an amount of the network's native asset. In Section 2.6, we will present additional use-cases. As described in the previous section, every transaction must be digitally signed by the sender in order to prove ownership and make the transaction verifiable. Thus, nodes can independently verify each transaction.

A predetermined number of valid transactions are bundled together and stored within a single block. In our generalized model, blocks are divided into a *header part*, holding

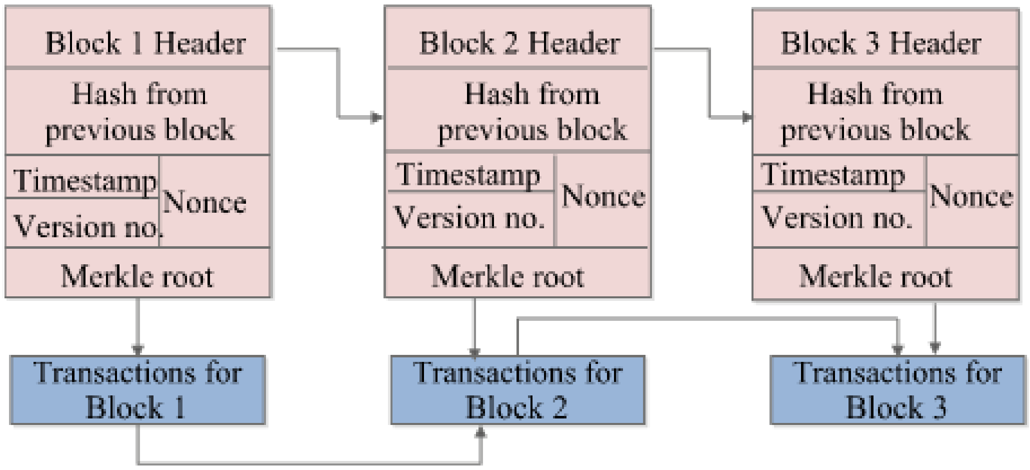


Figure 4: Concept for a block's data structure (Tanwar, 2022, pg. 5)

all the block-specific information, and a *body part*, containing all the transactions of the block (Rawal et al., 2022). The content of the block header is hashed in order to create the *block hash*. Most importantly, the block header contains the block hash of the previous block as well as a *nonce*. For example, the hash of block n_{-1} is included in the block header of block n and is therefore hashed again when generating the new block hash. This creates a connection via hashes of hashes, resulting in an immutable chain of connected blocks. The nonce can be viewed as the proof of validity for this block according to the blockchain's consensus protocol (see Section 2.2.3). This generalized view of blocks is illustrated in Figure 4.

2.2.3 Consensus Protocol

As previously elaborated, blockchain is a decentralized and distributed network of nodes operating on a P2P basis. Thus, every node has its own copy of the ledger and without a trusted third party mediating, a mechanism for finding agreement on the state of the ledger is required. This mechanism is referred to as the consensus protocol of the blockchain, which ensures that all honest nodes have the same copy of the distributed ledger even in the presence of malicious nodes (Rehmani, 2021).

The consensus protocol defines which transactions are legitimate and whether each node should delete or add a new block to its local copy of the blockchain. Furthermore, the consensus protocol determines other quantities of a blockchain, such as the *blocktime*, which is the time required for the network to add a new valid block to the blockchain. Additionally, the protocol governs the way new assets are created and added to the network.

Depending on the intended purpose of a blockchain, many consensus protocol models have been developed so far. Besides the type of blockchain (see Section 2.5), the consensus protocol is the most essential factor in determining how a particular blockchain operates. The models can differ concerning the following aspects (Puthal et al., 2018a):

- Intended type of blockchain
- Transaction rate
- Scalability
- Participation charges
- Trust Condition

For the rest of this section, we want to take a look at the two most common consensus protocols for public blockchains. As mentioned, various other protocols exist, but to dive into all of them is outside the scope of this work.

Proof of Work

Proof of Work (PoW) was the original consensus protocol for the Bitcoin blockchain introduced by Satoshi Nakamoto (Nakamoto, 2008). According to the protocol, certain nodes, called *miners*, compete to solve a cryptographic puzzle in order to prove the validity of a new block by using their computational power. Once the puzzle is solved, other nodes can easily check the validity of the block as well as the correctness of the solution of the puzzle. If it is a valid block, they include it in their copy of the ledger. As a reward for putting in the work, the miner receives new asset as well as a fee charged for the transactions. For example, in the case of Bitcoin, the consensus protocol states that the difficulty of the cryptographic puzzle is adjusted in such a way that a valid block is found by the network every 10 minutes (Nakamoto, 2008).

Proof of Stake

Proof of Stake (PoS) can be seen as the eco-friendly alternative to PoW because it requires hardly any computational power, which is directly correlated to the energy consumption of the network. Ethereum, the second-largest blockchain, switched from PoW to PoS in 2022 (Ethereum.org, 2022).

According to PoS, nodes called *validators*, stake some amount of their network's native asset. The validator for a new block is chosen randomly with respect to their staked amount. For producing a valid block, the validators receive incentives. However, if they produce a block that is not added to the ledger by the majority of nodes, they will lose some amount of their staked asset (Puthal et al., 2018a; Tanwar, 2022).

2.3 How does Blockchain work?

In order to better understand how the blockchain operates, we want to consider the process from the time of generating a new transaction until it is added to the blockchain and accepted by the majority of network participants.

The first step is the generation of a new transaction. As already stated, this happens on a P2P basis. Therefore, a node (sender) creates the transaction, and in order to prove that the sender is indeed the owner of the blockchain-address used for the transaction, he or she digitally signs the transaction with his or her private key. Then, the unverified transaction is broadcasted to the entire network. As a result, the authenticity of the new transaction can then be independently verified by the receiver of the transaction as well as all other network participants, according to the algorithm used for signing (e.g. ECDSA). Furthermore, it is confirmed that the issuer has sufficient funds for the indented transaction.

After the transaction is verified by the network, it has to be added to the blockchain. Therefore, miners or validators pick up verified transactions, bundle them together, and start working on the creation of a new valid block containing this transaction according to the consensus protocol of the blockchain.

Once a miner/validator is finished with the creation of the block, it is broadcasted to the entire network. Others can again verify the integrity of the block, by checking the block hash, and then add it to their copy of the blockchain[6]. Only upon the continuous acceptance of the block by the majority of nodes, it becomes confirmed, and the miner/validator receives the incentive (Puthal et al., 2018a; Tanwar, 2022).

2.4 Features of Blockchain

Based on the building blocks and architecture of blockchain, the technology enables certain unique characteristics. As we have shown in Section 2.1, blockchain technology can lead to *decentralization*, which provides users with control over the network. As we saw in the preceding section, all transactions and blocks are broadcast across the entire network in order to offer *transparency* for all nodes. In order to guarantee

[6]There is the possibility that two blocks are found at the same time. Then nodes would wait to see which block is added by the other nodes and accept the longest version of the chain.

privacy in such a transparent network, only hashed data is shared. This is regarded as *pseudonymity*[7]. In addition, blockchain technology is considered to be *append-only*, and its entries are *tamper-proof*. This means that data may only be appended to the blockchain, however once added, it cannot be changed, and any attempts to alter data in earlier blocks would be recognized by other participants.These features are further combined with cryptographic methods, introduced in Section 2.2.1, in order to create a cryptographically secured network. However, depending on the intended use and the consensus mechanism, not every blockchain entirely satisfies these characteristics. For certain applications, it might be necessary to omit one or the other feature in order to design a more scalable solution (Rehmani, 2021; Tanwar, 2022). This approach is the basis for the classification of blockchains, which will be explained in Section 2.5.

2.4.1 Smart Contracts

To use blockchain technology for purposes other than cryptocurrency, additional functionality is required[8]. This feature can be described as a blockchain's capacity to execute code stored in the ledger.

This is the concept behind *smart contracts*. The smart contract contains the code that represents the logic of the business rules required to reach an agreement between two or more parties. Since the smart contract operates on the distributed, decentralized blockchain, it is no longer required to involve centralized third parties in its governance. The smart contract is self-executable and is therefore automatically executed when the contract's requirements are met.

Smart contracts can be defined in a more precise way:

> *"Smart contracts are a set of digitally enforced protocols that permits users to exchange money, assets, or anything of significant value in a transparent, tamper-proof, and conflict-free removing the need for intermediaries."* (Rawal et al., 2022, pg.106)

The availability of smart contracts enables the creation of so-called *decentralized applications* (DApps). These applications use a blockchain for the back-end part of their

[7]Its not anonymity because there could be made connections from a person to its public key, which reveals the identity and eliminates the anonymity.

[8]However, not all blockchain platforms have this feature implemented.

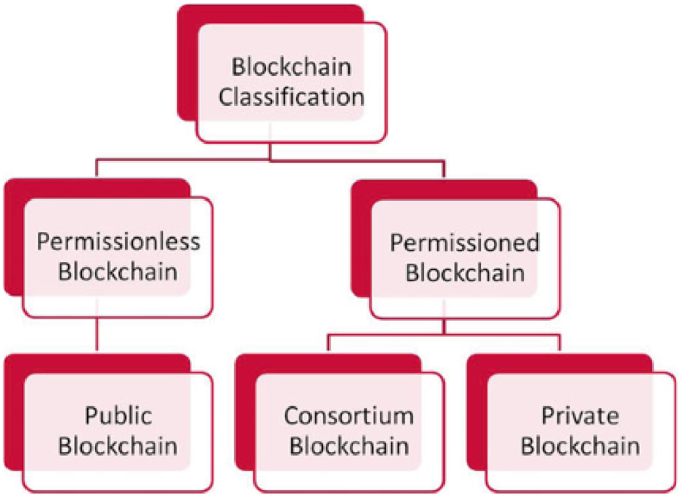


Figure 5: Schema for the classification of blockchain technologies (Rehmani, 2021, pg. 24).

code and therefore do not require a centralized server for running their code anymore (Rawal et al., 2022; Tanwar, 2022).

2.5 Classifying Blockchain Technologies

Blockchain technology can be classified either as *permissioned* or *permissionless* networks, which determines who (and how one) can participate in the network. Permissioned blockchains can be further separated into *private* and *consortium blockchains*. The permissionless blockchain is also called a *public blockchain*. This classification schema is shown in Figure 5 (Rehmani, 2021).

Whether a blockchain is designed as permissioned or permissionless plays an important role for the features that are offered by the blockchain. For example, permissioned blockchains give up on full decentralization and pseudonymity in order to create a more efficient network.

2.5.1 Public Blockchains

As already stated, public blockchains refer to permissionless blockchains. This implies that anyone can participate in the network as well as the mining/validation processes. The transaction information is available to every participant in the network. Such public blockchains are considered to be fully decentralized and distributed networks, where authority and control over the blockchain can be divided equally among all participants of the network. This effectively eliminates the need for a centralized party to govern the blockchain (Tanwar, 2022; Rehmani, 2021; Rawal et al., 2022).

Prominent examples of such blockchain types are Bitcoin and Ethereum. As introduced in Section 2.2.3, public blockchains require a consensus protocol to maintain a consistent ledger among all nodes. However, the process of achieving consensus introduced limitations on the efficiency of the network.

2.5.2 Private Blockchains

A private blockchain makes use of DLT, however, the permission to join the network can only be granted by a central authority. This central authority (often a company) has control over the level of participation of the nodes and can decide who can write and/or read transactions. Therefore, the consensus is not achieved via a consensus protocol but by the validation of transactions from the central authority (or nodes given the right to validate by the central authority). Since the central authority grants the participation rights to new participants, it knows who the new participants are, which effectively eliminates the pseudonymity of public blockchains.

Due to the limited number of participants and the fact that consensus has to be achieved, only by the central authority (and maybe a few privileged nodes), this is a very fast and efficient process, which allows a higher transaction throughput compared to public blockchains. However, this creates a single point of failure and is therefore less secure than their permissionless counterparts (Tanwar, 2022; Rawal et al., 2022).

2.5.3 Consortium Blockchains

Consortium or federate blockchains can be seen as a combination of public and private blockchain networks. It is a permissioned blockchain, thus access and participation has to be granted. However, the control over the network is not in the hands of a single central authority, like in the case of private blockchains, but rather to a group of preselected nodes. These nodes are referred to as the consortium, which holds the power to grant participation rights.

Because authority is not distributed equally among nodes, it is not a decentralized network; however, it is not as centralized as the private blockchain and is thus frequently referred to as a semi-centralized blockchain. Again, the efficiency is enhanced compared to public blockchains, but the security is not as strong since every consortium node creates a single point of failure (Tanwar, 2022).

2.6 Use-Cases for Blockchain Technologies

In this section, we want to introduce some of the different areas and applications of blockchain technology.

2.6.1 Cryptocurrencies and Tokens

As already introduced, cryptocurrencies were the first application for blockchain technology, suggested by Satoshi Nakamoto. Cryptocurrencies can be considered as the native asset of public blockchains such as Bitcoin or Ethereum. Their main purpose is to use the public ledger in order to keep track of transactions between the network's participants. Due to the adoption of smart contracts, however, blockchain platforms such as Ethereum enabled the creation of new cryptocurrencies, referred to as tokens, which can have a variety of capabilities and are built on the existing blockchain (Lantz and Cawrey, 2020).

These tokens can be categorized by their level of interchangeability. This can be defined in the following way:

> *"Fungible tokens all have the same value and are interchangeable with one another, whereas nonfungible tokens represent something that is unique."* (Lantz and Cawrey, 2020, pg.166)

Therefore, fungible tokens can be used to represent currencies with the same purpose as the native asset but without creating an entirely new blockchain network.

2.6.2 NFTs - Non fungible tokens

NFTs are not interchangeable and therefore represent a unique asset or value. This enables the application of blockchain technology for creating collectibles or for in-game assets in computer games, for example. Each token would represent one of the collectibles (e.g. digital baseball cards or an unique avatar for the game). The blockchain tracks who owns the token and can be further used to exchange the ownership of the token from one participant to another (Gray, 2021).

Furthermore, NFTs can also be used for tracking intellectual and real-world property. Tracking real-world properties benefits from the immutable and traceable nature of the blockchain and could help prevent corruption because no unauthorized changes can be made to the ledger. The participants can easily prove ownership of a property, which reduces the amount of trust required for the property exchange.

Proofing intellectual property is in general a problem when it comes to digital assets such as music (MP3), written works (PDF), or digital art (JPEG), because it is very easy to duplicate such digital files. However, using a blockchain for tracking the ownership creates an immutable source of truth about who is the rightful owner or creator of a digital asset (Gray, 2021).

2.6.3 Privacy Management

Blockchain technology (combined with zero-knowledge proofs[9]) enables the proper handling and sharing of sensitive data while maintaining privacy. An example could be found in the health care area, where individuals' medical records need to be protected while still being shared between the various parties involved. Using blockchain technology allows one to cryptographically secure information and ensure its validity, as well as expose data only to necessary parties and with the patient's permission. This ensures that the information cannot be used or exploited by third parties without the consent of the patient (Gray, 2021).

2.6.4 DeFi - Decentralized Finance

Decentralized finance refers to the ecosystem of financial services without the involvement of a centralized third party. DeFi provides the service without the use of intermediaries by utilizing blockchain technology, smart contracts, and cryptocurrency.
DeFi consists of services such as:

- lending: users borrow fiat against their cryptocurrency holdings.
- savings: users lock up cryptocurrency into a smart contract and receive a yield in the native cryptocurrency.
- derivatives: users use their cryptocurrencies to get assets like gold or other commodities.

[9]Zero-knowledge proofs (ZKP) enable that a participant can proof that she knows a secret without revealing the secret itself. While ZKP is very interesting, it is out of the scope of this thesis.

2.6.5 Tracking Goods

In the area of logistics, blockchain could be used to provide the ledger for many parties to store the transactional data concerning the exchange of a good or product. The entire path of an individual product becomes traceable and can be shared with customers or used for troubleshooting. Furthermore, the blockchain can also facilitate and track the properties of goods (e.g. temperature or weight) throughout their entire path (Gray, 2021).

This can further be combined with the Internet of Things (IoT) in order to automate the tracking process of the product and the writing process to blockchain. On the blockchain, a smart contract could be triggered to automatically perform a certain action based on the new data (Lantz and Cawrey, 2020).

2.7 Summary

In this chapter, we introduced the core principles, concepts, and workings of blockchain technology. Furthermore, we defined the features of blockchain and looked at the different types as well as some applications of the technology.

We could see that the secure and immutable nature of blockchain, combined with the ability to create complex business logic in the form of smart contracts allows for creating solutions to various problems throughout industries. The blockchain promotes a secure way of sharing data with other participants, and depending on the application, can allow for tamper-proof tracking of information.

The combination of tracking goods or states of products, the ability of securely sharing information and the possibility of automating processes with smart contracts create a technology that can potentially improve (or even disrupt) existing methods of supply chain management.

The combination of supply chain management and blockchain technology will be discussed in the following chapter.

3 Literature Review 2: Supply Chain Management

Having gained the necessary knowledge to comprehend the principles of blockchain in Chapter 2, we will now study how this technology might be utilized to improve supply chain management.

Therefore, in Section 3.1, we must introduce the reader to common definitions of supply chain management. Then, in Section 3.2, we provide a convenient model for understanding how the supply chain operates as well as the use of emerging and established technologies in supply chain management. In Section 3.3, we will analyze a case study to demonstrate how blockchain could be implemented for supply chain management and, furthermore, illustrate how blockchain could be used in different sectors of the supply chain. The last section focuses on the knowledge gap that was identified throughout our literature review.

3.1 What is Supply Chain Management?

This section is intended to introduce the reader to the fundamental concepts and definitions of *supply chain* (SC) and *supply chain management* (SCM). The following models should help the reader in evaluating the potential function of blockchain technology.

According to R. Ganeshan the supply chain can be defined as follows:

> *"A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers."* (Ganeshan, 1995, cited by Hugos, 2018)

Based on this definition, SCM can be seen as the methods, decisions, and processes that influence the workings of the supply chain:

> *"Supply chain management is the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served."* (Hugos, 2018, pg. 4)

From a SCM perspective, the various areas of the SC are regarded as a single entity, encompassing all of the involved organizations and functions. The objective of SCM is to improve customer service while simultaneously reducing operating costs throughout the entire SC. This perspective contrasts with the approach of logistics, which focuses primarily on elements that can be found and influenced within a single organization. In order to develop a more efficient SC, it is necessary to view the logistics of each member as part of and in relation to the logistics of the other participants. (Hugos, 2018).

Furthermore, SCM can be separated into five areas that represent the main drivers for the efficiency of the supply chain:

- Production
- Inventory
- Transportation
- Location
- Information

These main drivers are visualized in Figure 6. From the figure, one can also see that information connects all other areas. Thus, information has a special role because, based on the available information, organizations make decisions for the other areas as well as the overall strategy of the SC (Hugos, 2018).

3.1.1 Key Issues of modern SCs

We want to briefly present some of the key issues for SCM in modern supply chains.

As recent years have demonstrated, it is extremely difficult for SCs to remain proactive in the face of a crisis or an unexpected change in supply and/or demand. Such events are difficult to forecast, therefore demanding a highly responsive SC to maintain effectiveness during times of uncertainty. In addition, the lack of visibility and transparency in many SCs today makes it increasingly difficult for customers to verify claims made by organizations within the SC. Nevertheless, this lack of transparency is a concern not only for customers but also for the other SC members. Without accurate and timely status information, it is difficult for other organizations to make choices as well as to identify failures, weak points, and fraud in the supply chain. The final concern is the ongoing objective of making SCs more efficient. In a number of industries, such as food production, supply chains are still regarded as inefficient. For example, around 30% of all food produced worldwide is wasted. Therefore, a reduction in food waste could significantly increase the profits of the organizations within these SCs (Kshetri,

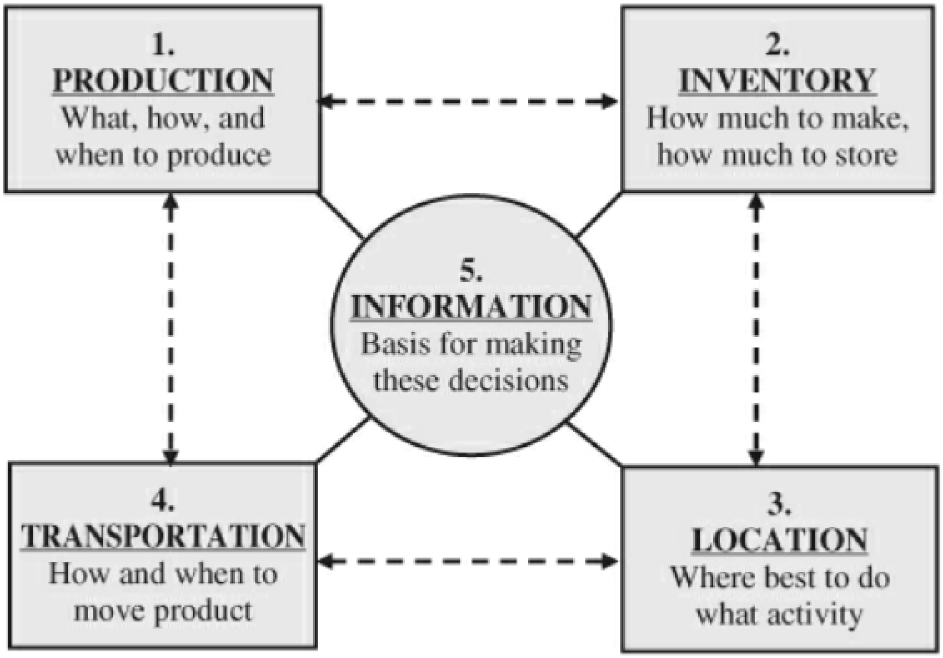


Figure 6: Key drivers of the supply chain (Hugos, 2018, pg. 17).

2021).

3.2 How does SCM work?

In this section, we want to provide the reader with the basics of how SCM works. Therefore, we present a streamlined version of the SCOR-Model (APICS, Inc., 2022). After that, we want to focus on the information area, which was defined as one of the main drivers for the SC in the previous section and explain the key technologies involved in this area.

According to (Hugos, 2018) the simplified version of SCOR consists of four categories of operations: plan, source, make, and deliver. The explanation for these categories can be seen in Table 1.

As indicated in the previous section, information serves as the foundation for all other areas. This is also true in the context of SC operations and processes. The quality and quantity of data (from which information can be derived) impacts how operations are conducted, how adaptive the execution is to current events and trends, and how quality and status of products are evaluated. Therefore, we will now discuss the most important SCM-related information technologies.

Category	Description	Activities
Planning	Covers all the operations needed to organize the other three categories.	Demand forecasting, product pricing, and inventory management
Sourcing	Covers all the operations for acquiring the necessary inputs for creating products or services.	Procurement, credit and collection.
Making	Covers all the operations involved in developing and creating the products or services.	Product design, production scheduling, and facility management
Delivering	Covers the activities for receiving orders and delivering the products to the customer.	Order management, delivery scheduling, and return processing

Table 1: Categories in the simplified SCOR Model (Hugos, 2018, pg. 41 ff.)

3.2.1 Enterprise Computing

Enterprise computing includes all software solutions created to address the needs of organizations. These may be distinct solutions for each problem or an integrated solution that incorporates multiple software solutions to create an enterprise system. Examples of enterprise software applications typically involve:

- Enterprise resource management
- Customer relationship management
- Project management
- Human resource management
- Business intelligence

Enterprise systems utilize and incorporate numerous technologies to offer value to organizations. Leveraging cloud computing, big data, AI, and the Internet of Things, they result in a higher level of SC digitalization. (Kshetri, 2021).

3.2.2 Data Transmission

Because there are various enterprise computing systems, it is necessary to establish data exchange standards between organizations. These standards are enabled by technologies such as electronic data exchange (EDI) and extensible markup language (XML).

They enable communication between different computing systems, thereby making the information accessible to the enterprise systems among all parties involved in the exchange (Hugos, 2018).

3.2.3 Internet of Things, Sensors and AI

Because of the many technological improvements and breakthroughs of the past few decades, we now live in a time when industries and organizations are quickly becoming digital.

This revolution relies heavily on the increasing availability of data. *Sensors* are devices that automatically measure the properties of physical items and, as a result, create new data. The *Internet of Things* (IoT) can be characterized as follows, based on sensors and previously introduced data exchange protocols:

> *"The IoT is the network of physical objects or "things" (e.g., machines, devices and appliances, animals, or people) embedded with electronics, software, and sensors, which are provided with unique identifiers and possess the ability to transfer data across the Web with minimal human interventions."* (Kshetri, 2021, pg. 73)

This indicates that devices can communicate and share data without the need for human involvement. On the basis of the collected data, further actions and adjustments can be initiated automatically.

Furthermore, IoT enables automatic and immediate tracking of products:

> *"One major form of the IoT is to attach radio frequency identification (RFID) tags to the target items and connect RFID reader to the Internet to identify, track, and monitor the item in real time."* (Kshetri, 2021, pg. 74)

While IoT and sensors can be seen as sources for getting data, another technology is required to make sense of the collected data. This part is often done by using *artificial intelligence* (AI), more specifically machine learning (ML). The idea is to train an algorithm or let it learn on its own from the data in order to find trends and common patterns, which can be used for predicting probable events for the future or interpreting the current status. Furthermore, AI can also be used to increase the quality of data by identifying bad data as well as statistical outliers.

3.2.4 The Role of Blockchain as a Technology in SCs

As already explained in Chapter 2, blockchain is an information technology that can be seen as a shared append-only database. In combination with smart contracts, this view can be extended to a shared computer that is able to perform complex business logic.

However, the blockchain is not considered to be the sole solution to SC's challenges. In particular, the combination of blockchain technology with other essential technologies may offer value to businesses. This will be elaborated on in the following section.

According to (Kshetri, 2021):

> *"IoT devices are key data sources that can be shared with SC participants. AI can help make sense of the data. Blockchain can keep track of the data, so that transparency and visibility can be achieved."* (Kshetri, 2021, pg. 68)

This indicates that blockchain can be the missing piece that keeps track of the data in a secure way while still enabling the sharing of data.

The application of the blockchain is determined by the data that is stored on the ledger. By using smart contracts, business operations such as payments can be automated based on the tracked data on the blockchain.

3.3 Blockchain Applications for SCM

In general, blockchain technology can be used to achieve two main goals in SCM. The first one is to lower the operational costs of the supply chain by making use of smart contracts and cryptocurrencies for business operations such as payments, procurement, and choosing new suppliers. The second purpose of BC in SCM is keeping track of product statuses and provenance in order to increase transparency and simplify auditing processes. As already stated, the tracking is very efficient and can be automated when it is combined with IoT (Rawal et al., 2022).

Because each SC is unique, different applications of BC for the SC can be developed, depending on the strategies and goals of the SCM. These goals have to be defined for each SC individually. For example, in the food supply chain, waste reduction is a big challenge. Thus, a combination of BC with IoT to track temperatures during transportation might make sense. In other industries, such us mining raw materials, provenance tracking might be very important to the companies in order to be able to prove that the materials are not from conflict areas. Due to this variety of strategies, we now want to look at how blockchain could be utilized in different areas of SCM.

3.3.1 Procurement

For improving procurement operations within a SC, blockchain might be useful in combination with cryptocurrencies as a payment method and smart contracts for automation of tasks. For example, a blockchain system used for payments might be very useful for a global supply chain because international transactions are performed very quickly and efficiently via blockchain compared to traditional banking systems.

Furthermore, blockchain can help reduce the necessary human-to-human interactions by tracking important metrics for procurement such as supplier capacities, cost of materials, or offers in the ledger. Other participants can create smart contracts based on these metrics and for example automate the choice for a supplier. This makes the SC more flexible and adaptive to supply disruptions.

A real-world example is given by BlocRice. This is a blockchain solution that uses smart contracts for negotiations and payments between Combodian small-scale rice farmers and buyers in the Netherlands. This not only ensures that farmers get paid the market price, but also makes it traceable for others. Furthermore, it stabilizes the availability of rice by reducing uncertainty for the farmers (Kshetri, 2021).

3.3.2 Auditing

Since everything that is tracked on the blockchain is immutable once it is added, this provides a single source of truth, which might be very useful for performing audits. Of course, what can be audited depends on the data that is tracked. Again, the combination with smart contracts allows for automation of such tasks.

For example, when payments are tracked, financial audits might become less complex. If provenance and locations are tracked, it might be useful to discover bottlenecks within the SC.

3.3.3 Quality Control and Risk Reduction

Using blockchain to track data about the physical properties of a product or the transportation environment can be very useful for ensuring the quality of the goods. In the event of a malfunction or a faulty product, the source can be quickly identified and the necessary actions can be taken.

As explained previously, the immutable nature of the blockchain creates a supply chain where it is easy to spot weak spots. The fact that everything can be traced back to its roots should encourage other participants to act as expected.

An example was given by the company Unilever, which started to use blockchain for its tea leaf supply chain. With their solution, they were able to reduce the costs of their supply chain and reinvest in educating the farmers. This further decreased quality issues. Furthermore, they used blockchain for tracking which gives immediate feedback that can be used for quality control as well (Kshetri, 2021).

3.3.4 Logistics

Tracking the live location of products could be achieved via the IoT, and information could be made available to other parties via blockchain. This allows for better planning and forecasting for the parties that await a product. This process could be combined with satellite imaging for verification of the locations.

For example, Maersk, the world's largest container shipping company, uses blockchain for tracking its containers all around the world. They were able to digitize most of the paperwork involved in the tracking process and store the data on the blockchain. Therefore, they drastically reduced the costs as well as created a single immutable source of truth that could be used for solving conflicts later (Kshetri, 2021).

3.4 Case Study: Renault - XCEED

3.4.1 What was the Problem?

The *Groupe Renault* was facing more and more difficulties in keeping track of all the certificates and documents required to remain in compliance with various regulations for producing cars. There are regulations for most aspects of a car, such as safety, cybersecurity, recycling, and the environment, which affect almost all of the 30 000 parts per car. As a consequence, Renault had to track millions of compliance documents across continents from hundreds of suppliers. This led to maintaining huge databases and following paper trails, which created enormous workloads but still lacked transparency and the sharing of information between participants (IBM, 2021).

3.4.2 Finding a Solution

The company discovered that *"the need for real-time information exchange, transparency and traceability will be exponential in the coming years"* (Le-Boucher, 2021) and started to explore blockchain technology as early as 2015. They realized that:

> *"The distributed ledger technology makes it possible to share and track information across various users. Permissions control access and visibility, so each party maintains confidentiality of its data. And users and transactions are verified and preserved by the blockchain. This creates a network of trust between participants, even if they don't know one another (...)"* (IBM, 2021),

and concluded, that implementing blockchain in their SCM enables real-time certification of compliance to partners, customers and regulators.

Together with IBM, they created the basis for the "*eXtended Compliance End-to-End Distribution*" (XCEED) blockchain solution. It was tested in 2019 and can today be considered as the first industrial-scale blockchain project in automotive (Le-Boucher, 2021).

3.4.3 The Solution

XCEED is created on the Hyperledger Blockchain and enables the certification of "*the conformity of vehicle components from design to production by creating a trusted network for sharing compliance information between parts manufacturers, throughout the supply chain to vehicle manufacturers*" (Le-Boucher, 2021).

The solution incorporates artificial intelligence and big data management in order to increase efficiency of the supply chain. They expect to increase productivity by at least 15% while decreasing costs by 10% and minimizing the non-compliance problems . An intriguing aspect of XCEED's approach is that they not only enable SMEs participation and use of their tool, but they also share the technology with their competitors. Their goal is to create a new basis for the entire automotive industry, based on trust and collaboration, in order to stay reactive and robust as an industry. They expect to keep improving upon this new basis in the future, by continuously adding features for their blockchain solution for SCM (Le-Boucher, 2021).

Nr.	BC enabled Benefit	Explanation
B1	Increase Digitization	Blockchain can help to digitize communication, contract negotiation, and other processes between supply chain members. This reduces the need for paperwork and the physical exchange of documents between parties.
B2	Secure Data Storage	Blockchain technology provides an efficient tool for storing data and files in a secure and immutable manner. This effectively creates a single source of truth for SC processes.
B3	Increase Transparency and Visibility	Data stored on a blockchain can be shared more easily between members of a blockchain network or with third parties. This creates a transparent system for exchanging information within and about a supply chain.
B4	Increased Traceability	If the relevant information is stored on a blockchain, it makes it possible to track products along their entire journey through the supply chain.
B5	Efficient Transaction Processing	Blockchain technology can be used to make payments by utilizing cryptocurrencies. Compared to traditional payment methods, this decreases transaction costs and increases the speed of settlement for international payments.
B6	Increase Security	Due to the DLT architecture, the cryptographic methods, and the decreased human involvement in blockchain applications for SCM, errors can be reduced and cybersecurity increased.
B7	Auditability	Based on the data storage and traceability of blockchains, this provides a trustable base for performing audits. Consequently, audits can be performed faster and more efficiently.
B8	Identity Management	Blockchain technology can be used for validating and ensuring the digital identities of the supply chain members. This increases the trust between the participants of a blockchain-based SCM application.

Table 2: Blockchain enabled Benefits for SCM, based on (Kshetri, 2021; Sharma and Shishodia, 2022)

3.5 Benefits of Blockchain Technology in SCM

In this section, we want to summarize the benefits that could be achieved by the use of blockchain technology for supply chain management. These were already illustrated in Section 3.3 and are based on the technological features of the blockchain (see Section 2.4). However, we want to summarize them in this section more clearly in order to answer Research Question 1.

Therefore, we identified benefits for SCM that are enabled by blockchain technology. These benefits and the corresponding explanations are shown in Table 2. In Table 3, we connect the benefits of blockchain technology for SCM to different SC objectives and explain how blockchain can help reach these goals.

SC Objective	**Explanation**	**Connected Benefits**
Reducing Costs	Blockchain allows for transactions and audits to be performed at lower costs. Digitization and automation enable further cost reduction in SCM.	B1, B5, B7
Assuring Quality	The traceability and auditability of blockchain technology enable organizations to quickly identify the roots of faulty or counterfeit products. As a result, it is easier to hold SC participants accountable for their actions, which should increase the quality.	B4, B7
Increasing Speed	International transactions and audits can be performed faster due to the blockchain. Furthermore, the reduction in human-to-human communication accelerates overall process speed. Based on a single source of truth, it is easier, and therefore faster, to settle problems.	B1, B2, B5, B7
Increasing Dependability	Based on the single source of truth and the traceability of products in blockchain applications for SCM, it is easier to exert pressure on SC members to be more responsible about their actions.	B2, B4
Reducing Risks	The identity management in blockchain applications allows only trusted parties to gain access to the network. Furthermore, files stored on the blockchain can be checked for unauthorized changes.	B2, B8
Increasing Sustainable Practices	Due to the increased visibility of processes within a SC, it becomes easier for third parties to verify claims about the sustainability of a product.	B3, B4
Increasing Flexibility	Due to the auditability, traceability, and transparency, it becomes easier to identify problems earlier and react accordingly. Furthermore, the increased speed of blockchain-based operations allows for faster and more effective responses to changes.	B3, B4, B7

Table 3: Table about blockchain technology can help to achieve SC objectives.

At this point, it should be mentioned that the benefits apply not only for the individual organization but rather for the entire supply chain. However, the organization that develops the blockchain solution is in charge of the purpose and, as a consequence, on the desired benefits. Therefore, the benefits, even though enabled for the entire supply chain, might not be equally important to all SC participants.

3.6 Gap of Knowledge 1 - Role of SMEs in BC adoption for SCM

After conducting the initial literature review for this thesis, we were able to recognize that the amount of implementations, research papers, and case studies related to blockchain technology for supply chain management is notably higher than in other application areas. We suppose this is due to the alignment of difficulties in modern supply chains (see Section 3.1.1) and the features blockchain can provide (see Section 2.4).

The majority of the case studies we analyzed throughout our literature review focused on solutions implemented by large organizations or industry consortiums. However, to achieve a valuable blockchain solution for SCM, all supply chain partners must participate in the blockchain network (Lanzini et al., 2021). Oftentimes, large businesses possess the necessary influence over their supply chain and can impose their solutions on their suppliers. Of course, the solutions should ultimately benefit the entire supply chain.

Consequently, two roles exist for SMEs in this potential SCM revolution. On the one hand, SMEs could benefit from blockchain technology for SCM by adopting a solution developed by a larger organization within their SC. On the other hand, they could create their own supply chain solutions. Due to the fact that SMEs often lack resources and control over their supply chain partners (Lanzini et al., 2021), this creates to two very distinct scenarios for the adoption of blockchain technologies for SCM for SMEs.

The difference between these roles for SMEs was identified as a knowledge gap in existing research. We intend to assist in bridging this gap by using technology adoption theory, the subject of the following chapter, for the study of blockchain technology adoption for SCM. The thesis' Research Questions 2 and 3 address this knowledge gap.

3.7 Summary

We began this chapter with an explanation of what the supply chain and the management thereof is. We outlined the relevant areas and noted some of the current SCM issues. As we've seen, information is a unique component of SCM because it serves as the basis for making decisions in the other areas. Thus, we discussed numerous information technologies and the function that blockchain technology plays in this ecosystem. We went on to discuss other SCM activities and how blockchain may be used to enhance them. Then, in order to demonstrate what a real-world use of BC in SCM looks like, we looked at Groupe Renault's blockchain solution for increasing the effectiveness of their supply chain. In Section 3.5 we summarized the possible benefits of blockchain technology for SCM.

The final section built on the earlier chapters and described the areas where our literature review revealed a knowledge gap. This creates the framework for the research questions and the chapters that follow.

4 Blockchain Technology Adoption

In this chapter, we want to introduce readers to the theoretical framework used for the empirical part of this thesis. Based on the background explained in chapters 2 and 3 about blockchain technology and its application in supply chain management, we want to argue in this chapter that a different approach to exploring blockchain technology adoption might be required in order to better understand the adoption of blockchain technology in supply chain management for small and medium-sized enterprises.

Therefore, we start this chapter with explaining the theoretic background of adoption theory in Section 4.1. The *technology-organization-environment* (TOE) framework and the *neo-institutional theory* (NIT) will be the focus of our discussion.

We continue in Section 4.2 with reviewing existing literature about blockchain adoption in supply chain management. The aim of this section is to present to the reader the findings and adoption frameworks of previous studies and explain how these relate to our work. Furthermore, we would like to highlight the shortcomings of current research and the reasons why a different approach may be required.

In Section 4.3, we develop our framework for exploring blockchain adoption in SCM for SMEs. This section can be seen as a synthesis of the previous chapters and the arguments presented in this chapter. Furthermore, we present our hypotheses for the further research of this thesis.

4.1 Adoption Theory

In this section, we introduce the reader to the basics of technology adoption theory.

The goal of technology adoption theory is to develop frameworks and models that increase the understanding of how and why new technologies are accepted or neglected by their users. Many frameworks for technology adoption have already been created. They primarily differ in the factors they consider as influences for technology adoption decisions. Furthermore, the models can be differentiated based on whether they explore adoption at an individual, group, firm, or industry level (Oliveira and Martins, 2011; Kühn et al., 2019).

Prominent frameworks are the *Technology Adoption Model* (TAM) (Davis, 1989), the *unified theory of acceptance and use of technology* (UTAUT) (Venkatesh et al., 2003),

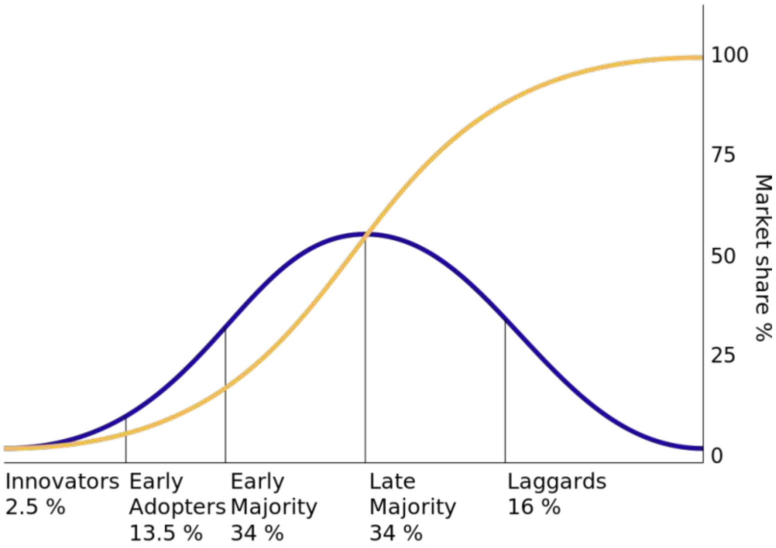


Figure 7: Classification of organizations based on the time of adopting a new technology (Rogers, 1983, retrieved from (Wikipedia, 2023)).

the *diffusion of innovations* (DOI) (Rogers, 1983), and the *technology-environment-organization model* (TOE) (Tornatzky et al., 1990). However, from these frameworks, we will mainly focus on TOE because, in contrast to TAM and UTAUT, it focuses on the firm level and not the individual level (Oliveira and Martins, 2011), which is more relevant for the intentions of this thesis. Furthermore, TOE is also consistent with the DOI framework (Oliveira and Martins, 2011), and therefore we will only explain some relevant ideas of Rogers and dive deeper into TOE in Section 4.1.1.

Rogers argued that the innovation adoption process is normally distributed. Dividing the curve into five segments allows us to classify firms based on the time they decide to adopt a new technology. This is illustrated in Figure 7. Furthermore, Rogers divides the decision to adopt an innovation into five steps (Rogers, 2003):

- Knowledge Phase
- Persuasion Phase
- Decision Phase
- Implementation Phase
- Confirmation Phase

For our thesis, the relevant phases are the knowledge phase, in which a person or firm becomes aware of an innovation and gains some understanding of how it works, and the persuasion phase, in which the user forms an attitude towards the technology (Kühn et al., 2019).

Since blockchain technology is an information technology, these frameworks are applicable for understanding the adoption of this technology, and several studies have already been conducted. We will have a closer look at the existing research in Section 4.2 and present its findings there.

However, this thesis focuses on the application of blockchain technology for supply chain management. As we have seen in Section 3.3, these types of blockchain solutions require the entire supply chain to collaborate and participate in order for them to work. Therefore, the technology can be seen as an inter-organizational system (IOS). Consequently, we will argue in Section 4.3 that the TOE framework, which focuses on the firm level, can be considered a micro-level analysis in the context of supply chain management. When the role of SMEs in the supply chain is considered, it becomes clear that a macro-level framework focusing on the structure of the supply chain itself may be more appropriate for understanding technology adoption. As a consequence, we want to introduce in Section 4.1.2 the neo-institutional theory for technology adoption and later on include it in our framework.

4.1.1 TOE

The technology-organization-environment (TOE) framework is a theoretical model for studying the adoption of an innovation at the organizational level and was initially described by Tornatzky and Fleischer in 1990. They analyzed the entire innovation process, from the early stages of innovation creation up to the adoption of the innovation by users.

This theoretical framework for technology adoption is based on the three contexts that influence an organization's decision to adopt a new technology (Tornatzky et al., 1990):

- Technology: The benefits and costs of a new technology, as well as how it works and what it can do, play a major role in shaping technology adoption decisions.
- Organization: Technology adoption is also affected by how the organization works on the inside, including its goals, values, culture, and resources.
- Environment: External factors like industry norms, pressures from regulators, and the influence of other organizations also affect decisions about when and how to use new technologies.

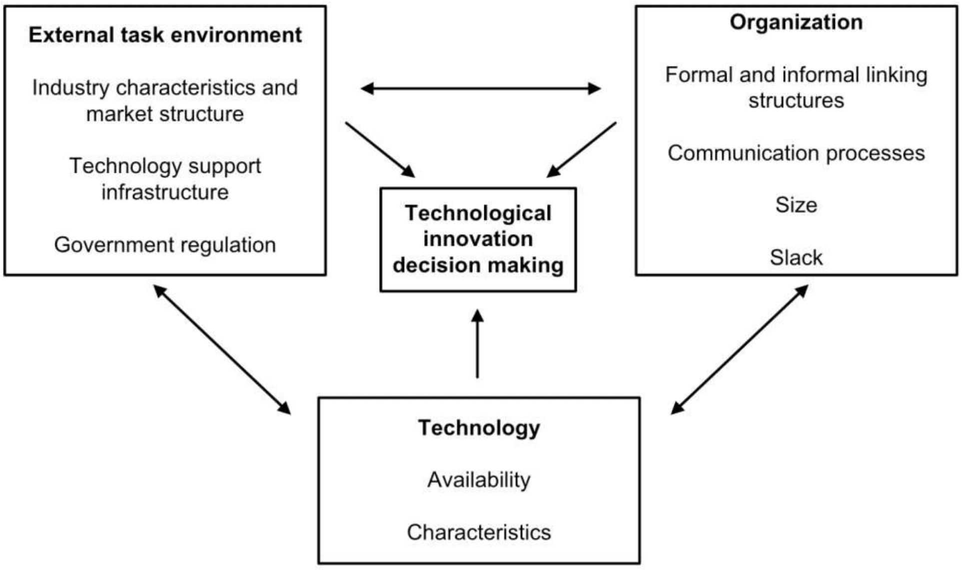


Figure 8: Illustration of the TOE adoption framework (Oliveira and Martins, 2011).

This framework is illustrated in Figure 8. As already mentioned, the TOE framework extends the DOI framework by also taking the organization's environment into account (Oliveira and Martins, 2011).

While the original TOE framework specifies the three contexts for studying the adoption of a new technology, it doesn't necessarily limit the subcategories of these contexts. Therefore, the factors can vary for different studies depending on the technology and focus of the research[10]. This is also one of the reasons why it is one of the most commonly used frameworks for understanding blockchain technology adoption, as we are going to see in Section 4.2.

4.1.2 NIT

The *new-* or *neo-institutional theory* (NIT) was first established by Meyer and Rowan in 1977 (Meyer and Rowan, 1977) and expanded by DiMaggio and Powell in 1983 (DiMaggio and Powell, 1983). It builds upon Selznick's *old-institutional theory*, which was first developed in 1949, and extends it by providing the processes that lead to organizational change (Selznick, 1996).

Organizations, according to institutional theory, can be viewed as social constructions that are influenced by the environment in which they operate. Consequently, "*orga-*

[10]For examples see (Oliveira and Martins, 2011).

nizational decisions are not driven purely by rational goals of efficiency, but also by social and cultural factors and concerns for legitimacy." (Oliveira and Martins, 2011, pg. 116) As a result, organizational change can be seen as the consequence of processes that make organizations more similar to each other. The concept of isomorphism best describes this process of organizational homogenization. Institutional isomorphic change can be separated into three mechanisms: coercive isomorphism, mimetic isomorphism and normative isomorphism (DiMaggio and Powell, 1983).

Coercive isomorphism covers all types of formal and informal pressures placed on an organization by other organizations upon which it depends. Furthermore, DiMaggio and Powell stated that cultural expectations and a common legal environment could lead to coercive isomorphic change. This also includes standards for the operational processes of an industry or organization. Mimetic isomorphism describes the process of an organization imitating the innovations and solutions of other organizations. One of the main forces leading to this type of imitation is uncertainty. If the uncertainty of an innovation is high, organizations tend to model their solutions based on other successful implementations in order to save resources and limit their own risks. Normative isomorphism is associated with the professionalization of employees. According to DiMaggio and Powell, the two most important aspects of professionalization are formal education and professional networks that spread new ideas across professions. Consequently, similar roles in different organizations have the same educational background and are confronted with the same ideas through their networks (DiMaggio and Powell, 1983).

The NIT creates a very broad framework for understanding why organizations are becoming more and more similar over time. This model is not limited to technology adoption but can be used for all types of procedures in an organizational context. Nevertheless, it proved to be useful for studying technology adoption (Oliveira and Martins, 2011).

The TOE and NIT frameworks for technology adoption have several similarities since they both view the environment of an organization as an important influence on adoption decisions. However, the neo-institutional theory places even more focus on the social, political, and economic context, which allows it to be used on a broader scale beyond the organizational level.

DiMaggio and Powell described this broader level as the organizational field of an organization in the following way:

> *"By organizational field,-we mean those organizations that, in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products."* (DiMaggio and Powell, 1983, pg.145)

Thus, this field contains all relevant actors for an organization, and the structure of an organizational field cannot be defined in general but has to be studied individually for a given scenario. According to DiMaggio, this process of defining such an organizational field consists of four parts (DiMaggio and Powell, 1983):

- The extend of interaction
- The definition of inter-organizational structures
- The information load between the organizations within a field
- The development of a mutual awareness

Within these types of fields, the early adopters of new technologies want to improve their performance via innovation. However, over time, these innovations spread throughout the entire organizational field due to the mechanisms of isomorphism (DiMaggio and Powell, 1983).

Finally, we want to present some of the hypotheses from DiMaggio and Powell about organizations, organizational fields, and the influences that lead to an increase in isomorphic change (DiMaggio and Powell, 1983, pg.154 ff.):

> **H 1.** *"The greater the dependence of an organization on another organization, the more similar it will become to that organization in structure, climate, and behavioral focus."*
>
> **H 2.** *"The greater the extent to which an organizational field is dependent upon a single (or several similar) source of support for vital resources, the higher the level of isomorphism."*
>
> **H 3.** *"The greater the extent to which technologies are uncertain or goals are ambiguous within afield, the greater the rate of isomorphic change."*

4.2 Existing Literature: Blockchain Technology Adoption

In this section, we want to look at existing research that has already been conducted and is useful for understanding blockchain adoption in the field of supply chain management. Over the past years, many studies about blockchain technology adoption have been performed, which indicates the growing importance of this topic. However, only a few of them are generalizable and provide value outside of the scope of their study. The rapid changes and developments in the field of blockchain technology, in particular, can be problematic for such studies. Therefore, we tried to prioritize recent research. At first, we want to elaborate on two systematic literature review studies from 2022 that summarize many of the studies that have been performed so far. Following that, we'd like to look at specific studies that focused on SMEs' adoption of blockchain technology.

In "*A Critical Review of Blockchain Acceptance Models—Blockchain Technology Adoption Frameworks and Applications*" by Hamed Taherdoost, he analyzes 56 studies about blockchain adoption and tries to identify the most common adoption frameworks used in these studies. Furthermore, the review analyzed the sectors in which these studies have been performed. This work is interesting in the context of this thesis since it looks at blockchain adoption in general but also analyzes the field of supply chain individually. Taherdoost concluded that supply chain and other industry fields were the most studied application areas of blockchain technology adoption. Furthermore, he showed that the TAM and TOE frameworks were the most commonly used for studying blockchain adoption. The TOE framework was either used on its own or extended with other models (Taherdoost, 2022).

Another interesting literature review was performed by AlShamsi et al. From 902 articles about blockchain adoption, they analyzed 30 eligible ones according to their quality assessment criteria. They came to similar conclusions about the used frameworks and the sectors as Taherdoost did, namely that TOE was the most used framework for examining adoption on the organizational level as well as that supply chain management is the main domain for these studies. However, they also looked at the methods used in the studies and identified that over three quarters of all studies used surveys as their main method for studying blockchain adoption. Furthermore, AlShamsi et al. listed the factors illustrated in Figure 9 as the most frequent external factors identified in the studies for influencing blockchain adoption decisions (AlShamsi et al., 2022).

While the two literature reviews mentioned above provide a great overview of the field

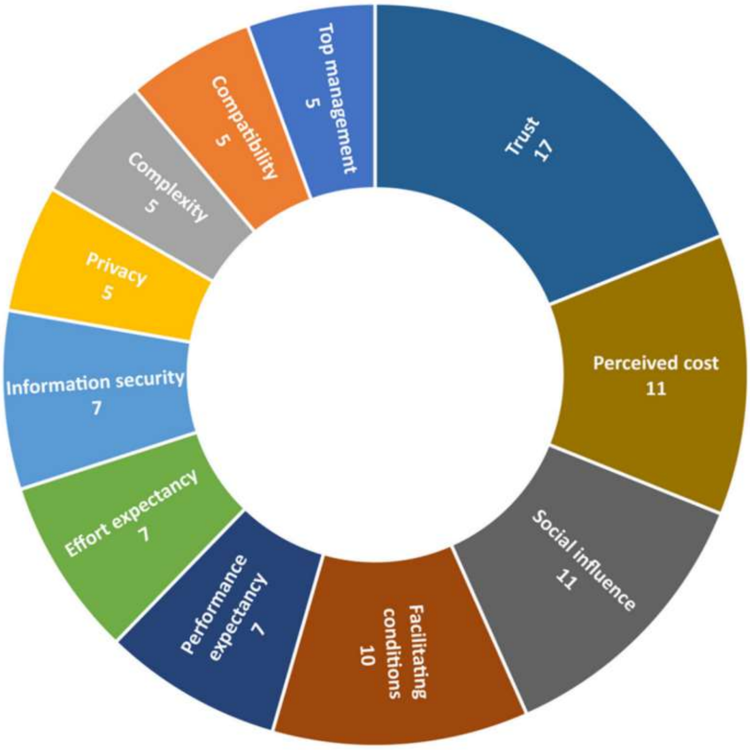
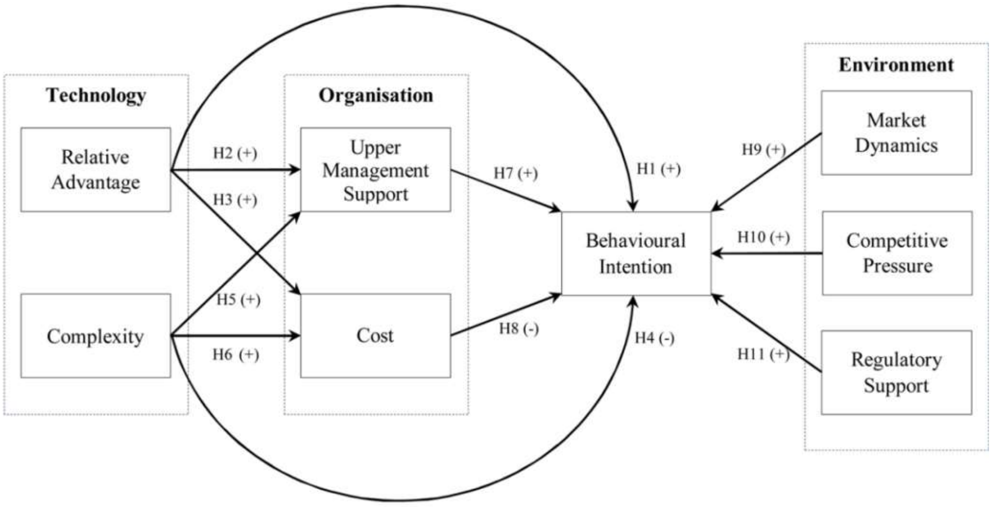


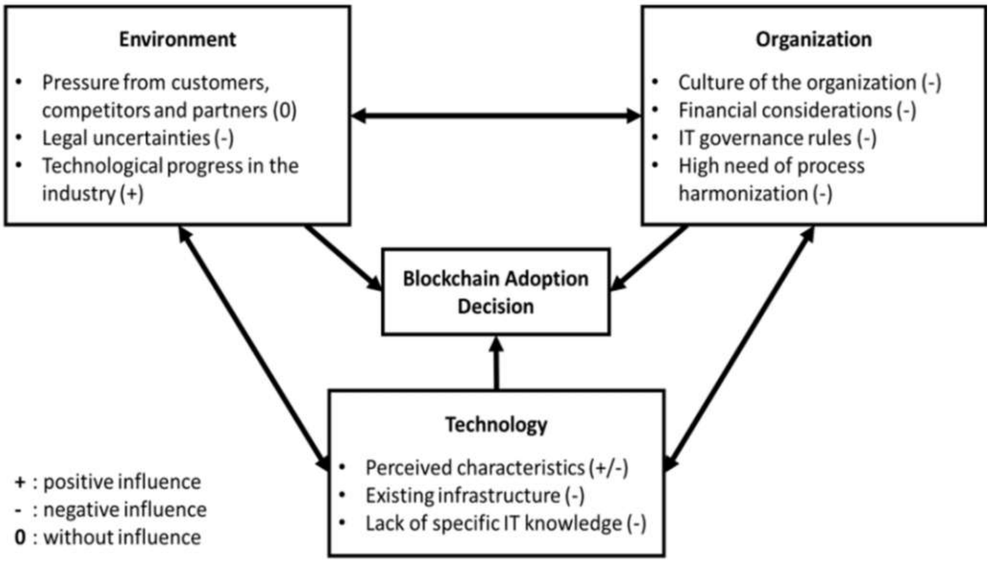
Figure 9: Common blockchain adoption factors (AlShamsi et al., 2022)

of blockchain adoption, the role of SMEs is not explicitly mentioned by them, and there is no differentiation between the various sizes of enterprises within the supply chains. Therefore, we now want to provide a brief overview of studies that focused on the blockchain adoption of SMEs.

Lanzini et al. conducted a blockchain adoption study for SMEs in Europe, with a focus on Italy and the Netherlands in 2021. They used the TOE framework and the survey approach to analyze the future intentions of SMEs to use blockchain technology and identified that SMEs are primarily influenced by organizational factors rather than environmental or technological factors. Therefore, SMEs are best supported by increasing the blockchain knowledge of senior executives and showing the organizational benefits of blockchain technology (Lanzini et al., 2021). Another study that focused on SMEs in Italy was performed by Bracci et al. in 2021. Contrary to Lanzini et al., they used the TAM framework for understanding adoption behavior. Their findings are consistent with those of Lanzini et al., who conclude that there is a link between the low adoption rate of blockchain technology in SMEs and knowledge of the technology (Bracci et al., 2021). A similar study, which also used the TOE framework, was performed by Wong et al. for the Malaysian area in 2020. However, their findings are seemingly in conflict with Lanzini et al. because they concluded that the influence of upper management support is insignificant compared to competitive pressure, com-



(a) Framework used by (Wong et al., 2020).



(b) Framework used by (Kühn et al., 2019).

Figure 10: TOE frameworks and factors used for blockchain adoption studies at SMEs.

plexity, cost, and the relative advantage of the technology (Wong et al., 2020). Their framework is illustrated in Figure 10a. The fourth study we were able to identify was from Kühn et al. and focused on the blockchain adoption of German logistics providers in 2019. Since their work didn't look at SMEs only, they were able to compare SMEs with larger logistic providers and came to the conclusion that smaller enterprises are less interested in and involved in the adoption of blockchain technology so far (Kühn et al., 2019). They used the TOE framework, which is shown in Figure 10b, in order to identify relevant adoption factors.

To summarize, all of the papers that focused on blockchain adoption of SMEs, mentioned, that this field is very little researched so far and that further research has to be performed. The fact that their findings are not particularly aligned, could be based on cultural differences of the different regions as well as differences in the years in which the research was performed. Nevertheless, this research indicates the importance of knowledge about the blockchain technology as well as an influence of competitive pressure on the adoption decison.

4.3 Developing our Framework

4.3.1 Gap of Knowledge 2: Why we need a different approach for studying blockchain adoption?

According to Bracci et al.:

> *"The adoption of blockchain is defined as the process of accepting and implementing blockchain technology to deliver services and enhance managerial processes."* (Bracci et al., 2021, pg. 1.389)

From this definition of blockchain technology adoption, we can conclude that there exist different scenarios of how SMEs could adopt blockchain technology for supply chain management. These scenarios can be classified by who develops the blockchain solution. Up until now, most of the solutions have been developed by large enterprises or industry consortiums (Lanzini et al., 2021). Another approach would be for several organizations within a supply chain to collaborate on finding a blockchain solution. The last scenario for SMEs to implement blockchain technology would be to develop their own solution.

Independently of who develops the blockchain solution, in order for the supply chain to profit from the technology, it has to be used by all participants involved in the process of interest (Lanzini et al., 2021). As a result, the role of SMEs varies depending on the scenario described above. On the one hand, if the solution is not developed by the SME itself, it has to at least participate in the blockchain network in order to adopt the technology. On the other hand, if a SME develops a blockchain solution itself, other members of the supply chain have to participate in order for the solution to be beneficial. Each of these scenarios comes with different factors and influences that have to be considered when analyzing blockchain adoption decisions. To the best of our knowledge, there are no studies that take these different scenarios into account. We assume that one reason for this is that for larger enterprises, which have been the main subject of research so far, this is not as important as it is for SMEs. The reason for this is that large enterprises have more financial resources than SMEs, as well as more power and control over their supply chain, so they do not have to worry about other supply chain members not participating. However, since many SMEs lack exactly these resources, it might be significantly more difficult for them to implement their own solutions. Consequently, we argue that the different scenarios for adopting blockchain technology, which mainly depend on the structure of the supply chain of a SME, have a high impact on the adoption decision.

Another reason why we decided to create a new framework is that blockchain technology, and especially its application in SCM, can be considered an IOS. The adoption of such systems is very difficult since they need to be adopted beyond the borders of a single organization. We already explained that in order for a blockchain solution to prove useful, all supply chain members need to participate. This creates an interorganizational environment for the adoption of the new technology. Consequently, the unit of analysis for blockchain adoption studies in SCM should also be the entire supply chain. However, previous studies about this topic have mostly used factor approaches that focused on the organizational level and tried to explain the broader level mainly via the critical mass effect (Kurnia and Johnston, 2000).

All of the studies about the adoption of blockchain technology that we have identified used this factor approach, where they assumed that technology adoption is determined by various factors, depending mainly on the framework they used. However, such studies are unable to capture the complex and dynamic relationships among individual organizations (Kurnia and Johnston, 2000). The factor approach is attractive for research studies since it allows for statistical testing and fits the purpose of surveys, which have been the main method as explained in Section 4.2. Furthermore, they assume that all of the factors are external, which contradicts the intentions of modern supply chain management, which aims for higher collaboration between supply chain members in order to increase efficiency. From the Renault case study (see 3.4), we can see that they are willing to share their solution throughout the entire automotive industry. This willingness for collaboration changes the scenario for blockchain adoption for an entire industry. As elaborated above, such changes to the adoption scenario have a lot of influence on the adoption decisions of other organizations. However, such events could hardly be captured using the factor approach.

To summarize, we argue that different scenarios for who develops a solution and shares it with others have a lot of influence on the adoption decisions of other organizations. However, such scenarios can only be identified if the unit of analysis goes beyond the organizational level and focuses on the entire supply chain or even entire industries. Consequently, the factor approach, which has been the dominant research method so far, is not suitable to capture all of these effects, and therefore a different approach is required.

4.3.2 What is our framework?

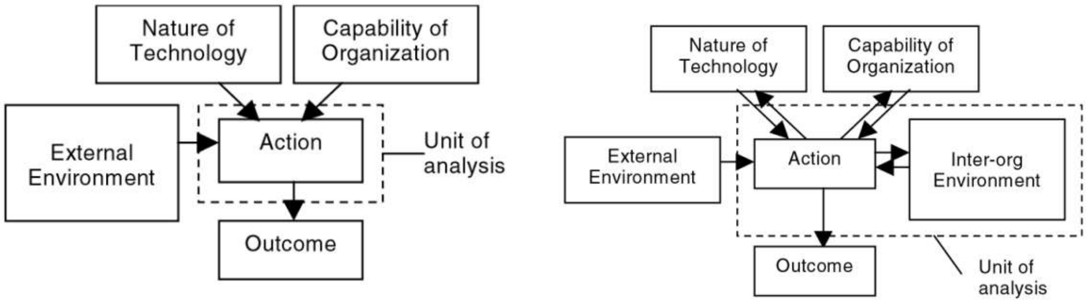
For our framework, we want to adapt the ideas from Kurnia and Johnston. They created a *processual approach* for studying the adoption of IOSs for electronic commerce in Australia. As illustrated in Figure 11, Kurina and Johnston moved from a typical factor towards a processual approach. Their idea is that organizations exercise a certain amount of influence over their environment, and consequently, some of the influences of the environment cannot be considered to be completely external anymore. Furthermore, they argue that by moving to the pocessual approach:

> *"Now, not only are actions of an organization mediated by the nature of the technology factors, its capability factors, and environmental factors, but these factors are themselves altered by mutual interactions of the focal firm with its inter-organizational environment."* (Kurnia and Johnston, 2000, pg. 5)

This describes the situation we face with the adoption of blockchain technology for SCM in SMEs very well. A change in the adoption scenario, e.g., a large industry or supply chain member developing a blockchain solution, which would be considered an influence on the inter-organizational environment, alters the factors of the nature of the technology. In this example, the factors that would be altered could be the costs, the knowledge requirements, the participation of other supply chain members, and so on. However, due to interactions between the variables in this framework, it is hard to be evaluated by statistical methods and requires a more in-depth interpretative research method (Kurnia and Johnston, 2000).

We suggest a framework based on TOE and NIT as a way to understand the results. TOE should be used for interpreting external factors related to technology, organization, and environment. The NIT provides the framework for analyzing the relations and influences within the inter-organizational field. For the scope of this thesis, we will focus on the latter part, in order to verify the importance of changing the unit of analysis and switching to the suggested processual approach.

This approach is aligned with Oliveira and Martins suggestion that *" (...) in terms of further research, we think that for more complex new technology adoption it is important to combine more than one theoretical model to achieve a better understanding of*



(a) Factor Approach

(b) Processual Approach

Figure 11: Illustration of how the framework changes when moving from a factor approach to a process approach and using the inter-organizational environment as the unit of analysis. This allows for evaluating the interactions between an organization and its environment as well as how these influence the adoption decision for blockchain technology in SCM (Kurnia and Johnston, 2000).

the IT adoption phenomenon" (Oliveira and Martins, 2011, pg. 11), as well as Kurnia and Johnston, who *"advocate the use of both factor and processual approaches in a complementary way to give a better total understanding of adoption of inter-organizational systems"* (Kurnia and Johnston, 2000, pg. 6).

In this framework, we want to use NIT to identify the inter-organizational environment as the organizational field, as described by DiMaggio and Powell in Section 4.1.2. As explained earlier, the organizational field includes key suppliers, consumers, regulatory agencies, and other organizations from the industry. Nevertheless, this is aligned with our approach of considering the supply chain as the unit of analysis since modern supply chain management tries to involve all of these parties in their operations, as explained in Section 3.

4.3.3 Hypotheses

In this section, we want to summarize the main points that led to our research approach, which is based on the processual approach from (Kurnia and Johnston, 2000) and the NIT, and we want to write them down as hypotheses that can be tested empirically later.

Based on the assumption that there exist different adoption scenarios for SMEs, we argue that the barriers for SMEs to adopting blockchain technology are much lower if the solution is developed by another organization or consortium of organizations. This is a logical conclusion, since major barriers for SMEs are cost and development-related, as was identified by previous research (see Section 4.2). Consequently, our first hypothesis is the following:

Hypothesis 1. *SMEs are more likely to participate in a blockchain solution developed by other industry or supply chain organizations, than to develop their own solution.*

We already argued that which adoption scenario is relevant for a SME mainly depends on the structure and the participants of the supply chain. Therefore, as a consequence of the first hypothesis, what follows is:

Hypothesis 2. *The structure and participants of the supply chain of a SME, have the highest influence on the adoption decision of blockchain technology for supply chain management for SMEs.*

These two hypotheses are aligned with DiMaggio and Powell's Hypotheses 1 and 2 about isomorphic change, as explained in Section 4.1.2. These hypotheses state that the greater an organization's or organizational field's reliance on key players, the greater the rate of isomorphic change. The rate of isomorphic change in our context can be seen as the rate of blockchain adoption. So far, large organizations, which act as key players, have been the main developers of blockchain solutions. As a result, the presence of such actors in a SME's supply chain increases the likelihood of implementation because they have the necessary power over the supply chain to entice other organizations to participate, thereby increasing the homogenization of the entire supply chain, as theorized by the NIT.

Our third hypothesis focuses on SMEs in Austria, where we assume, based on the results of similar research studies in other regions (see Section 4.2), that:

Hypothesis 3. *Austrian SMEs are mainly in the knowledge or persuasion phase of blockchain adoption.*

A lower level of knowledge is associated with greater uncertainty about a technology. DiMaggio and Powell's Hypothesis 3 explains that in cases of higher uncertainty, the level of isomorphic change increases. On the one hand, this further strengthens our first hypothesis that SMEs are more likely to behave similarly to other key players and participate in their blockchain solutions. On the other hand, it raises the question of what happens if there are no such key players in the organizational field of a SME. This indicates a risk for SMEs of falling behind in blockchain adoption, which may necessitate specific actions by the Austrian government to compensate. We will further investigate this topic in Chapter 7.

5 Methodology

In this chapter, we want to elaborate on the empirical methods used for this thesis. The goal of the empirical part of the study consists, on the one hand, of testing the hypotheses formulated in Section 4.3.3, and, on the other hand, of finding answers to the research questions introduced in Section 1.4.

As a reminder, the research questions are shown in Table 4. While RQ1 is a question about the benefits of blockchain technology for SCM in general, which is answered in Section 3.5, all other questions are focusing on the situation of blockchain adoption for SCM in Austria. Since RQ1 can be answered based on the literature reviews in Chapters 2 and 3, the design of our research study will focus on giving insights towards RQ2, RQ3, and RQ4. RQ5 should be answered based on the conclusions drawn from the findings about the other research questions.

Besides answering the research questions, we also want to test our hypotheses, which are based on previous studies and the technology adoption theory. While the hypotheses are in principle aligned with the research questions, Hypotheses 1 and 2 tend to focus more on validating the assumptions we made for developing our approach towards studying blockchain adoption for SCM. Only Hypothesis 3 is directly related to the research questions, as it is concerned with the situation for blockchain adoption in SCM in Austria.

Abbreviation	**Research Question**
RQ1	*What are the benefits of blockchain technology for supply chain management?*
RQ2	*What is the present state and future ambition of Austrian organizations regarding the adoption of blockchain for supply chain management?*
RQ3	*How does the adoption-process of blockchain technology for supply chain management differ for Austrian SMEs compared to larger organizations?*
RQ4	*What are the difficulties, enablers and barriers for blockchain adoption for supply chain management for Austrian organizations?*
RQ5	*What calls-for-action, in the context of blockchain adoption for supply chain management, can be made for policymakers and organizations in Austria?*

Table 4: Research Questions

5.1 Research Design

For testing our framework and answering the research questions, we decided to use guided interviews with employees in management positions of five Austrian companies in order to gain insights concerning the current situation of blockchain adoption for SCM. Therefore, we tried to evaluate the level of knowledge, the current situation, future intentions, barriers, and enablers for the adoption process of blockchain technology for SCM in Austrian organizations.

Due to the scope and timeframe of this thesis, it was only possible to perform a preliminary study, consisting of a handful of interviews, with the goal of validating our framework and getting indications for the problems and barriers faced by Austrian organizations in the process of adopting blockchain technology for SCM. However, further and especially broader research about this topic will be required and should be performed in the future.

Also, based on the short timeframe and the low number of participants in the study, we decided to use a qualitative research approach. This is aligned with suggestions from AlShamsi et al., which stated that *"(...) it is suggested that further research [about blockchain adoption] would consider the mixed-research approach by involving interviews or focus groups."*(AlShamsi et al., 2022, pg.10) Qualitative research can provide a more in-depth understanding than the common approach of using surveys to study blockchain adoption (AlShamsi et al., 2022). Furthermore, for using our processual approach to technology adoption, an interpretative research method is better suited than the use of statistical methods (Kurnia and Johnston, 2000).

As already mentioned, we want to use our framework based on NIT and TOE for interpreting the findings of the interviews and gaining new insights. Therefore, the interview should be analyzed thematically and interpreted accordingly in order to generate valuable findings and directions for future studies. The design of the interview questions was based on our framework for blockchain adoption, described in Section 4.3. However, testing the entire framework, which would have required studying the external factors in depth as well, would have been out of the scope of the thesis. As a result, in order to demonstrate the validity of our approach, we focus on questioning the importance of the inter-organizational environment in the interviews, which is the main difference between our approach and the so far common factor approaches. Therefore, we tried to identify in the interviews the role of the supply chain of an organization for the adoption decisions towards blockchain technologies. Furthermore, we used questions for determining the level of knowledge and identifying the overall

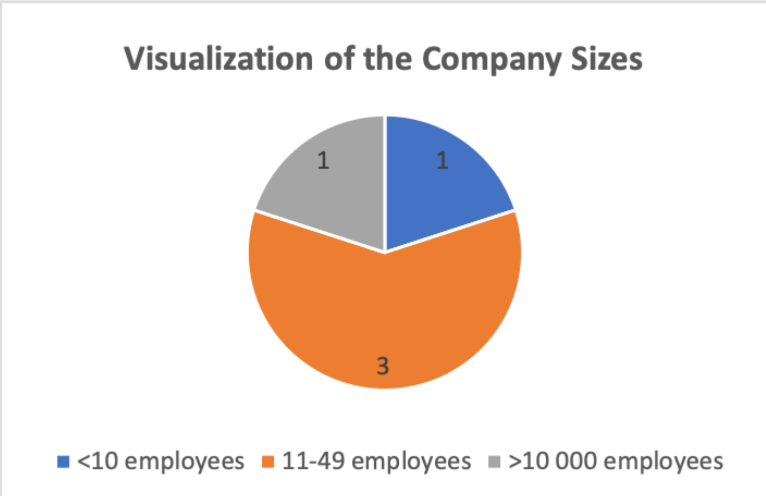


Figure 12: Piechart illustrating the sizes of the interviewed companies.

intentions and barriers of the organizations towards the use of blockchain technology for supply chain management in the interviews, which should help to better understand the situation in Austria.

Our sampling strategy was mainly based on the goal of identifying the role of SMEs in the adoption process of the technology. Based on the fact that we looked at the supply chain as the unit of analysis, we decided to talk to both small and large businesses to find out what made them different and to include both types of SC participants. The distribution of the participating companies, based on the number of employees, can be seen in Figure 12. As it can be seen in the figure, we interviewed four SMEs and one large organization, with more than 10000 employees. The covered industries by the interviews included manufacturing, defense, construction, and a logistics provider.

5.2 Limitations

As stated above, this research should be considered a preliminary study and not a broad research study, which would be required to fully verify our approach. Therefore, the study cannot be considered general and needs to be tested for other regions independently.

The main limitation of the research is the small sample size. Consequently, it is suggested that the research should be repeated on a larger scale. Furthermore, we identified a bias in our sample organizations. Only companies with an interest in or prior knowledge of the technology were willing to participate. The main reason given for not participating in the interviews we got from organizations was that they did not feel comfortable enough with their level of knowledge about this topic in order to participate. While we tried to take the SC as the unit of analysis, the interviews were still conducted with individuals from different organizations and therefore different supply chains. As a result, the interviewee has an individual bias toward the technology. In order to test our framework more in depth, it would be interesting to study the blockchain adoption intentions of several organizations within one supply chain. This would allow us to determine the power dynamics existing in the supply chain and the role they play in the adoption process much more clearly. However, due to a lack of resources and time, such a study was not possible within the scope of this thesis.

5.3 Summary

In this chapter, we briefly introduced our methodology for the empirical part of this thesis. We explained that we used interviews to gain insights concerning blockchain adoption for SCM in five Austrian organizations. In Section 5.1, we gave arguments for why we decided to use this method as well as elaborated on the goals and structure of the interviews. We also discussed the limitations of our study in Section 5.2. Based on the small sample group, this work should only be considered a preliminary study, and further research will be required.

6 Findings

In this chapter, we will present to the reader our findings from the conducted interviews. Accordingly, we will begin by looking into what information we gathered about the current state of blockchain technology adoption for supply chain management in Austria from the interviewees. Secondly, we assess the companies' expectations regarding the adoption of the technology. In the final section of this chapter, we will examine the challenges and drivers for blockchain technology adoption in SCM. The main findings are emphasized in the following text. However, since our study is not generalizable, the findings should be seen in regards to the conducted interviews and not the situation in Austria in general.

6.1 Knowledge and Current Situation

As was previously indicated, all of our interviews were done with management-level individuals. In Figure 9, management support is indicated as one of the adoption factors. In order to evaluate this, we attempted to determine whether their general perception of blockchain technology is positive or negative. In particular, we wanted to assess their level of knowledge about blockchain technology and its application in supply chain management, so we asked the participants to rank their expertise on a scale from 1 to 5. Figure 13 illustrates the corresponding results.

6.1.1 Organizations indicate a positive Attitude towards Blockchain Technology.

As depicted in Figure 13, four of the five interviewees assessed their general attitude as positive (4 on the scale) or highly positive (5 on the scale). The following quotes from the interviews illustrate this sentiment further[11]:

> *"[My attitude is positive because] it [blockchain technology] is the technology of the future and the connected world is unimaginable without it."*

> *"[My attitude is] in general positive, I think there is no way around it for larger organizations."*

Only one interviewee rated their opinion of blockchain technology as neutral (3 on the scale), based on their lack of understanding and the fact that they are not totally convinced that blockchain technology will be widely adopted as it can be identified by their comment:

[11] All quotes presented in this chapter, if not specified otherwise, are cited from one of the interviewees and have been translated by the author.

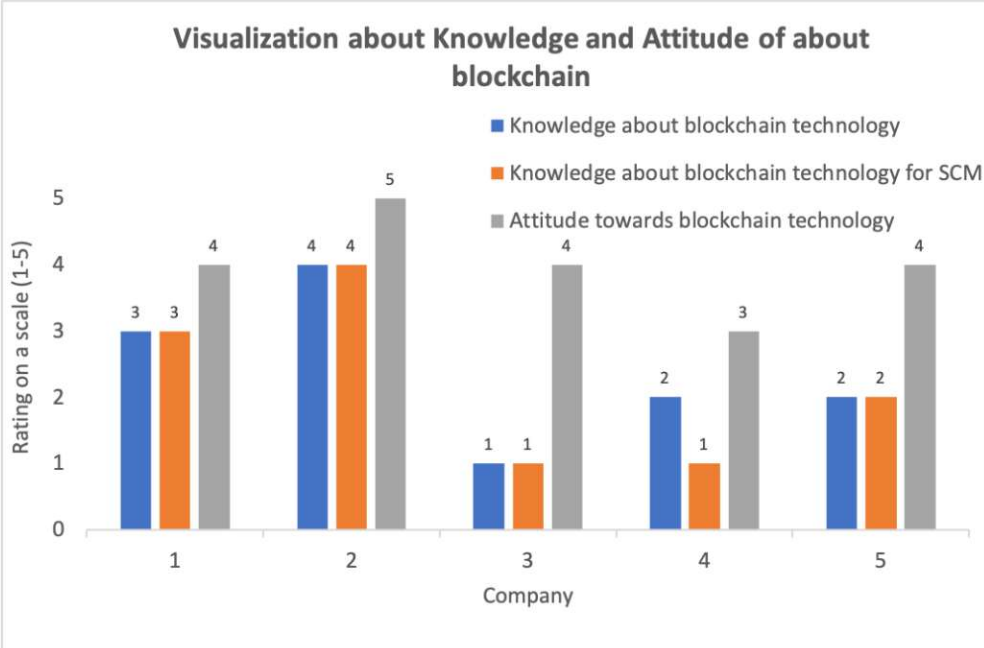


Figure 13: Barchart showing the answers of the interviewees about their knowledge and opinion about blockchain technology.

> *"[My attitude is] neutral, because you don't know exactly what to use it for. Some say this is the holy grail; if I have it, I can do anything. Others say you can also misuse it. Therefore, neither negative nor positive, but that is probably related to [my] knowledge."*

Due to the fact that we interviewed one company that was significantly larger than the others, we must differentiate between the sizes of the companies when evaluating this question, as the influence of the manager on an adoption decision can be viewed as being significantly greater for smaller organizations. In addition, we discovered that all of our interviewees had a general understanding of how or why blockchain technology might be implemented in their supply chain or industry. However, only two of the respondents reported knowledge of existing solutions in their respective industries.

6.1.2 No Implementations of Blockchain Technologies so far.

None of the companies that participated in the interviews had explicitly explored how blockchain technology might be applied to their SCM. In addition, only one interviewee was aware of the benefits and, more importantly, the competitive advantage of blockchain technology for supply chain management:

> *"It [blockchain] leads to transparency without third parties. The benefits are well known. (...) I am surprised that it is not yet more widely used."*

All other interviewees responded that they are not yet fully aware of blockchain's benefits for SCM.

6.1.3 Participation in a Blockchain Solution for SCM could be demanded.

When questioned about the structure of their supply chains, four of the five respondents indicated that there are larger or more powerful organizations within their supply chains that may demand participation in their blockchain solution for SCM, if one were developed. Some participants described it as follows:

> *"Some customers will come our way, and then we will have to do it (...) if we want to keep the business."*

> *"Any [large] corporation can force this [implementation] on you if you are dependent [on them]."*

The majority of SC dependability occurs on the customer side, not the supplier side, according to all respondents. Interestingly, this is true not only for SMEs but also for larger institutions. One of the interviewees explained the situation in the following way:

> *"For customers, I would say a definite yes [for dependability] if they say you can only participate if you use blockchain for this. For suppliers, it is a bit different. It is not so strict there."*

In addition, just two firms responded that they believe companies in their supply chains would work together to discover a blockchain solution. However, only the large organization considered itself a member of this collaboration:

> *"I could imagine [that] for example, three companies [including ours] collaborate to bring something like this to the market."*

Moreover, based on the degree of digitalization of their supply chains, two organizations believe that other supply chain participants would be willing to adopt blockchain technology for SCM.

6.2 Expectations of Austrian Organizations about Blockchain Adoption for SCM

In order to gain a better understanding of Austrian organizations' expectations regarding the adoption of blockchain technology for supply chain management, we asked interview participants how much they anticipate this technology to influence their companies or industries in the future. Their responses are illustrated in Figure 14.

6.2.1 Expectations concerning the Impact of Blockchain Technologies for SCM are varying.

Companies 1 and 2 anticipate that it will have a significant impact on their respective sectors in the future years:

> *"The impact [on our industry] will come as more and more companies start doing it."*

> *"I expect the impact will increase. (...) because something [one of the blockchain solutions] will prevail. Not because I hope so, but because a large [company] will use it and all suppliers will have to participate."*

Compared to their general opinion of blockchain technology shown in Figure 13, it can be seen that these two interviewees have a higher degree of expertise and a positive or very positive opinion of blockchain technology. In contrast, companies 3 and 5 expect little future effects on their operations and industries, despite a positive attitude toward the technology. According to them, their responses are mostly based on the low degree of digitalization of current operations within their industries and supply chains. One of the interviewees stated it in the following way:

> *"Everyone uses a different system [for doing business], most of it is still done over the phone. I do not think that will change so quickly."*

They anticipate that the majority of organizations in their respective fields will maintain their present business practices and that just a few of the large organizations would adopt blockchain technologies. However, they do not expect that this will necessarily effect them. Company 4 stated that they anticipate a moderate impact:

> *"It is not yet visible for what we will use it; for what data exchange. (...) If it is used [widely and successfully], then there can be a breakthrough [in adoption]. If it is not used [widely and successfully] (...), then it can disappear very quickly."*

This corresponds to their neutral opinion, which was based on the fact that blockchain technology has not yet shown its relevance. However, they also anticipate that this uncertainty will be resolved in the coming years, and depending on the results, they stated that their firm could either see a significant impact or none at all.

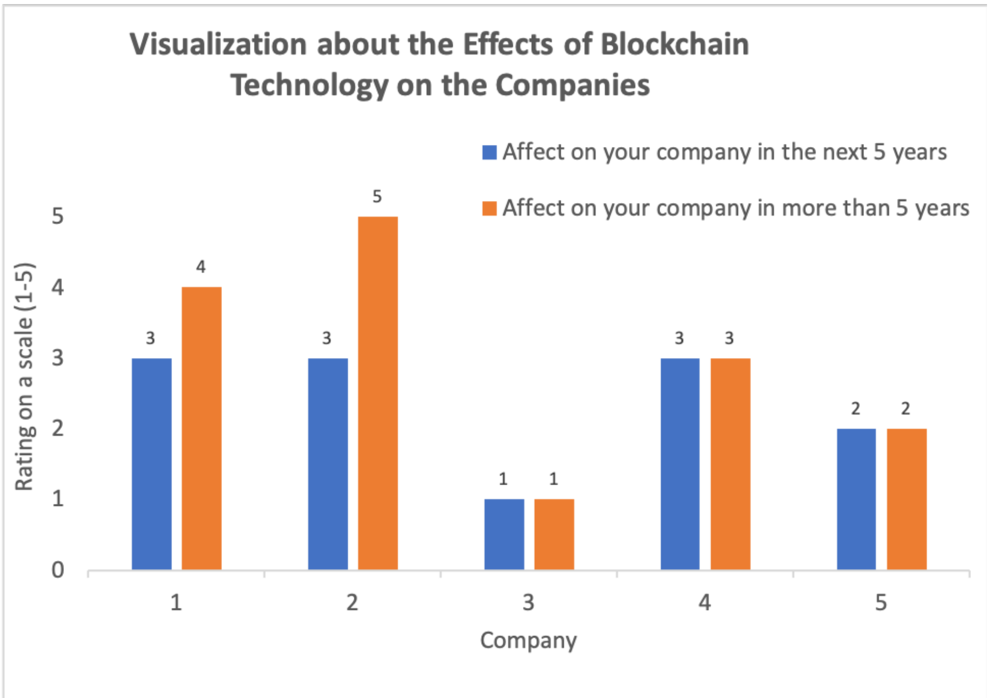


Figure 14: Barchart showing the answers of the interviewees about their expectations regarding the influence of blockchain technology for SCM for their company.

6.2.2 Participation is more likely than developing an own Blockchain Solution for SCM.

We asked the interviewees, based on the structure of their supply chains, which adoption scenario they considered to be most likely for the development of a blockchain solution for supply chain management. As expected, based on the literature review, the large company was the only one to indicate that it would be possible for them to develop their own blockchain solution for SCM. They noted, however, that if they developed a solution, it was more likely to be focused on the supplier side, because they have more influence on that side of their supply chain compared to the customer side. However, they mentioned that it is also possible for a blockchain solution to be developed by a single organization or a consortium from the client side, in which they would be required to participate. In addition, they mentioned that if they were to develop their own solution, their preferred approach would generally involve other organizations. Thus, a collaboration for developing a solution could also be an option for them. The four SMEs we interviewed stated that since they lack the power to convince other SC members to participate, neither of them considers developing their own solution as a possibility. This sentiment is illustrated by the following quotes:

"It will not start with the small ones [companies], they are only followers."

"I don't think that others could be convinced to participate [in our solu-

tion], we are way too irrelevant."

"They will not change their systems because of one customer."

In addition, they all responded that they assume a consortium approach within their industries for the development of a blockchain solution for SCM to be a realistic option. Furthermore, two interviewees explained that they expect large organizations within their supply chains to develop their own solutions, in which they would be required to participate.

6.2.3 Forced Participation will lead to Adoption of Blockchain Technology for SCM.

Finally, we want to summarize what we discovered about the expectations and willingness of the interviewed companies to adopt blockchain technology for SCM. Two of the SMEs stated that they do not expect to adopt blockchain technology until it has become a standard technology to use for SCM, which means that the benefits of the technology are widely accepted and that it is used on a very broad scale within their industries. The following quote illustrates this:

"If there is a good idea or if it is being simplified I think it is a good idea [to adopt] in itself. (...) [However] if three customers use blockchain and 10 customers do not, then we have no overview at all."

According to them, the answers are mostly based on the way operations are handled at the moment. Furthermore, they explained that even though there might exist organizations within their supply chains that would possess the power and importance to demand the implementation, they do not expect these companies to make use of blockchain technology in the near future. The other two SMEs that have been interviewed expect that they will have to adopt blockchain technology for SCM, whether they want to or not. Their answers are based on the fact that they assume that the larger organizations within their supply chains will make use of the technology because it would make sense for their industries. One interviewee reported it as follows:

"A customer of ours could be one of the first [in Austria to use blockchain for SCM] (...) If he comes to us, we will have no choice."

The other interviewee mentioned that he is aware of the fact that key customers of his company are already looking into the possibilities of using blockchain technology for this purpose. However, both of these interviewees mentioned that they believed in general that this could be beneficial for them, as it might give them a competitive advantage that could lead to new possibilities for their companies. This is indicated by the following quote:

"Yes we [will] adopt, why, because we have to. The standard [process within their SC] states that if you want to sell something [to the larger companies], then this is how it works now - take it or leave it. But at the end of the day, also because it is "smart" [to adopt].

Lastly, we want to discuss the situation of the larger company. On the one hand, for developing their own solution, they have yet to be fully convinced of the relative advantage of blockchain technologies compared to other solutions that could solve some of the current SCM goals. On the other hand, they are also aware that they might have to adopt blockchain technology in order to keep up with demands from their customers.

6.3 Barriers and Enablers for the Adoption of Blockchain Technology for SCM

We also attempted to comprehend the barriers and enablers for the adoption of blockchain technology for SCM.

6.3.1 Supply Chain Members are the biggest Enablers for the Adoption of Blockchain Technology for SCM.

From the gathered responses, we could determine that, at this stage, the largest factor that could lead to the adoption of this technology is the involvement of larger enterprises within the supply chain. As previously noted, the main reason for this is that they possess the necessary influence over supply chains to develop a solution and distribute it among participants. According to the interviews, this is expected to continue until the relative advantage of the technology is widely recognized, as it can be seen in the quotes stated previously. This situation for smaller companies can be summarized by the following comment of one of the interviewees:

"For my company, developing a blockchain solution would be the same as being the first person to develop a phone. It would be great, but I still could not talk to anyone else."

At the point in time, when the technology is adopted broadly, further convincing of SC participants is no longer necessary. This is supported by the fact that all five interviewees regarded a lack of influence as the most serious barrier to the adoption of blockchain technology for SCM. The existence of such large companies in the supply chain that provide solutions seems to be the most important factor in determining whether a company will adopt or not.

6.3.2 Lack of Knowledge and Difficulties in Process Harmonization are the biggest Barriers towards the Adoption of Blockchain Technology for SCM.

Further, all interviewees stated that a lack of knowledge about the technology and its benefits for SCM is a significant barrier to its adoption. In addition, there is little information on how to prepare and the implications of participating in a blockchain-based SCM solution. Harmonization of processes throughout the supply chain was also mentioned by all interviewees as a barrier to the adoption of the technology. Their answers were based on the fact that many of the companies in their supply chains use different methods and systems for managing the supply chain.

For the two companies that do not anticipate adopting it in the near future, even in the case where an industry consortium would develop a solution, identifying the benefits of the technology in relation to the resources required for its implementation is a barrier to the adoption of blockchain technology for SCM. One of the interviewees reported it in the following way:

> *"There is the question of how far this [adoption of blockchain technology for SCM] makes sense at all [for my company]. I would say, in the future, when this [blockchain technology for SCM] becomes significant, that this is used everywhere, then yes, but at the moment I see no compelling reason for doing this [participating or developing] and also no advantage, except that it is a lot of effort."*

According to the larger company, this also applies to their situation of developing their own solution. However, this barrier can be connected to the lack of knowledge and information mentioned above.

Finally, all interviewees stated that, at the current moment, in order to prepare for blockchain adoption for SCM, their companies could be best supported by being provided with further information, use-case examples, case studies, and best practices.

6.4 Summary

In this chapter, we presented the findings from our empirical study about blockchain adoption for SCM in Austrian organizations. With the interviews, we were able to evaluate the current situation and level of knowledge of the participating companies. Furthermore, we presented the expectations of the interviewees about their futures related to this topic. Lastly, we summarized the identified barriers and enablers for the adoption of blockchain technology for SCM. We are going to discuss these findings in the next chapter.

7 Discussion

In this chapter, we want to discuss the findings presented in the previous chapter in more detail. Our focus will be on making the connection between the findings, the research questions, and our hypotheses. Furthermore, we want to reevaluate our proposed framework for studying blockchain adoption for supply chain management based on what we learned from the interviews. In Section 7.4, we want to share with the reader our thoughts on the future of blockchain technology adoption for SCM. This is required because in the last chapter we want to give some recommendations for how to address problems and barriers that might come up during the various stages of the adoption process.

7.1 Review of our Hypotheses

We presented the hypotheses for this study in Section 4.3.3. We want to evaluate them now in light of the findings shown in the previous chapter.

Hypothesis 1. *SMEs are more likely to participate in a blockchain solution developed by other industry or supply chain organizations, than to develop their own solution.*

Hypothesis 1 states that SMEs are more likely to participate in a blockchain solution than develop one on their own. Based on the findings in Sections 6.2.2 and 6.2.3, we can evaluate the validity of this statement. According to the interviews, participation is not only more likely, but it may be the only option for the majority of SMEs to adopt blockchain technologies for SCM. Furthermore, we discovered that, to some extent, the demanded participation of other SC members is also a very likely adoption scenario for larger organizations, though not the only option for adoption, as it is for SMEs.

In Section 4.3.3 we explained that our argument for this hypothesis is based on the reduction in development costs for the participants if other companies were to develop the solution. However, according to the interviewees, this behavior is currently governed more by a lack of influence over other supply chain members than by financial concerns.

Even though the findings support our hypothesis in general, we want to modify it and add a time limit to the statement. As identified, forced participation is expected to be the primary enabler for the adoption of blockchain technology for SCM until widespread adoption occurs. At this point in time, the importance of influence over the SC might decrease, allowing more organizations to develop their own solutions.

	Modified Hypothesis	Comment
H1	Until blockchain technology for SCM is widespread, the majority of SMEs will only be able to participate in a blockchain solution developed by other industry or supply chain organizations and not develop their own solution.	Added time limitations and stated that it is the only possibility not just more likely.
H2	Until blockchain technology for SCM is widespread, the structure and participants of the supply chain of an organization, have the highest influence on the adoption decision of blockchain technology for supply chain management.	Added time limit and extended to all organizations not just SMEs.
H3	Austrian organizations are currently mainly in the knowledge or persuasion phase of blockchain adoption.	Extended to all organizations and not just SMEs.

Table 5: Modified Hypotheses

Therefore, we want to add to the hypothesis that it is valid for the first phases of the adoption process. The modified hypothesis can be found in Table 5.

Hypothesis 2. *The structure and participants of the supply chain of a SME, have the highest influence on the adoption decision of blockchain technology for supply chain management for SMEs.*

The second hypothesis says that the structure of the SC has the most impact on SMEs' decisions about whether or not to adopt. In Section 6.2.3, we identified that forced participation will be a main driver for the adoption of blockchain technology for SCM. We were also able to present in Section 6.3.1 that the supply chain members of an organization have the biggest impact on the adoption decision at the moment. Furthermore, as shown in Section 6.3.2, the interviewees mentioned the difficulties of process harmonization as a major barrier, which is again related to the structure of the supply chain.

While we think this hypothesis could be accepted as it is for SMEs, we still want to extend it. As the interviews have indicated, this statement is not only true for SMEs but for larger organizations as well. As with the first hypothesis, we want to again limit this hypothesis to the first phases of the adoption process. The modified hypothesis is shown in Table 5.

Hypothesis 3. *Austrian SMEs are mainly in the knowledge or persuasion phase of blockchain adoption.*

In Section 6.1.2 we presented the finding that none of the interviewed organizations have so far implemented or explored explicitly how to use blockchain technologies for their SCM. Furthermore, in Section 6.3.2, we identified the lack of knowledge as a major barrier, which led to the wish of all interviewees to be supported by being provided with further information, use-cases, best practices, and case studies about blockchain technology for SCM. Therefore, we argue that this hypothesis can be accepted for Austrian organizations in general, but without further research on a broader scale with larger sample groups, this cannot be stated with certainty.

7.2 Review of our Research Questions

In this section we want to evaluate our research questions based on the findings.

RQ 1. *What are the benefits of blockchain technology for supply chain management?*

In principle, this research question has already been answered in Section 3.5, based on the literature review. Nevertheless, there are still some comments to be made about the way this question is typically addressed in literature and also in this thesis. First of all, the presented benefits cover a wide range of application areas within the supply chain. However, it is likely that in the early stages of blockchain technology adoption for SCM, a possible solution will not incorporate all of these areas. It seems more likely that a solution would target particular problems in the SC. Therefore, the presented benefits are only partially achieved, and presenting them in this manner may paint an overly optimistic picture of the adoption process at this early stage of the process.

Nonetheless, this totality of benefits could be realized if blockchain technology for SCM is adopted on a very large scale. Thus, presenting the benefits in this way might encourage the adoption of blockchain for this purpose on a broader scale and help set the direction for a blockchain-based future for SCM. However, in these early phases, for the adoption of a specific blockchain solution, the benefits must be evaluated individually.

Furthermore, regarding the benefits of blockchain technology for SCM, a distinction should be made between the benefits for the developing company and the companies that participate in the solution. While, in principle, the benefits should apply to all participants in the SC, for some cases, this is only true if the technology has already been adopted on a broad scale beyond the supply chain of the developing company. As a result, the benefits for the participating organizations must be assessed individually for each solution. For example, if blockchain is used to increase supply chain transparency, there may be numerous benefits for participants. However, in the case of auditing, the primary benefit may remain on the side of the developing company. The reason for this is that the developing company is able to store all their transactions with their suppliers for audits on the blockchain, whereas the participants only have the record of one of their customers stored on this blockchain. As a result, the participants cannot use the blockchain ledger for the audits until all of their other customers use a similar solution and store the information in the same ledger.

RQ 2. *What is the present state and future ambition of Austrian organizations regarding the adoption of blockchain for supply chain management?*

The answer to this research question was provided in Sections 6.1 and 6.2 of the findings chapter. However, as explained in Section 5.2, the findings of our empirical study cannot be generalized to all of Austria due to the small sample size. The presented findings should be considered as indications of the current state and expectations about the adoption of blockchain technology for supply chain management in Austrian organizations.

As stated by Hypothesis 3, Austrian organizations are mainly in the knowledge and persuasion phase of adopting blockchain technology for SCM at the current moment. Furthermore, we could identify that for SMEs the most likely scenario for adoption is the demanded participation in a solution developed by larger SC members. For the majority of SMEs this is the only possible form of adopting at this time. While larger organizations face the same situation, where they could be forced to adopt a blockchain solution by their customers, they are also in a position to develop their own solutions.

RQ 3. *How does the adoption-process of blockchain technology for supply chain management differ for Austrian SMEs compared to larger organizations?*

This question has also been directly answered by the findings presented in Chapter 6. The most notable, though not surprising, difference between SMEs and larger organizations is that the latter have the possibility to develop their own blockchain-based solutions for SCM. However, as previously stated, it is possible that this difference might lessen as the technology becomes more widespread.

As explained in Section 4.3.3, we expected that there would be a distinction between large organizations and SMEs concerning the forced participation in a blockchain solution. However, as it turned out the situation is for SMEs and large organizations alike. This provides some support for our research approach, which emphasizes the structure of the SC when studying blockchain adoption for SCM. However, this might suggest that a strict differentiation between SMEs and larger organizations is not the best approach to this type of study. Separating studies based on different adoption scenarios or similar structures of inter-organizational environments might make more sense. This will be covered in greater detail in Section 7.3.

RQ 4. *What are the difficulties, enablers and barriers for blockchain adoption for supply chain management for Austrian organizations?*

From our interviews, we identified three barriers for this early phase of blockchain adoption for SCM, namely a lack of knowledge, a lack of influence over the SC, as well as the difficulties for harmonizing processes throughout the SCs and industries. We can see that latter two of these barriers are connected to the supply chains of the companies, and therefore can be considered as part of the inter-organizational environment. Furthermore, we could see that the existence of large enterprises, within the supply chain, that want to implement a solution, is the biggest enabler for the adoption.

In addition, the findings showed, that all of the interviewees could be supported with more information about blockchain technologies for SCM.

RQ 5. *What calls-for-action, in the context of blockchain adoption for supply chain management, can be made for policymakers and organizations in Austria?*

Based on the fact that all of our interviewees stated that their companies could currently benefit most from receiving more information, case studies, use cases, and best practices regarding blockchain technology for SCM. We want to make a call-for-action for Austrian policymakers to support Austrian organizations by fostering research on this topic and providing the results to companies. This is the most critical and required call-for-action that we could identify. In Section 8.2, we want to further discuss the implications of this suggestion and state our recommendation for how and what information should be provided at the different stages of the adoption process.

7.3 Evaluation of our and existing Blockchain Adoption Frameworks for SCM

We presented our framework in Section 4.3 and explained that it is based on a processual approach that incorporates TOE and NIT. In Section 4.3.1,we elaborated on the shortcomings of existing approaches to studying blockchain adoption. Therefore, we want to rather focus on the evaluation of our framework in this section based on the findings of our study. Because our approach is an extension of existing frameworks, we can expect its validity to be regarded as proof for existing framework issues. The main difference between our framework and other frameworks is that we want to recognize the inter-organizational environment as the unit of analysis. For our study, the supply chain represented the inter-organizational environment.

As stated in the previous sections, we can assume that Hypothesis 2 holds true for the first phases of the adoption process. Thus, we can acknowledge the importance of the supply chain structure and, consequently, of the inter-organizational environment for the adoption decision. In principle, this validates the processual approach of our study, and despite the small size of our research study, we could identify three significantly different adoption scenarios among the five companies interviewed. The scenarios included mandatory participation, the development of an own blockchain solution, or no possibility of adopting blockchain technology for SCM at the moment. The differences can be considered direct results of the different inter-organizational environments of the companies. This indicates the importance of taking the structure of the supply chain into account for future blockchain adoption studies, since the adoption factors vary significantly depending on the scenario. For example, the required financial resources or the requirements for training the employees have completely different dimensions for each adoption scenario. Therefore, without specifying this context, adoption studies end up comparing dissimilar things. This emphasizes the main concept of the processual approach, which is that the inter-organizational environment itself can change the importance of external factors.

According to NIT, the inter-organizational environment can be regarded as the organizational field of the company. We confirmed this by identifying forced adoption due to the demands of larger organizations within the supply chain as the primary influence at this time. However, interpreting this with NIT allows us to recognize this process as coercive isomorphism-based company homogenization. Furthermore, since all of our interviewees asked for further and more detailed case studies, best practices, and lessons learned, we can anticipate that in the future also the mimetic isomorphism will play an important role.

Unfortunately, due to the scope of this thesis, we were unable to test the entire framework. The fact that we were able to validate the significance of the inter-organizational environment can only be considered the first step. The next step should include conducting studies for similar inter-organizational environments or adoption scenarios and identifying their specific adoption factors. One could then compare the results for various groups of inter-organizational environments and, as a result, determine how the differences in the environment influence the relevance of the adoption factors.

In general, we can claim that the framework proved to be useful, at least for the early stages of blockchain technology adoption in SCM. As a consequence, we also want to state that using a sole factor approach, like TOE, might not be sufficient and should be combined with an evaluation of the inter-organizational environment. Furthermore, we suggest the implementation of NIT in this process for evaluating the inter-organizational environment and the influences on adoption decisions arising from it. However, much more research is required on this topic.

7.4 The Future of Blockchain Adoption for SCM - Our Expectations

Clearly, it is impossible to predict the future of a technology with absolute certainty at this time. Before one can be certain that blockchain technologies for SCM are here to stay, a significant amount of uncertainty has to be removed. However, there are many indications, which we have attempted to present throughout this thesis, that suggest that blockchain technology might prove useful for this purpose. For the event that it does, we want to describe how we anticipate the adoption process to evolve in the future, based on NIT and the findings of this thesis.

In order to explain our expectations for the future of blockchain technology adoption for SCM, we want to refer to Figure 7 and elaborate on the different stages of the adoption process. As it can be seen in the first phase, only innovators will utilize the technology. Due to the required influence over the supply chain and the necessary resources, the majority of innovators will be very large enterprises. As elaborated earlier, they will demand that their suppliers participate. As a result, this form of coercive isomorphism might provide not only the innovators themselves but also the participants with a competitive advantage. However, the advantage for the participants will present itself in the later phases, when, based on mimetic isomorphism, more and more large organizations will utilize blockchain technology for SCM. They will develop their solutions based on the best practices learned from the innovators. Again, they will demand their suppliers and other SC members to participate, which can again be considered coercive isomorphism. However, at this time, new opportunities may arise for companies that are already involved in previous blockchain solutions. Since they are already prepared to fulfill demands for new blockchain solutions, they might be able to acquire new customers.

We expect this cycle to repeat over and over again, and with every repetition, more companies are available on the market that are ready to participate. As a result, we anticipate that the required influence over the supply chain will decrease, allowing more organizations to develop their own solutions. This process will likely continue until the majority of companies have adopted the technology. However, we also assume that these adoption processes will happen at different times across industries. The industries that struggle the most with SC problems that blockchain technologies could solve will be the first to adopt the technologies. Consequently, the cycle may begin earlier for companies in these industries than for others.

7.5 Summary

In this chapter, we discussed the findings of the conducted interviews. At first, we analyzed whether our hypotheses held up and presented the slightly modified hypotheses. We continued with evaluating how the findings answer our research questions. Afterwards, we tried to explain whether the interviews and the findings thereof validated our research approach and the adoption framework. Finally, we presented our expectations about the future of the blockchain adoption process for SCM. We are going to conclude this thesis in the following chapter.

8 Conclusion

In this thesis, we performed a comprehensive study of blockchain technology for supply chain management, with the goal of evaluating the current and future adoption of this technology in Austria.

Therefore, we started by conducting a literature review about the fundamentals of blockchain technology, where we examined what it is, how it works, what the building blocks of the technology are, and what features it can provide. Equipped with this knowledge, we could explore the application of the technology to the operations of supply chain management, where we looked at the existing practices of supply chain management and how they could improve by incorporating blockchain technologies. We investigated existing blockchain solutions as well as possible areas of application within modern supply chains, which led to the identification of the general benefits of blockchain technology for SCM. In order to achieve the overreaching goal of understanding the adoption of this technology in Austria, we had to investigate adoption theory and existing adoption studies and evaluate how they relate to the Austrian context. We could identify that the dominant frameworks for studying blockchain adoption for supply chain management were not sufficient for this purpose. As a result, we decided to develop a new framework that would help us understand the role of small and medium-sized enterprises better, which is important for understanding the situation in Austria.

Our framework is based on the processual approach developed by Kurnia et al. for the study of the adoption of inter-organizational systems. Furthermore, we tried to include the neo-institutional theory and the TOE framework for interpreting the results of this research approach in order to draw conclusions about the future of blockchain adoption for SCM from them. After developing the framework, we tried to validate it by conducting a preliminary study consisting of interviews with managers in Austrian organizations.

8.1 Key Objectives of the Thesis

The overarching objective of this master's thesis was to identify the potential benefits of blockchain technologies in the context of supply chain management as well as to evaluate the current situation and future intentions for its adoption, with a particular focus on Austria. The first goal was achieved through an extensive literature review on blockchain technology and its application to SCM, which provided insights into the general benefits that could potentially be achieved.

The second objective of the thesis, assessing the adoption of blockchain in Austria, proved to be more challenging. We identified that existing frameworks for blockchain adoption are not suitable for our research objectives. Consequently, a new approach was developed to study blockchain adoption for SCM, however, this necessitated a shift in the focus of the empirical part of this thesis from sole exploration of the adoption situation regarding blockchain technologies for SCM in Austria towards also including the validation of the framework. Given the constraints of time and scope, the thesis could not incorporate testing the entire framework, and instead, the focus was directed towards examining the role of the inter-organizational environment, which is the main difference in our approach compared to existing factor-based approaches.

The most significant difficulty we encountered during the thesis was finding companies willing to participate in the study. Many of the firms that neglected participation cited their lack of knowledge in the field as a hindrance to participation. Consequently, only five companies were interviewed, making the results of the interviews not generalizable but still indicative. Nevertheless, we were able to answer the research questions to a certain extent. However, because of the aforementioned reasons, the answers to research questions 2, 3, and 4 can only be considered as indications of the true nature of the adoption situation in Austria. Identifying the barriers that Austrian organizations face in adopting blockchain technology for SCM proved particularly difficult. On the one hand, this is based on the fact that interviewees had no practical experience with the implementation of these technologies, which made the answers about potential barriers very speculative. On the other side, due to the scope of the thesis, we were not able to include the factor approach for studying the adoption factors properly, namely based on the inter-organizational environment, as suggested in our framework. Although we could not use the entire framework, our hypotheses were validated, and none had to be removed. However, we had to modify them slightly as we discovered that they seemed to be true only for the initial phases of blockchain adoption.

8.2 Implications of the Research for Policymakers, Scholarship, and Managers

We mentioned in Section 7.2 that we were able to identify in our interviews the need for more information, use-cases, case studies, and best practices about blockchain technology for SCM in Austrian organizations.

We would now like to elaborate on what information we believe is required and why.

Again, we suggest a separation based on the adoption scenarios. In the current phase of blockchain adoption, we believe policymakers should prioritize assisting companies that may be forced to adopt a blockchain solution. Those organizations, if not prepared properly, might lose key customers, which could cause irreparable harm to their businesses. As explained previously, preparing the companies for their participation not only prevents this risk but could also create a competitive advantage in the future. Companies that are not required to participate in the near future but anticipate having to do so in the future must identify which use cases make the most sense within their supply chains and industries. Based on this understanding, they can prepare, for instance, by investing in other technologies that might be involved in a blockchain solution, as described in Section 3.2. In this case, it may be essential to provide information and best practices regarding the optimal configuration of these technologies for future use in blockchain solutions. Due to mimetic isomorphism, we assume that companies that are in a position to develop their own blockchain solutions for supply chain management will lean towards case studies of larger organizations. However, we explained in the previous section, that we expect cyclic behavior for the adoption of blockchain technology for SCM. Therefore, these organizations will act as models for other Austrian organizations in the future. Consequently, it might be important to involve advocacy groups from the various industries in the development of these first solutions in order to develop sustainable practices and models right from the beginning.

Furthermore, we would like to address the work of Austrian agencies on this subject. These agencies have been briefly introduced in Section 1.5. As explained, they work on a blockchain that can be used by Austrian organizations for the deployment of their own solutions. While this can be a very useful and valuable tool, it aims at large Austrian organizations that could already develop their own solutions. Austrian industries consist mainly of SMEs, and these will not be able to develop their solutions until the majority of companies are ready to participate. Therefore, this project can be considered to aim for the later stages of the adoption process, as described in the previous section. However, supporting companies in the earlier phases of the adoption process might be of more importance at the current stage.

Finally, the most important call-for-action should be directed to managers and companies. They need to evaluate and observe their own inter-organizational environments in order to identify the most relevant adoption scenario for their company and determine how they need to prepare accordingly.

8.3 Future Research

In the previous section, we explained what information is required and when. In this section, we want to discuss what these studies should look like. We want to present two suggestions that can assist in validating our framework further and generate new insights about blockchain adoption for SCM.

In this thesis, we tried to validate our framework by showing that the inter-organizational environment plays an important role in the adoption decision. The next step would be to explore what this role exactly is. Therefore, our first suggestion is to make a study on a larger scale, where at first the participating companies are grouped on the basis of similarities in their inter-organizational environment, or the adoption scenario. Afterwards, TOE would be used to study the adoption factors for each group. Later on, we should be able to compare the adoption factors for various adoption scenarios and, as a result, identify the impact of the inter-organizational environment on the adoption decision.

The second suggestion is to use our framework to look in depth at one supply chain. This should include all of the companies within this SC and aid in understanding the power distribution within and its impact on the adoption decision. Furthermore, a study like this should provide insights into the differences between the developing and participating companies.

8.4 Closing Remarks

In summary, this master's thesis aimed to explore the potential benefits of blockchain technologies for supply chain management and highlight the importance of considering the inter-organizational environment in adoption studies. Our adoption framework, although not fully utilized in this thesis, can be a useful tool for such research and can be seen as a building block for future adoption studies. Policymakers should foster further studies about use cases, case studies, and best practices for the adoption of blockchain technology for SCM.

Finally, we hope that this master's thesis provides insights and encourages further research in the field of blockchain technology and its potential application to supply chain management. The potential benefits of blockchain technologies for SCM are significant, and with further research and development, the adoption of this technology can greatly improve supply chain operations and transparency.

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