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Smart Contracts: a Law and Economics Approach

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Table of Contents

INTRODUCTION

1.1. Introductory remarks

Imagine you are in a clothing store. Store employees offer you products such as t-shirts, trousers, coats, etc. Whichever product you are interested in, you can buy it by paying the price of that product. In this process, the role of contract law in the legislation is of no importance.

Now imagine you are the owner or CEO of a clothing store. You think you need new products to be sold in your stores. After doing the necessary research, you find a reliable and attractively priced product in Turkey. But this transaction is quite risky because you do not know the exporter. The exporter may send you a poor quality product or may not ship it at all. The same problem applies to the exporter. The exporter also does not trust you because you may not pay for the product after receiving it. So how can we minimize mutual risk?

Official contract law comes into play to resolve such situations. Contract law takes the following situations into consideration. Both the importer and the exporter do not trust each other because they do not want to share some information with the other party (for example, the quality of the product sold or the importer's willingness to pay for the product). In this case, it is the source of uncertainty because the information the parties have is not equal. Preparing a contract will be considered the best solution to resolve this uncertainty. However, after the contract, which is thought to be the solution to the problem, is signed, different questions arise. What are the legal rules governing the contract? In which country will the solution court be located in case of a problem that arises? Is there a possibility that the other party will not implement the judicial decisions if the case is won? Is it possible for the parties to pay a penalty imposed pursuant to the contract? As a result of these problems arising from the contract, it may be considered difficult and costly to implement this bilateral contract between the importer and exporter, even if it is sufficient.

We can think of an intermediary institution that can correct the distrust between the parties. This brokerage firm could be a bank or insurance company. The

intermediary institution may give a guarantee to the exporter in case the importer does not pay. After the mutual trust issue is resolved, the exporter delivers the product and the importer makes the payment after checking the product. As it can be seen, the contracts helped to eliminate the problems caused by distrust etc.

There are two important learnings from the example above. First, it shows that contracts are one of the most important tools for protecting parties against opportunistic or malicious behavior. The second is that even though the contracts are made, a third intermediary is needed for their assurance. So, despite the lack of mutual trust, can these contracts be made without the need for third parties?

In this study, we will discuss the usability of a digital contract that can be created with blockchain technology. With smart contracts, the fulfillment of contractual obligations can be coded with software. The codes used in the contract are unchangeable and virtually unhackable. This ensures that the parties are confident that they will receive the profits promised to them from the agreement. In smart contracts, it does not matter who the parties are if they have the necessary resources. Therefore, there is no need for third intermediaries, which would cause huge costs.

1.2. Literature review

In this thesis, we will analyze the performance of traditional contracts and smart contracts in terms of assurance, efficiency and transaction costs. The thesis will also analyze how blockchain technology, which creates smart contract technology, works technically, its current and future working areas, and the definition of smart contracts from a legal perspective. No specific research appears to have been done on this topic. Therefore, we will need to independently analyze all the elements separately to draw normative conclusions.

1.3. Research question and methodology

Considering the complex scenario that will arise due to smart contracts, the researcher aims to answer the following research question:

Under what conditions are smart contracts more efficient and useful than traditional contracts, as examined by transaction cost economics?

In order to find an answer to the main research question, it is necessary to examine the following sub-questions:

What is a smart contract? How does it work technically?

To what extent can smart contracts prevent contractual dangers?

What are the benefits of smart contracts over traditional contracts? What are its real-life and future uses?

What are the positive and negative effects in terms of transaction costs when using smart contracts instead of traditional contracts?

What is the legal infrastructure of smart contracts?

WHAT IS CONTRACTS, TRANSACTION AND THEIR COSTS?

2.1. Introduction

A contract is a legal transaction consisting of mutual and compatible declarations of will of the parties to produce a certain legal result.[1] As a rule, there must be at least one creditor and debtor in a contract. However, it is possible for more than one person to constitute the creditor and/or debtor side. In this case, the contract is established between the two parties.

In order for a contract to be formed, the parties' declarations of intent must be mutual. When it comes to mutual declarations of will, it is understood that each party must direct its own declaration of will to the other party and at the same time address the other party's declaration of will. Each party to the contract is both the owner of the statement of intent and the addressee of the other party's statement of intent. In order for the contract to be established, the offer to conclude a contract made by one of the parties to the contract must be accepted by the other party. The most important feature of the contract made between the parties is that it creates legally binding obligations.[2] Contracts can be defined as a legally binding bond made between the parties regarding the enforceability of a promise.

[1] Mitchell Catherine, Interpretation of Contracts (Taylor and Francis, 2007), p.11.
[2] Oliver Wendell Holmes, The Common Law, (Harvard University Press, 1881), p.12.

2.2. Why do we need Contracts?

The reason why contracts are widely used is that they provide legal protection between the parties. This protection determines the legal rights of the parties and the protection of these rights. If the parties fail to comply with the contract, legal sanctions come into play. In addition, contracts may determine how and through which arbitration or court a possible dispute between the parties will be resolved. Contracts eliminate uncertainties and prevent distrust by specifying the conditions under which the parties' expectations and services will be provided. Written contracts between the parties create trust and make the cooperation regular and safe. As a result, contracts are one of the most important tools to regulate and protect the rights, obligations and expectations of the parties in various fields such as business and personal relationships. In the following sections, we will analyze the moral, economic, efficiency and sustainability of contract justifications.

2.3. Moral Justification

In Roman law, the concepts of "bono fides" and later "aequitas", which are based on the values of "not harming others and not doing harm to anyone", are based on "the values of keeping secrets, trust between people and protecting the weak".[3] Bono fides is inspired by Fides, the Roman goddess of promises. During this period, the place where Fides sat was considered the right hand of man. Therefore, the contracting parties would shake hands and thus put their promises under the sanction of the goddess, which is where today's handshake custom comes from.[4]

The concept of morality, on the one hand, is the social and social order rules that regulate what should and should not be done, according to the value judgments created by social relations and interaction, and serve to evaluate both the behavior and mutual relations of individuals. According to the belief in society, trust is powered by the principle of mutual promises, but broken promises mean abuse of trust. This

[3] Béatrice Jaluzot, La bonne foi dans les contras (Paris, Editions Dalloz - Sirey, 2001), p.19.
[4] Vasfi Raşit Seviğ, Ahlakın Umumiyetle Hukuk ve Mukaveleler Üzerine Tesiri (Ankara, Arsebük Armağanı, 1958), p. 525.

situation also negatively affects social enterprises that provide collective benefit. This is possible through contracts to ensure an environment of trust and prevent abuse.

2.4. Economic Reasons

Contract is undoubtedly the central concept of economics. Markets that allocate resources are networks of contracts. The coming together of supply and demand and the exchange of goods and services can only occur by establishing a contract between the parties. Despite this importance, interestingly, the contract has not occupied much conceptual attention in economics until recently. Transactions in the market have been seen as a pure exchange, i.e. an act of performance, and the underlying commitment phase, the debt relationship, and the rights and obligations associated with it have been ignored.[5]

Contracts are the main (or even the only) means of social welfare maximization according to the pareto criterion. The main reason for this is that the transaction is based on consent. Since each party tends to maximize its own utility, a consensual transaction creates a strong presumption that it increases the utility of the parties. Consensual contracts, then, guarantee that social resources are allocated in a utility-enhancing manner. On the other hand, no clear judgment can be made about the welfare impact of non-consensual transactions and policies. This is because, in the absence of consent, it is not possible to know to what extent and in what direction benefits are affected.

About the economic function of contracts, 4 functions can be mentioned. Contracts discourage opportunistic behavior, reduce transaction costs, address the information problem and externalities.[6]

2.5. Efficiency and Sustainability Reasons

These two reasons play a key role in making and implementing contracts. Contracts encourage mutual cooperation and a more efficient process. When goals,

[5] Steven Shavell, Foundations of Economic Analysis of Law (Cambridge, Harvard University Press, 2004), p.291.
[6] Kerem Cem Sanlı, Hukuk ve Ekonomi Perspektifinden Sözleşme Hukuku ve Sözleşme Yaptırımlarının Ekonomik Analizi (On İki Levha Yayıncılık, 2015), p.24.

tasks, and responsibilities are determined between the parties, the workflow is managed more effectively, ensuring better and more efficient use of resources.[7]

Contracts can contribute to economic sustainability. It helps contracts to be sustainable by making agreements on ensuring a fair financial distribution between the parties and effective management of finances. Contracts also encourage the effective execution of business by enabling parties to evaluate their performance.

2.6. Transaction and Their Costs

According to transaction cost theory (TCT), written contracts are viewed as a protection mechanism against opportunistic behavior of the parties in a buyer-seller relationship.[8] According to TCT, asset specificity and uncertainty of transactions are transaction-based characteristics that will create risk in an exchange relationship.[9] Contract duration is one of the control mechanisms to be used to avoid risks that may arise due to asset specificity and uncertainty of transactions.[10] Therefore, determining the contract duration correctly is a critical element that will affect the success of a contractual relationship. For example, a long contract period reduces the costs of research and re-collaboration negotiations as it does not require finding a new buyer/supplier.

Transaction cost theory (TCT) has its roots in economics and contract law. The theory was first used by economist Ronald Coase in his 1937 article "The Nature of the Firm" with the question, "Why do firms exist?" Coase asked, “If markets are so efficient, then why are there organizations?” He tried to explain the existence of organizations with transaction costs.[11]

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[7] Pierre Fleckinger and David Martimort, "Contract Theory in the Spotlight: Oliver Hart and Bengt Holmström (Revue d'économie politique, Dalloz, 2018), p.497.
[8] Oliver Eaton Williamson, Transaction-cost economics: The governance of contractual relations (Journal of Law and Economics 22(2), 1985), p.233-261.
[9] Oliver Eaton Williamson, The economic institutions of capitalism (New York, NY: Simon&Schuster Inc. 1985), p.281.
[10] Keith Crocker and Scott Masten, Mitigating contractual hazards: Unilateral options and contract length (The RAND Journal of Economics 19(3), 1988), p.327-342.
[11] Rabia Arzu Kalemci, İşlem maliyeti kuramının davranışsal varsayımlarında güvenin yeri tartışması (İş Ahlakı Dergisi, 2013), p.55-83.

Transaction cost theory, whose foundations were laid by Coase, was developed by Oliver Eaton Williamson.[12] According to Williamson, the cost of a transaction is divided into two: before (ex-ante) and after (ex-post). Preparation of the contract, negotiation process and maintenance of the contract are pre-contract costs. Costs such as performance control and correction of errors made during the contract are also post-contract costs.[13]

Studies on transaction cost theory have focused on different sources of uncertainty. For example, while Williamson discussed the first and second types of uncertainty,[14] discussed environmental uncertainty, and Bayon and Diaz[15] focused on technological uncertainty and demand uncertainty. We will focus on environmental uncertainty and demand uncertainty.

Environmental uncertainty is the difficulty of predicting situations and problems that are likely to occur in the future. It can be caused by environmental uncertainty, political environment and economic instability. According to transaction cost theory, in commercial relations where environmental uncertainty is high, the parties want to prepare contracts that foresee every situation, but in an environment where uncertainty is high, the preparation of contracts becomes more costly due to the difficulty in obtaining information and the negotiation process.[16] This environmental uncertainty prevents possible long-term agreements between the parties.[17]

[12] Oliver Eaton Williamson, Transaction-cost economics: The governance of contractual relations (Journal of Law and Economics, 1979).
[13] Oliver Eaton Williamson,The economic institutions of capitalism (New York, NY: Simon&Schuster Inc. 1985).
[14] Milton Harris and Bengt Holmstrom, On the Duration of Agreements (International Economic Review, 1987), p.389.
[15] Susana López Bayón and Manuel González Díaz, Indefinite contract duration: Evidence from electronics subcontracting (International Review of Law and Economics, 2010), p.145-159.
[16] Aric Rindfleisch and Jan Heide, Transaction cost analysis: Past, present, and future applications (The Journal of Marketing, 1997), p. 44.
[17] Stephane Saussier and Scott Masten, Econometrics of contracts: An assessment of developments in the empirical literature on contracting (Revue d'économie industrielle, 2000), p.218.

The other type of uncertainty is demand uncertainty. Demand uncertainty is the uncertainty that occurs in the buyer's demand.[18] In a situation where demand uncertainty is high, the supplier has difficulty monitoring the buyer's performance in the contract and affects the supplier's efficiency.[19] In this case, the supplier will prefer the contract to be short-term in order to avoid the risk of swapping.[20]

2.7. Conclusions

Contracts are legal instruments used to protect and regulate economic exchange in cases where mutual trust is lacking. These documents regulate economic relations by reducing potential distrust between the parties and controlling or balancing deception tendencies. This regulation plays a critical role in ensuring that transactions occur that preserve wealth at the highest level. Contracts allow parties to clearly define their mutual obligations and include future contingencies. This is important in order to strengthen cooperation between the parties and prevent disputes. Additionally, contracts are designed to provide resolution in case of possible breaches, so that parties can find a framework to resolve disputes and continue cooperation.

However, given the complexity of real life, we are faced with the fact that even current conditions cannot be fully predicted and future events can only be predicted with limited accuracy. Therefore, parties have limited information about the relevant elements of a contractual relationship and uncertainty is quite common. This requires the parties to a contract, when initially planning, to mobilize significant resources to adapt to variable conditions that may arise during the execution of the contract and to monitor the relevant actions of the counterparty in relation to the performance of the contract.

[18] Bayon and Diaz, Indefinite contract duration: Evidence from electronics subcontracting, p.152.
[19] Rindfleisch and Heide, Transaction cost analysis: Past, present, and future application, p.49.
[20] Johannes Fuhr, Contractual Design and Functions - Evidence from Service Contracts in the European Air Transport Industry (Working Papers, Center for Network Industries and Infrastructure, 2007), p.22.

No matter how much effort the parties make, one must face the fact that complete information cannot always be obtained during a contract process. This means that the contracting process will always be incomplete and costly. These costs are often called transaction costs. Uncertainties in the contract process increase the parties' efforts to adapt to constantly changing conditions and resolve disputes, which is an important factor for the sustainability of contractual relations.

The next chapter will analyze the problems posed by traditional contracts and the solutions offered by smart contracts to the transaction costs caused by these problems.

SMART CONTRACTS AND BLOCKCHAIN TECHNOLOGY

3.1. Introduction

Conventional contracts are tools that regulate the obligations and rights between the parties as a very important part of the legal structure and business life. While it is sometimes possible for a contract between the parties to emerge in a short time, sometimes it may take weeks or even months due to bargaining problems and disagreements. However, signing the contract alone does not ensure the conclusion of the contract. Implementation of the contract also creates a separate burden for the parties. Contracts are a process that continues from the writing of the first sentence until the contract is implemented with the last sentence. However, this process creates a more tiring and costly legal process due to non-contractual behavior between the parties and a broken trust environment.

Nowadays, where our lives are faster in every field and are controlled by information technologies, the efficiency to be obtained from a contract will not always be one hundred percent. It is possible to minimize the time loss, workload and costs that occur from the creation of a contract to its completion with today's technologies. The solution that can exist in today's technology, while carrying the functions and guarantees of a contract, points to smart contracts.

When smart contracts were invented in the early 1990s, they were not created to fulfill the "contract" function in the traditional and legal sense. However, with

today's requirements and rapidly developing blockchain technology, contracts between the parties can be automated. In this context, many problems that may arise during the creation and conclusion of traditional contracts are eliminated; A very transparent and clear contract process is formed.

3.2. What is a Smart Contract?

The concept of smart contracts was first coined by Nick Szabo in the early 1990s as "protocols in digital form that fulfill the promises of parties."[21] With this definition, smart contracts were first used to define objects in the rights management layer of The Stanford Infobus system, which is part of the Stanford Digital Library Project.[22] The main idea about smart contracts is based on the assumption that a large number of contract records can be placed in software and hardware in a way that makes it uneconomic for either party to violate the contract. Here, important information such as the details of the contract, the parties and their obligations are recorded in the software. In case of a possible breach of obligation, the digital program alone carries out the legal consequences for the situation in question.[23]

Smart contracts are computer protocols that receive, send and control information and where data can be changed according to predetermined rules.[24] The basis of a smart contract is a code included in the protocol and designed as a rule-based, mechanical-causal system. If a condition in the code is met, it is applied to a particular action or transaction. In other words, smart contracts have records containing a networked and self-executing "If ...., ... then" algorithm.[25] Product vending machines constitute the first prototype of smart contracts. Here, the

[21] Nick Szabo, Smart Contracts, 1994, https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html (accessed 12.12.2023)
[22] Max Raskin, The Law and Legality of Smart Contracts (Georgetown Law Technology Review, 2017).
[23] Martin Fries, Smart Contracts: Brauchen schlaue Verträge noch Anwälte? Zusammenspiel von Smart Contracts mit dem Beweismittelrecht der ZPO. (München, 2018).
[24] Markus Kaulartz and Jörn Heckmann, Smart Contracts – Anwendungen der Blockchain-Technologie, (Computer und Recht Journal, 2016).
[25] Christoph Simmchen, Blockchain (R)Evolution – Verwendungsmöglichkeiten und Risiken (MultiMedia und Recht, 2017), p.163.

establishment and implementation of the contract in question takes place not with an algorithm but with a mechanical "if...,... then" mechanism.[26]

3.3. Implementation and Functioning of Smart Contract

A smart contract is a phrase used to describe a computer program to facilitate the exchange of money, content, property, shares or any digitized asset. We can define a smart contract running on a blockchain as a computer program that runs automatically on its own when certain conditions are met. One or more smart contracts are used together to realize a specific use case, forming distributed applications. The use cases of blockchain technology are determined by distributed applications based on smart contracts. In the blockchain technology use case map prepared by the World Economic Forum (WEF), we see that the technology is used in areas such as identity management, sustainability, asset management, governance and supply chain.[27]

[26] Simmchen, Blockchain (R)Evolution, 164.

[27] Oliver Krause, Blockchain / WEFs Transformation Map outlines the areas of impact of the technology, (2017), URL:https://www.linkedin.com/pulse/blockhain-wefs-transformation-map-outlines-areas-impact-krause/ (accessed 08.12.2023).

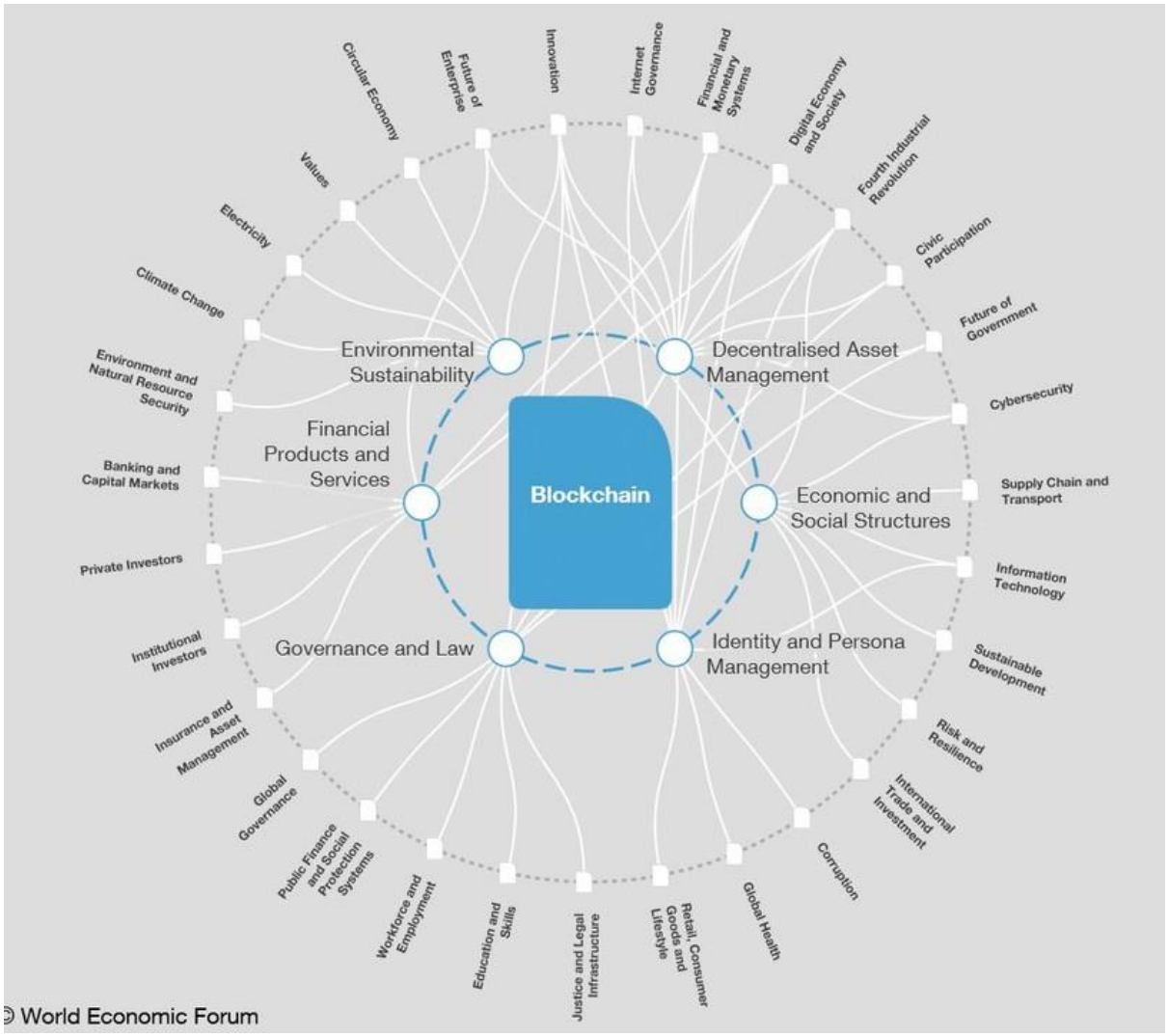

Figure 3.1: Blockchain Usage Area Map Prepared by the World Economic Forum

It would be more accurate to examine the functioning of smart contracts through the working principle of the Ethereum protocol, which is the first practical use of the concept (we will explain the Ethereum protocol and its details in Chapter 4). Smart contracts allow to automatically change and update the ownership of digitized assets stored on the blockchain network under certain conditions. These automatic operations are coded as functions within the smart contract.

Each function executed within the smart contract living on the blockchain will require a processing power and storage capacity on the Ethereum virtual machine of each peer, which is an Ethereum node on the network. Because of the immutability characteristic of the blockchain, smart contracts must be carefully coded against

vulnerabilities from the outset and published on the blockchain network. A vulnerability in a smart contract can render the relevant distributed application vulnerable to cyber-attacks and cause it to cease to function.

In the Ethereum Yellow Paper, each operation in the smart contract code has a corresponding machine code.[28] At the end of the day, the smart contract code is converted by a compiler for Solidity or Vyper into bitcode (bytecode) that is executed by the Ethereum virtual machine.

The smart contract prepared by the developer is converted into bitcode by the compiler and prepared to be published throughout the network.[29] The smart contract's identity and new address on the Ethereum network are generated uniquely from the bitcode. The graphic below shows the steps involved in the preparation and execution of smart contracts.

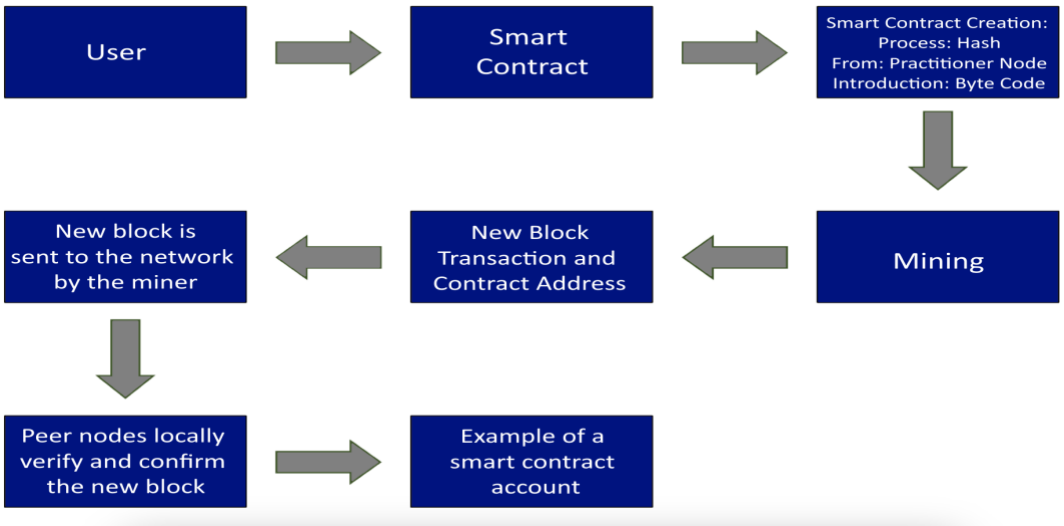

Figure 3.2: Preparation and Operation of Smart Contracts

As can be understood from the steps given in Figure 2, the process of deploying a smart contract is triggered by a transaction. The entry into force of the transaction takes place with this trigger. Mining is performed "competitively" by peer nodes. The new block created by the miner will be published to the peer nodes. The peer nodes

[28] Ethereum: A Secure Decentralised Generalised Transaction Ledger, 2023. https://ethereum.github.io/yellowpaper/paper.pdf. (accessed 12.12.2023)
[29] Margherita Renieri, Ethereum Smart Contracts Optimization (Master Thesis, 2020), URL:https://computerscience.unicam.it/marcantoni/tesi/Ethereum%20Smart%20Contracts%20Optimization.pdf (accessed 12.12.2023)

will verify the new block before it is officially added to the local blockchain. The new instance of the smart contract contains a unique address. This address must be registered for the next step, the execution of the contract.

The next step is how smart contracts work. On the Ethereum network, users and smart contracts use alphanumeric addresses, which are their identities within the network, to interact with each other.[30] To interact with functions within smart contracts, requests must be sent from users or other smart contracts. The steps that are executed after the request is sent are described in the graph below.

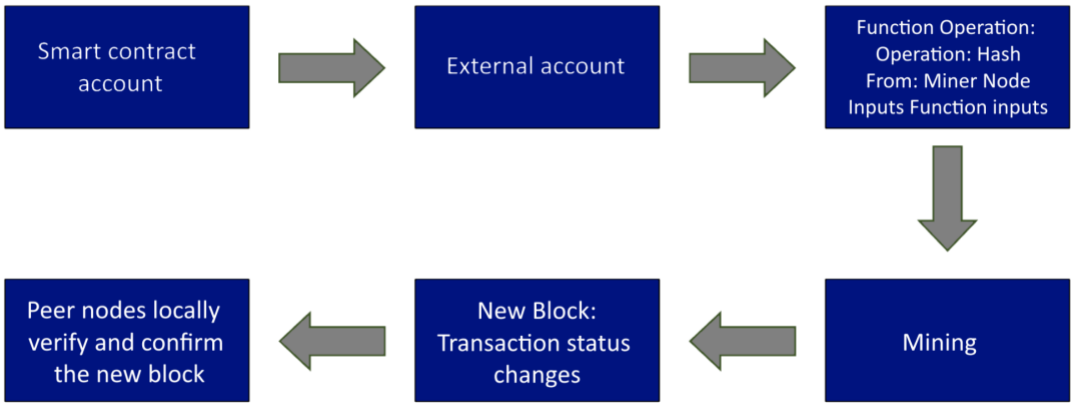

Figure 3.3: How Smart Contracts Work

As can be seen from the steps given in Figure 3, the address of the smart contract is obtained to execute a function defined in the smart contract. Each function that makes a state change calls a transaction. The transaction needs to be processed by miners to be validated. This transaction will be in the new block created after a successful mining operation. The new block created by the miner will be published to peer nodes. Peer nodes will authenticate the new block, allowing it to be officially incorporated into the local blockchain.[31]

[30] Oluwatosin Serah, Mastering Addresses In Ethereum (Jun 1, 2023), URL:https://medium.com/@ajaotosinserah/mastering-addresses-in-ethereum-5411ba6c3b0f (accessed 15.12.2023).

[31] Sebastian Ma, Getting Started With Ethereum Private Blockchain, URL:https://dzone.com/refcardz/getting-started-with-etherium-private-blockchain (accessed 13.12.2023).

3.4. Key Features of Smart Contracts

In fact, it is not a new phenomenon that transactions are automated by using computers or that the will to establish a contract is made through computers. Electronic contracts, which have an increasingly larger place in our lives with digital transformation, refer to agreements implemented by the parties using an electronic communication tool, often even over the internet. Although smart contracts are also established electronically, they are not identical to electronic contracts. First of all, in smart contracts, unlike electronic contracts, there is a transaction or execution made using "distributed ledger technology". Secondly, unlike electronic contracts, the contract parties or third parties do not need to act in order for the smart contract to be executed. In smart contracts, actions and counter-actions, determined in advance in the programming language, are automatically exchanged using software and hardware.

In electronic contracts established on the Internet, the element of trust is an important weakness. Because the internet is not a safe environment. For this reason, reliable intermediaries are needed to confirm the identities of people who do not know each other and do not trust each other and to ensure that the transaction can be carried out. However, in smart contracts issued electronically, the contract parties do not need to know and trust each other. "Trust", which is the basis of contract law, is replaced by trust in the computer algorithm in smart contracts established on the blockchain. The execution of the smart contract is guaranteed by the principles in the blockchain. Even if the parties to the contract do not know or trust each other, they can easily make transactions through smart contracts without the need for intermediaries, since they trust the working mechanisms of the blockchain system.[32] In addition, smart contracts established electronically must have digital content. Acquisitions that cannot be digitally verified cannot constitute the subject of a smart contract.

[32] Eliza Mik, Smart contracts: terminology, technical limitations and real world complexity (Law, Innovation and Technology Vol. 9(2), 2017), p. 269.

Smart contracts are computer programs prepared in a programming language. In countries where the principles of freedom of contract and, accordingly, freedom of form have been adopted, this situation does not pose a legal problem. Because, as long as the parties agree, it is possible to establish contracts in foreign languages or encrypted.

Since smart contracts are essentially computer programs, it is thought that it is not possible to make contracts that are required to be made by law or by the parties in a certain way, with smart contracts.[33] For example, it is not possible to sell a house, which must be done officially with the officer, on the blockchain.[34] However, with the legal regulations to be made, if it is determined that the private and public keys that run smart contracts are equivalent to a secure electronic signature, these transactions may be possible through smart contracts.

Smart contracts have conditional content. They work on the same principle as product vending machines.[35] If the buyer inserts 5 Euros into the vending machine, the machine gives him an item of the buyer's choice worth the 5 Euros. This indicates that when the condition agreed upon by the parties while preparing the smart contract is fulfilled, the contract will be executed in the direction in which the smart contract is programmed. For example, in the smart contract, the parties can decide to conclude a loan agreement between the borrower and the lender when loan interest rates drop to a certain rate. To explain with another example, the parties can make a smart contract in which the insurance compensation can be automatically determined and paid to the passenger in case of a flight delay beyond a certain hour or flight cancellation.

The conditions previously determined by the parties may be conditions that the smart contract can determine from the data in the blockchain ("on-chain"), or they may

[33] Clifford Chance, “Smart Contracts: Legal Framework and Proposed Guidelines for Lawmakers”, October 2018, URL: https://talkingtech.cliffordchance.com/en/emerging- technologies/smart-contracts/smart-contracts--legal-framework- and-proposed-guidelines-for-law.html (accessed 14.12.2023).
[34] Mateja Durovic and Franciszek Lech, The enforceability of smart contracts (Italian Law Journal, 2019), p. 493.
[35] Raskin, The Law and Legality of Smart Contracts, p.312.

require the transfer of data outside the blockchain ("off-chain") to the smart contract. In this case, the smart contract determines whether the condition specified by the parties in the smart contract has been fulfilled through the information source called oracle.[36] This information may be related to interest rates or aircraft landing and take-off times.

The conditions set by the parties for the smart contract to be implemented must be clear and precise. Statements that are difficult to understand and require interpretation used in traditional contracts cannot be determined as a condition for the realization of smart contracts. Because it is not possible for the smart contract to interpret such statements. This makes smart contracts inflexible and deterministic contracts.[37] For this reason, it is unlikely that there will be differences in interpretation in smart contracts that may occur in classical contracts.[38]

Some smart contracts, although they have conditional content, remain outside the scope of law. For example, a smart contract might program shutters to close when sunlight reaches a certain level. In this case, the condition is that the sunlight reaches a certain level, but when this condition is met, closing the shutters has no relevance to the legal order.

Smart contracts are automatically implemented once established. The parties do not need to take any additional action or intervene for the transaction to take place. Due to the structure of the smart contract, it is not possible for the parties to make such an additional transaction or intervention or influence the transaction. When it is determined by the smart contract protocol that the condition stipulated for the implementation of the smart contract has been met, the smart contract is automatically implemented ("self-enforcement") without the need for the intervention of the parties

[36] Eric Tjong Tjin Tai, Challenges of smart contracts: Implementing excuses (Cambridge University Press, 2019), p. 80.
[37] Kevin Werbach and Nicolas Cornell, “Contracts Ex Machina” (Duke Law Journal, 2017), p. 365.
[38] Michèle Finck, Blockchain Regulation and Governance in Europe (Cambridge University Press, 2019), p. 27.

or any intermediary (such as banks or financial institutions).[39] Therefore, smart contracts are expected to reduce transaction costs and expenses required to establish and implement traditional contracts.

3.5. Smart Contract Types

3.5.1 Off-chain Smart Contracts

Smart contracts are sometimes set up to partially or fully implement on the blockchain the gains agreed upon in a contract established outside the blockchain.[40] In this case, two types of contracts can be mentioned: the main contract established by traditional means outside the blockchain and the smart contract established to implement this contract in the blockchain. The parties first create a contract in natural languages and then agree that the parts of this contract that can be implemented with computer code can be implemented automatically with a smart contract.

In off-chain contracts, translating a contract written in natural language into programming language is a difficult task for two reasons. First, despite advances in the field of machine learning, there is not yet a computer program that can perform this translation accurately. Secondly, a contract written in natural language contains abstract and long expressions and concepts due to the nature of the legal language. Therefore, the text that needs to be translated into computer code is a text written in legal language. This requires first interpreting what legal expressions mean and then translating them into code.

In off-chain smart contracts, when there is a conflict between the main contract and the provisions of the smart contract, the provisions in the main contract prevail. When the smart contract needs to be interpreted, the provisions of the main contract are taken into account primarily in accordance with the principle of superiority of individual agreements.

[39] Jeremy Sklaroff, "Smart Contracts And The Cost Of Inflexibility" (University of Pennsylvania Law Review, 2017), p. 276.
[40] IOTA Foundation, "An Introduction to IOTA Smart Contracts", URL: https://blog.iota.org/an-introduction-to-iota-smart-contracts-16ea6f247936/ (accessed 15.12.2023).

3.5.2. On-chain Smart Contracts

It is also possible to establish smart contracts first and only on the blockchain, without a prior contract being established by the parties, or even without the parties knowing each other. On-chain smart contracts are built from start to finish in a programming language. Accordingly, if an issue is not included in the smart contract code, this issue does not become part of the agreement between the parties of the smart contract. Smart contract code plays a central role in both the establishment and execution of the contract.[41]

On-chain smart contracts do not have the ambiguity problem that natural languages pose. In this way, the difficulties in translating legal language into computer code are eliminated. However, for the contract to properly emerge as a direct code, the smart contract code must be written by people with knowledge of software and law. In on-chain smart contracts, parties can set out their rights and obligations more clearly and regularly from the beginning, and objective and measurable conditions necessary for the implementation of the smart contract can be determined.[42]

3.6. Advantages of Smart Contracts

Smart contracts include a structure that is organized entirely in a digital environment and enables contracts to be executed without external intervention if certain conditions are met. The code written in this structure, which is used by using computer programs, is stored in blocks within the blockchain and cannot be tampered with in any way afterwards.[43]

One of the key advantages of smart contracts is certainty. Written contracts in daily life allow for some disputes and breaches of contract between the parties. However, smart contracts have a more determinable content compared to normal

[41] Luca Olivieri, Fausto Spoto, and Fabio Tagliaferro, On-Chain Smart Contract Verification over Tendermint (Financial Cryptography and Data Security. FC 2021 International Workshops, 2021), URL:https://iris.univr.it/retrieve/e14ff6e5-d38d-0209-e053-6605fe0ad24c/on-chain_verification_smart_contracts.pdf

[42] Chance, "Smart Contracts: Legal Framework and Proposed Guidelines for Lawmakers, p.12-13.

[43] Gülşen Gedik, Akıllı sözleşmelerin vergilendirme süreci üzerindeki etkileri (Legal Mali Hukuk Dergisi, 2020), p.1209.

written contracts due to 2 main features of smart contracts. Due to its "if this, then that" loop, it will logically reduce the errors that people make in reading and writing and allow for less ambiguity. In addition, due to blockchain technology, information about the content of the smart contract is encrypted and stored in the system.[44] A copy of this information is available to all persons involved in the system. It is ensured that the conditions set in the smart contract are undeniably recorded in the system by all stakeholders.

Another advantage of smart contracts is their independence from third party intervention. It is thought that if any third party is eliminated in the execution of contracts, the code on the network will automatically execute the contract, thus preventing manipulation of the contract by humans.[45]

Smart contracts are less costly than classic contracts. Smart contracts are less costly than classical contracts due to the fact that the time required for the performance of a classical contract is reduced with smart contracts, no money is paid to any intermediary for the performance of the contract in this regard, and the parties are prevented from paying extra money due to improper performance in classical contracts.[46]

The encryption of smart contracts and their data in a decentralized distributed data network using cryptography techniques in blockchain technology increases the security of the contracts. Since smart contracts are copied on the code in each blockchain by every user on the blockchain network, it is technically very difficult to break into the system without authorization.

In addition, smart contracts are likely to open up other opportunities or business models, as they are characteristically an automatically implemented contract model. To give an example in this regard, in the future, there is an idea that electric

[44] Ethereum: A Secure Decentralised Generalised Transaction Ledger, 2023. https://ethereum.github.io/yellowpaper/paper.pdf.
[45] Silas Nzuva, Smart Contracts Implementation, Applications, Benefits, and Limitations, 2019. URL:http://dx.doi.org/10.7176/JIEA/9-5-07.
[46] Cemal Araalan, Akıllı Sözleşmeler (Terazi Hukuk Dergisi, 2020), p.512.

cars can be self-charged by induction with IoT(Internet of things) technology by utilizing the relevant station or traffic lights as they pass on the road.[47] With a smart contract, the conditions under which an electric car can charge itself using IoT technology can be uploaded as software to a code on the blockchain network.

3.7. Disadvantages of Smart Contracts

Due to the encryption on the blockchain network, which we mentioned in the advantages section of smart contracts, it is difficult to enter the system without permission, but it is obvious that the system does not yet inspire sufficient confidence in users in terms of information security since blockchain technology is still a new technology. The past and recent cyber-attacks on the Ethereum and Bitcoin platforms, which are among the platforms where smart contracts are especially implemented, show that the system in question has some weaknesses in terms of information security and it is an inevitable fact that it may create some question marks in terms of trust.[48]

Regulations on blockchain and smart contracts have been insufficient. In many countries around the world, it is seen that there are already uncertainties about the legal rules under which smart contracts should be regulated. In order to effectively combat cyber-attacks, especially in blockchain technology, and to prevent financial and reputational losses as a result of these attacks, it is considered critically important for state legislators to enact effective regulations on this issue.[49]

Confidentiality of smart contracts cannot be ensured. While it is possible to ensure confidentiality in traditional written contracts by physically storing the contract by the parties, it is stated that smart contracts cannot be preferred in terms of confidentiality since the codes related to smart contracts are recorded in the

[47] It is known that the German company RWE has developed a project for electric car users to benefit from this technology by communicating directly with electric charging stations using IOT technology through smart contracts on the Ethereum platform. For related news, see. https://www.trustnodes.com/2017/04/29/germanys-energy-giant-launches-100s-ethereum-based-electric-cars-charging-stations. (accessed 27.12.2023)

[48] Ahmet Usta and Serkan Dogantekin. Blockchain 101 (BKM, 2017), p.135.

[49] Raskin, The Law and Legality of Smart Contracts, p.309.

distributed data network on the blockchain network and are open to all stakeholders in accordance with the consensus mechanism.[50]

Smart contracts need access to external information. Since smart contracts work on the blockchain network as a code, reliable data systems called oracles are needed to transfer events and information from external systems to the blockchain network.[51]

Even though smart contracts are capable of automated transactions, they are systems that are programmed by humans and run on code embedded in the blockchain. This makes it incredibly difficult to modify or renegotiate a smart contract once it has been activated.[52] This lack of flexibility can be costly, problematic and time-consuming in the event of a possible breach or the emergence of unforeseen circumstances, or if the terms of the contract need to be readjusted. For example, in a traditional contract, if the parties to the contract want to make a change to the terms of the contract, the contract can be renegotiated. However, once the code underlying smart contracts is placed on the blockchain, it becomes immutable unless there is a protocol that allows the parties to make changes by consensus. This means that a change in the terms of the contract would require the creation of a new smart contract. This would naturally lead to additional costs and potential complexity between the parties. In addition, a change to the terms of a smart contract may result in potential legal costs as it may require obtaining legal advice and guidance, with the additional costs of creating a new smart contract.

3.8. Blockchain Technology

In general terms, blockchain can be defined as a decentralized, immutable database application where transactions are stored publicly and pseudonymously in the form of blocks by being approved by stakeholders in the network, and which

[50] Deloitte, Getting smart about smart contracts (CFO Insights, 2016). URL:https://www2.deloitte.com/content/dam/Deloitte/tr/Documents/finance/cfo-insights-getting-smart-contracts.pdf. (accessed 27.12.2023)
[51] Mik, Smart contracts, p.23.
[52] Weiqin Zou and David Lo, Smart Contract Development: Challenges and Opportunities (IEEE Transactions on Software Engineering (Volume: 47, 2021).

grows as blocks are added.[53] First of all, blockchain technology has a decentralized structure. More concretely, blockchain is a "peer-to-peer" / P2P network with a decentralized data recording system and a decentralized consensus system.[54]

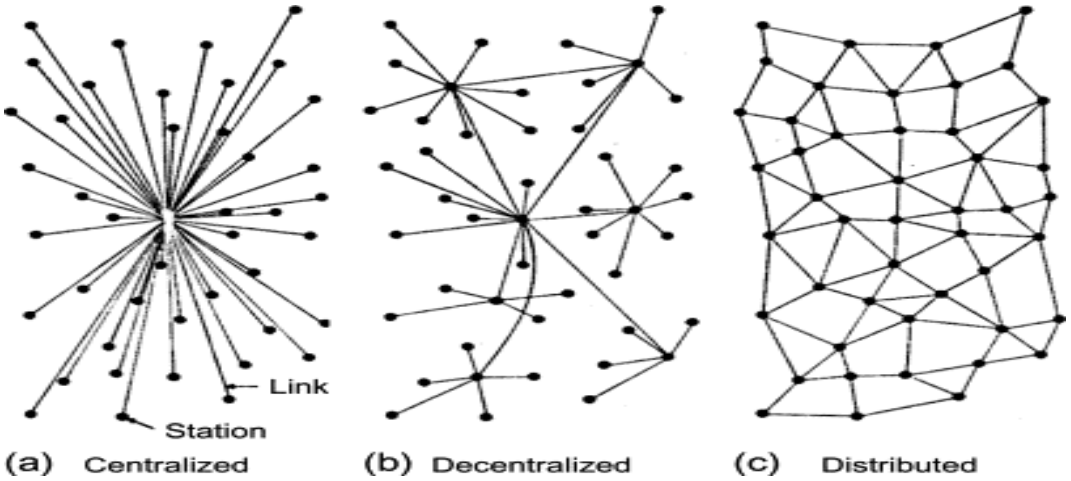

Figure 3.4: The image included in Paul Baran's On Distributed Communications Networks (1962) illustrates the two basic systems of data transmission networks: centralized and distributed, also known as grid or mesh.

Decentralization refers to an autonomous structure within distributed ledger technologies that makes it possible to understand the validity and security of a transaction without any centralized entity. Here, the sustainability of the system does not depend on the participation of each user in the blockchain network, but a key majority is considered sufficient.

Another feature of blockchain technology is its immutability. In the theoretical sense, a change would only require changing the data subject to the change before and after the data subject to the change, as well as the blocks associated with it.[55] On the other hand, a hacker attack is not very meaningful because the transaction history is stored on many different processors.[56] They can recognize a modified blockchain and will not allow the transaction.

[53] Joachim Schrey and Thomas Thalhofer, Rechtliche Aspekte der Blockchain (NJW, Heft 20, 2017), p.1431.
[54] Mustafa Tanrıverdi, Blokzinciri Teknolojisi Nedir? Ne Değildir? (Bilişim Teknolojileri Derneği No:12, 2019), p.204.
[55] Ece Su Üstün, TBK Kapsamında Geleneksel Sözleşmeler ile Mukayeseli Olarak Akıllı Sözleşmeler Blokzinciri Teknolojisi, (Ankara 2021), p.30.
[56] Stephan Breidenbach, Die Digitalisierung des Rechts (in: Rechtshandbuch Legal Tech, München 2018), p.17.

Intermediation is another feature of the blockchain. In this sense, eliminating the need for intermediary institutions such as banks and notaries, reducing costs and increasing trust with end-to-end encrypted cryptographic transactions are among the prominent features of blockchain technology.[57]

In blockchain technology, which is likened to a trust machine and is said to provide trustless trust, trust in the certainty and directness of this technology replaces trust in each other. While disintermediation is a prominent feature, we can point out that new intermediaries such as wallet service providers, cryptocurrency exchanges, miner pools, etc., which are preferred in the blockchain ecosystem especially for their user-friendly interfaces, may also come into question.[58]

In addition, privacy is at the forefront in public blockchain networks. Users can choose to use pseudonyms and not share their personal information with the other party, thus fulfilling their privacy and confidentiality needs.

Another aspect that needs to be emphasized is the transparency of blockchain networks, where transactions must be conducted in a way that can be seen and audited by blockchain participants.[59] In the doctrine, it is stated that the simultaneous inclusion of transparency and confidentiality among the features of blockchain is not a contradiction, but rather reflects the emphasis on data, not parties.

Another feature of the blockchain is security. Some of the features mentioned above also support this feature. In this sense, first of all, the decentralized structure of the blockchain provides trust and certainty.[60] From the user perspective, blockchain is a technology that attracts attention with its security aspect. Different encryption techniques coexist here. The cryptographic encryption technique used in blockchain technology has a special feature.

[57] Rolf H. Weber, Blockchain als rechtliche Herausforderung (Jusletter IT, 2017), p.3.
[58] Üstün, TBK Kapsamında Geleneksel Sözleşmeler ile Mukayeseli Olarak Akıllı Sözleşmeler Blokzinciri Teknolojisi, p.64.
[59] Tanrıverdi, Blokzinciri Teknolojisi Nedir? Ne Değildir?, p.205.
[60] Dimitrios Linardatos, Smart Contracts - einige klarstellende Bemerkungen (K&R, 2018), p.5.

Blockchain, as the name suggests, is a structure made up of blocks. Blocks contain data and manage communication between users, who record and control every transaction that interacts with the data and give their consent. Blocks contain chunks of legitimate transactions that are hashed and structured into a Merkle tree. Each block contains the cryptographic hash function of the previous block in the blockchain and combines the two. The blocks thus linked together form a chain. This process continues in a continuous loop in the network, verifying the integrity of the previous block back to the original starting block (Genesis block). In a blockchain, each block has its own unique signature. In blockchain applications, signatures are generated by a special mathematical application. As soon as each block is created, information including date and time information is added to the block. Thus, blocks of data, each with its own signature, recorded at a specific point in time, are sequenced one after the other, forming a blockchain. [61]

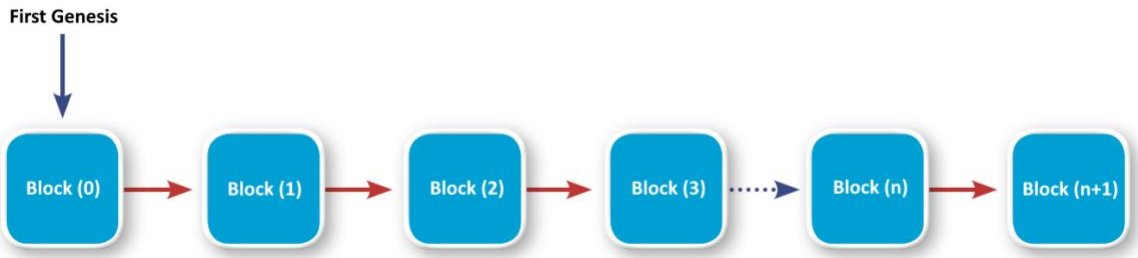

Figure 3.5: Structure where all blocks follow each other after the first block (Genesis) recording.

Now, in this new structure, even in the event of a change, each block will have the signature of the previous block at the time of its creation, so a careful check of our blockchain will easily reveal that the order has been broken. The first block created is called Genesis, or the starting block, since there is no block before it, and it carries only its own digital signature.[62] However, each subsequent block will carry the unique

[61] Marcela Tuler de Oliveira and Célio Vinicius N. Albuquerque, Towards a Performance Evaluation of Private Blockchain Frameworks using aRealistic Workload (Conference Paper, February 2019).
[62] Hector Roussille, Önder Gürcan and Fabien Michel, AGR4BS: A Generic Multi-Agent Organizational Model for Blockchain Systems (MDPI, 2021).

signature of the previous one, as well as its own. Thus, a sequential record structure becomes possible in the digital world.

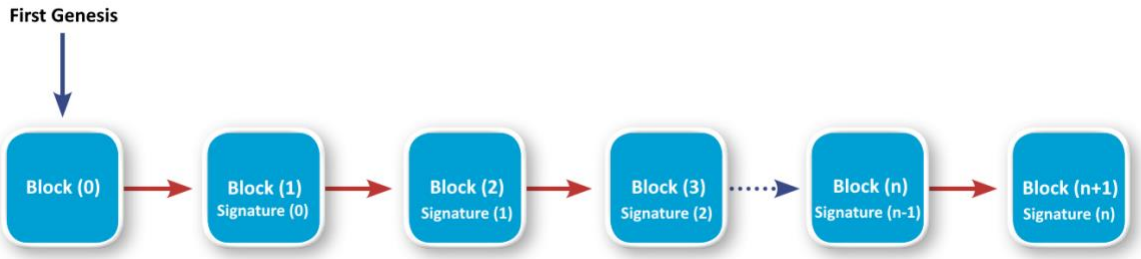

Figure 3.6: Structure in which all new blocks follow each other after the first block (Genesis) registration, including the digital signature of the previous block.

The block duration is a period that we set when designing the blockchain. It is the time it takes for the network to generate one additional block in the blockchain. It is up to us to determine the block duration. But it is important to remember that blocks contain transactions and data. The longer the block generation time, the more data we can get into the block, and if we are a currency, our supply will speed up considerably from the queue of transactions waiting in line to enter the block. We also need to set the block duration in direct proportion to the block size. For example, if we set the block size to 1024 KB, we can only put 1024 KB of data into the block. If we set the block duration to 5 minutes, we need to generate new blocks when the capacity of our block is full. Otherwise, transactions become queued and it becomes very difficult to move from point to point in our network. For example, Ethereum has a block time of 14 to 15 seconds, Litecoin 2.5 minutes and Bitcoin 10 minutes.[63]

3.9.1. Authentication and Encryption on Blockchain

The asymmetric key algorithm used in blockchain technology has public and private (encryption) keys. More concretely, the security technology in question here is primarily a public key and also a private key (with double-sided encryption).[64] These

[63] Bitstamp, What is block time? August 17, 2022, URL: https://www.bitstamp.net/learn/crypto-101/what-is-block-time/. (accessed 28.12.2023)
[64] Markus Krall, Bank-, Börsen- und Finanztransaktionen – Umwälzung durch die Blockchain (Rechtshandbuch Legal Tech, München 2018), p.18.

cryptographically overlap with each other. We can see the encryption and decryption in the asymmetric key algorithm in the following example image.

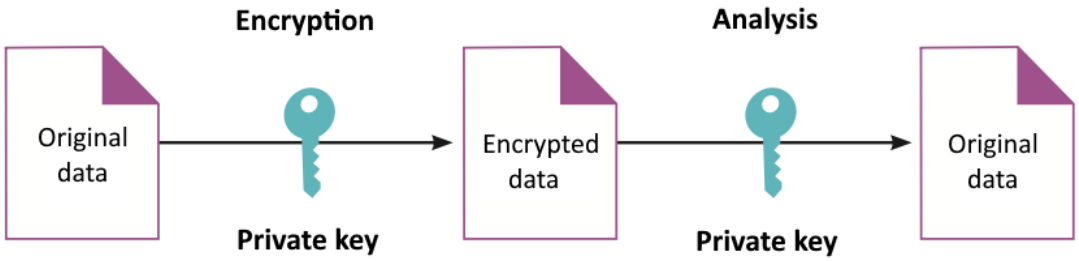

Figure 3.7: encryption and decryption in the asymmetric key algorithm

Because of the mathematical connection between them, the public key is generated only from the private key and there is only one private key corresponding to each public key. To use an analogy often used in internet mobile banking, if the public key is a person's IBAN number or account number, the private key is their banking password. The private key serves to digitally sign the transaction. One party signs a transaction with its private key and sends it to the other party (in the case of a smart contract).[65] The digital signature in this transaction serves to authenticate the user transmitting the message, to ensure that the fact of transmission of this message cannot be denied, and to provide assurance that it has not been altered during transmission. This transaction is also audited by other users in the blockchain with a public key.[66] In this way, it is ensured that the transaction was carried out by authorized parties.

In addition, what needs to be ensured is that the relevant party to the contract does not make any prior disposition of the product that is the subject of the transaction. Double expenditure: Refers to spending cryptocurrency more than once with the same ownership information and the same digital signature. It is one of the risks of not being able to verify cryptocurrency activities by a centralized system.[67] For

[65] Martin Hanzl, Handbuch Blockchain und Smart Contracts (Linde Verlag, 2020), p. 18.
[66] Eleonor Gyr, Blockchain und Smart Contracts: Die vertragsrechlichen Implikationen einer neuen Technologie (Basel 2019), p.60.
[67] Hukuk, düzenlemeler ve Kamu İlişkileri Çalışma Grubu, Blokzinciri Teknolojisi Terminoloji Çalışması (Türkiye Bilişim Vakfı, 2019), p.14.

this, the decentralized processor in the blockchain network corrects and adjusts the transaction history, including the timestamp.[68] In this sense, blockchain technology does not have a centralized control structure that controls double spending, but it can prevent double spending with its security features such as transparency and reconciliation mechanism.[69]

Blockchain technology, whose foundations were laid with the birth of databases and the distributed ledger, needed to be protected from the security challenges of P2P (Peer-to-peer) and other vulnerabilities.[70] First of all, a solution was needed to hide the data from third eyes and make it quickly searchable in a large database. As a solution, encryption methods were incorporated into the network. Encryption transforms any data set into a seemingly random data set using a rule structure. This seemingly random data set can only be transformed into something original and meaningful by those who have the key used in encryption. For those who do not have this key, it is meaningless. Thus, no matter where and how the encrypted data is stored, it remains meaningful only to the key holder.

3.9.2. Hashing and Merkle trees

We can explain the hash function in a simple way with an example. Imagine that you have just bought a new product and when you pick it up and examine it, the packaging is torn or the box is damaged. When you encounter such a situation, you can easily guess that the product has been opened, used, perhaps replaced or damaged before. Hash functions perform exactly the same task for digital data. Hash functions weave a package over the desired data, just like a physical object, so that when the data is examined later, it is easy to know whether the data has been interfered with or altered.

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[68] BaFin, Distributed Ledger: Die Technologie hinter den virtuellen Währungen am Beispiel der Blockchain, (BaFin Journal, 2016), p.28-29. URL: https://www.bafin.de/SharedDocs/Veroeffentlichungen/DE/Fachartikel/2016/fa_bj_1602_blockchain.html. (accessed 28.12.2023)

[69] Benedikt Seiler and Daniel Seiler, Sind Kryptowährungen wie Bitcoin (BTC), Ethereum (ETH) und Ripple (XRP) als Sachen im Sinne des ZGB zu behandeln? (sui generis, 2018), p.149-163.

[70] Daron Dedeoğlu, A'dan Z'ye Blockchain (Kodlab, 2022), p.21.

Hash functions convert digital information or any input you make into a message of a certain length that cannot be returned. The data you enter, called a hash key, is converted by a mathematical operation into a hash value of a certain length, which is impossible to reverse engineer with today's computers.[71] In this way, the information or files you send are securely transmitted to the recipient. The hash value to be generated for each input, i.e. hash key, is unique.[72] The only way to get the same hash value is to enter exactly the same input into the hash function. Changing even a single character in the input text or file will result in a completely different, unrecognizable hash value.

Hashing Algorithm	Sample Data	Hash information
SHA-1	Sapienza Università di Roma	37c002ade9ea7821890c50d39da4a9a8febafe8e
SHA-1	Sapienza Università di Roma.	39d72ae88732554b9c68305c7af27c25d575b746

Figure 3.8: Completely changed hash information due to the insertion of a dot.[73]

While hashing and encryption sound like the same thing, they are different. In encryption, the information you enter is rendered unreadable by a specific algorithm and a decryption key, but if you have that decryption key, the data can be restored and read. In hash applications, the situation is a bit different. Since hashing is a one-way operation, even if the hash value is obtained, it is impossible to restore the input with today's computers.

In order to verify more than one element, a Merkle tree is constructed by summarizing the elements of the whole in pairs and obtaining a single summary value. Developed by Ralph Merkle in 1979, this structure can quickly verify chunks of

[71] Wahome Macharia, Cryptographic Hash Functions (London, 2021).
[72] European Data Protection Supervisor, Introduction to the hash function as a personal data pseudonymisation technique (October, 2019), URL:https://edps.europa.eu/sites/edp/files/publication/19-10-30_aepd-edps_paper_hash_final_en.pdf. (accessed 30.12.2023)
[73] https://www.hashgenerator.de/

data.[74] The elements in the data chunk are placed at the bottom level by creating a binary tree structure, then the binary summary values are taken to obtain a summary value for the whole tree. This value is the root value of the tree, and only by comparing this root value can it be verified that the entire tree has not been modified.[75]

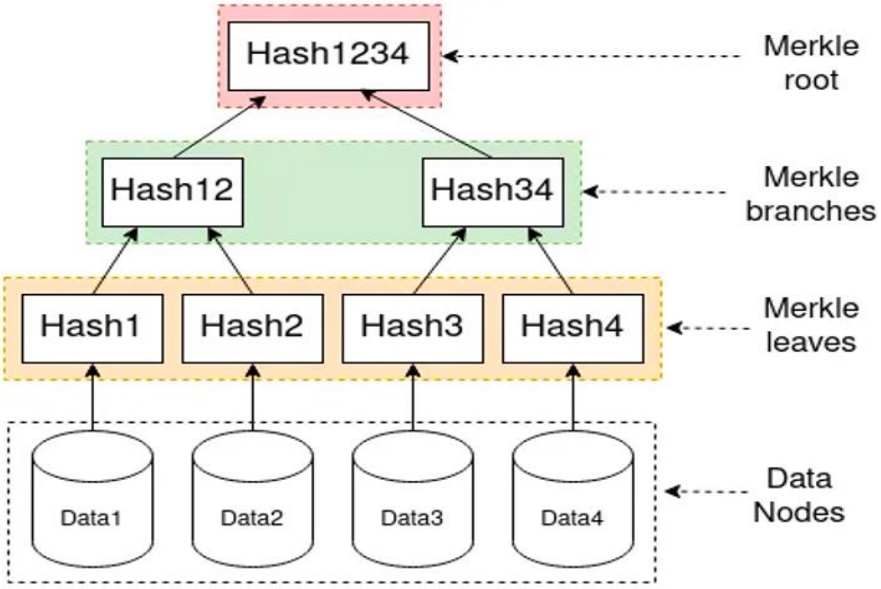

Figure 3.9: A very small Merkle tree[76]

3.9.3. Types of Blockchains

The distinction in types of blockchain network can be made according to the exit points.[77] First of all, public blockchain and private blockchain can be distinguished according to whether anyone can participate in the blockchain network (whether they are authorized to read it or not).[78] On the other hand, depending on whether anyone who wishes as a starting point has a certain control, more concretely, the authorization to write (add a block), the distinction is made between permissioned and permissionless blockchains.[79] Again, regarding permissioned blockchains, it is seen in

[74] Ralph C. Merkle, A Digital Signature Based on a Conventional Encryption Function (Advances in Cryptology CRYPTO '87, 1987).
[75] Usta and Dogantekin, Blockchain 101, p.114.
[76] Teemu Kanstrén, Merkle Trees: Concepts and Use Cases (February 16, 2021), URL:https://medium.com/coinmonks/merkle-trees-concepts-and-use-cases-5da873702318 (accessed 01.01.2024).
[77] Gyr, Blockchain und Smart Contracts, p.32.
[78] Hanzl, Handbuch Blockchain und Smart Contracts, p.6.
[79] Damla Beril Çubukçu, Teknik ve Hukuki Yönleriyle Akıllı Sözleşmeler (Ankara, 2021), p.14.

some studies that blockchain is also sub-divided according to whether it requires partial or complete permission.

Blockchains with open source code, such as Bitcoin, which we often hear about today, and Ethereum blockchain networks, which we will examine in the context of our topic, are public permissionless blockchain.[80] In private blockchain networks, there is a centralized structure, and it is often seen that transaction rights are subject to permission, in other words, it is a private permissioned blockchain.[81] Private blockchains can be used, for example, in sectoral projects or in exchanges between companies and public institutions. In the image below we can see a diagram of the types of blockchain.

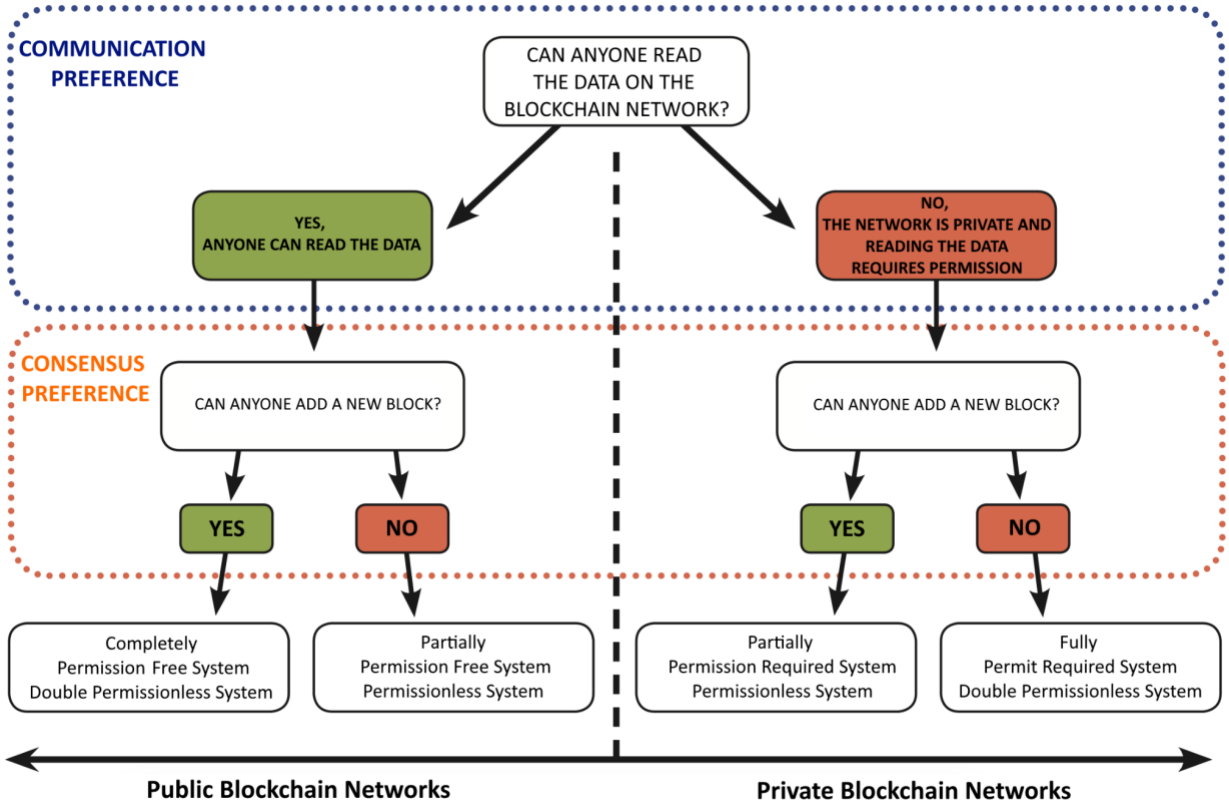

Figure 3.10: Blockchain types

We can visualize the structure in which being included in the blockchain network and participating in the consensus system is evaluated in terms of interest with the following diagram.

[80] Finck, Blockchain Regulation and Governance in Europe, p.20.
[81] Tanrıverdi, Blokzinciri Teknolojisi Nedir? Ne Değildir?, p.206.

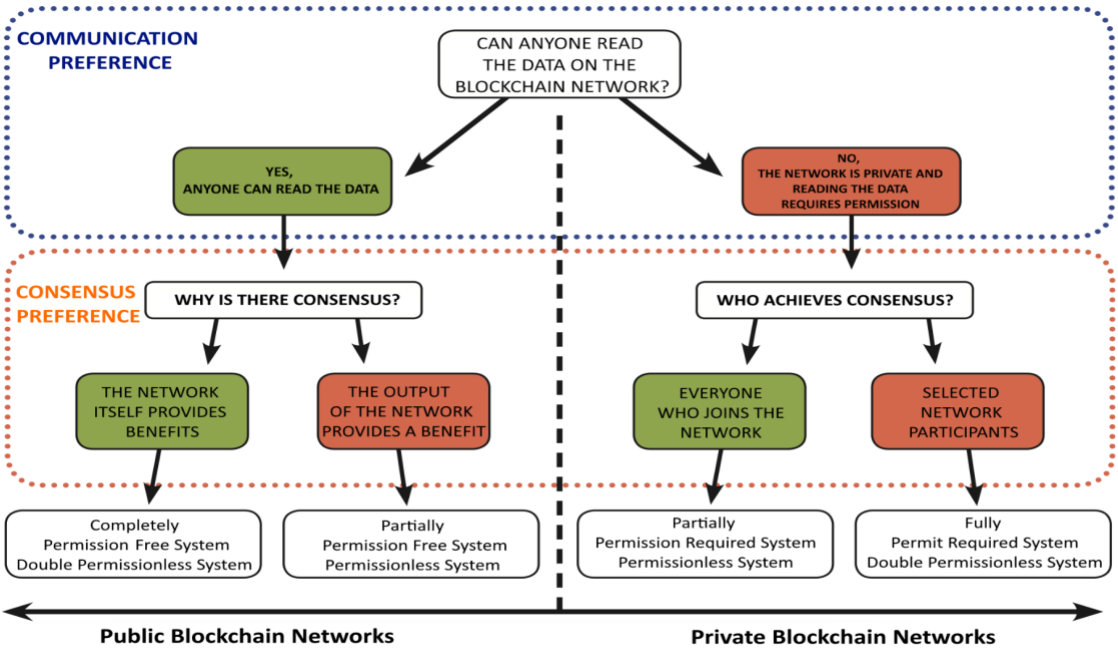

Figure 3.11: Consensus Interest

Although both diagrams are similar at first glance, the "Consensus Preference and Reason" layer is different.

3.9.3.1. Blockchain Networks that are Completely Permissionless

If you don't need permission to enter a blockchain network to read stored data, and you don't need permission to participate in the "consensus process" to add new blocks by complying with the network's "consensus structure", such networks are called "completely permissionless blockchain networks".[82]

The aim of such networks is to involve as many people as possible and for everyone involved to take part in the "consensus process". In this way, as more people join the network, the number of points in the network that have a copy of the data chain will increase and the network will become more and more secure.[83]

The question to be asked here is what will be the interest or the benefit to the people involved in this network? Anyone involved in any "completely permissionless blockchain network" must have a vested interest. In this case, the system itself has

[82] Amber Seira, Jeffrey Allen, Cy Watsky, and Richard Alley, Governance of Permissionless Blockchain Networks, (FEDS Notes, February 09, 2024), URL: https://www.federalreserve.gov/econres/notes/feds-notes/governance-of-permissionless-blockchain-networks-20240209.html (accessed 05.01.2024)

[83] Soner Canko and Okan Yildiz, Discover: The Secrets of Blockchain: BBN Phase I (2018), p.16.

value. An example of such a completely permissionless blockchain network is the Bitcoin platform, the most popular and the one that gave us blockchain technology. In the Bitcoin network, people participate in the system, creating an endpoint that participates in the "consensus process" within the network. They carry a copy of the data chain to make the network more secure. When they or other points in the network add a new block, they check whether it complies with the "consensus structure". Those who add a new block in this process (in accordance with the network's rules, of course) are rewarded with a certain amount of bitcoins by the network itself.[84]

3.9.3.2. Blockchain Networks that are Partially Permissionless

If you don't need permission to enter a blockchain network to read stored data, but you do need permission to add new blocks and participate in the "consensus process" by complying with the "consensus structure" of that network, such networks are called partially permissionless blockchain networks.[85]

In such networks, while the data provides value to those who access it, the network itself is often designed to serve private purposes.[86] Now, those involved in the "consensus process" of publicly accessible data records must be selected. To take a contemporary example, one of the most important problems in the world today is the reliability of news sources. Even very large news agencies, especially those on social media, are sometimes mistaken in reporting erroneous news. Let's consider a blockchain network created to solve this problem. Let's call it "Secure News Blockchain Network". In this network, each news is recorded as a new block and anyone who wishes can access this network and read the news. However, in order to add a new news item to the network, the "consensus structure" requires being an official news agency. When an official news agency sends a news item to the network,

[84] Ittay Eyal, Proof of Work and Blockchains (Distributed Cryptocurrencies and Consensus Ledgers, July 2017), URL:https://www.zurich.ibm.com/dccl/papers/eyal_dccl_slides.pdf (accessed 23.02.2024)
[85] Nikola Božić, Blockchain technologies and their application to secure virtualized infrastructure control (Artificial Intelligence [cs.AI]. Sorbonne Université, 2019), URL: https://theses.hal.science/tel-03337153.
[86] Tushar Dhiman, Vidit Gulyani and Bharat Bhushan, Application, Classification and System Requirements of Blockchain Technology, International Conference on Innovative Computing and Communication (ICICC-2020), 2020.

it must be approved by three other independent news agencies (the consensus process), and once these approvals are received, the news item is added to the network as a block.

Let's give another example: Let's consider a blockchain platform where independent musicians publish their tracks. In this case, anyone who enters the system can listen to and access all the bands. However, due to the "consensus structure", only independent musicians are allowed to add tracks to the system. The "consensus process" ensures that these tracks are original and unique. In this case, it is in the interest of those accessing the network to listen to the music, and in the interest of those providing the consensus to have their works recorded (taking into account the royalty and perhaps revenue processes).

Blockchain networks that are completely permissionless and partially permissionless are grouped as public blockchain networks because they are accessible to everyone.[87]

On the other hand, companies, organizations and public institutions may find it inconvenient to store data on and make use of open blockchain networks. Yes, it is possible to encrypt data and distribute it on such networks, but these encryptions can be broken or people with the keys can leak the information.[88] In short, there may be security concerns, or there may be no reason why the data to be written on such a network should be publicly available. This is where the other group, private blockchain networks, come in. The most basic feature of private blockchain networks is that in order to read the data stored on such networks, it is necessary to log in with permission from the network itself.

[87] Christine Helliar, Louise Crawford, Laura Rocca and Claudio Teodori, Permissionless and permissioned blockchain diffusion (nternational Journal of Information Management 54(3), 2020).
[88] Privacy International, SECURING PRIVACY: Privacy International on End-to-End Encryption (September 2022), p.24-30, URL:https://privacyinternational.org/sites/default/files/2022-09/SECURING%20PRIVACY%20-%20PI%20on%20End-to-End%20Encryption.pdf (accessed 24.02.2024)

3.9.3.3. Blockchain Networks that are Partially Permission Required

If we need permission to enter a blockchain network to read stored data, but then need permission to add new blocks and participate in the "consensus process" by complying with the network's "consensus structure", such networks are called partially permissioned blockchain networks. The goal of such networks is to make the recorded data accessible only to interested parties, but to include everyone who enters the network in the "consensus process".[89] In this way, a secure data recording system is created between those involved in the network.[90]

Let's explain this with an example: Let's take the example of a bank's remittance system between its branches. In order to keep track of remittance transactions between branches of a bank and access a blockchain network dedicated to that bank, it would be mandatory to have a branch of the bank. However, once a branch is logged in, it will now be involved in the "consensus structure" and the "consensus process". Thus, even if all the systems of one branch or a group of branches were to fail, remittances between other branches could continue and a very secure infrastructure would be established as data records are distributed across all branches.

3.9.3.4. Blockchain Networks that are Fully Permissioned

The most closed to outside influence among blockchain types, where we need permission to enter a blockchain network to read the stored data and then comply with the "consensus structure" of that network to add new blocks and participate in the "consensus process" without needing permission again, such networks are called fully permissioned blockchain networks.[91]

The aim of such networks is to make the recorded data accessible only to interested parties and to involve only selected parties in the "reconciliation process"

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[89] Papaioannou Dimitrios, Distributed Consensus Inference and Blockchain (July 2022), p. 27. URL: https://web.archive.org/web/20230218101307id_/https://ikee.lib.auth.gr/record/343441/files/GRI-2022-37407.pdf (accessed 24.02.2024).

[90] Karl Wüst and Arthur Gervais, Do you need a Blockchain? (2017).

[91] Siamak Solat and Philippe Calvez, Permissioned vs. Permissionless Blockchain: How and Why There is Only One Right Choice (December 2020), URL:https://www.researchgate.net/publication/349537863_Permissioned_vs_Permissionless_Blockchain_How_and_Why_There_Is_Only_One_Right_Choice (accessed 24.02.2024).

among those who are allowed access to the data.[92] In this way, a multi-layered secure data recording system is created between those involved in the network.[93]

A real-life example of a fully permissioned blockchain network is electronic fund transfer (EFT) transactions between banks. An EFT transaction requires access to a private blockchain network established between all banks, and you need to be a bank to gain access. Among the banks that enter the system, only two branches that will make EFTs between themselves are allowed to write data. Thus, these records will only be kept at the level of the bank and its branch. All banks and branches that are allowed into the system can read the data, but due to the "consensus structure", only the two branches that transact between themselves will be allowed to create records in the "consensus process".

3.10. Comparison of Smart Contracts Against Traditional Contracts

Smart contracts offer faster execution and efficiency than traditional contracts. Once the contract code is written and approved, execution is completed automatically if the contract clauses are realized. Traditional contracts, on the other hand, require a longer process as the contract preparation and review processes are manually monitored.

Because smart contracts are composed of digital code, they allow complex logic and events to be embedded in the contract code. Traditional contracts, on the other hand, do not have the ability to automatically adjust and execute to circumstances that may arise after the contract is created, even if external factors that may occur during drafting are taken into account.

Traditional contracts require the intervention of people, intermediaries and intermediaries during the creation, execution and enforcement phases.[94] Since smart

[92] United Nations Economic Commission for Europe, White Paper Blockchain in Trade Facilitation (2020), p.157-159. URL: https://unece.org/DAM/trade/Publications/ECE-TRADE-457E_WPBlockchainTF.pdf (accessed 24.02.2024).
[93] Mohammad Javad Amiri, Divyakant Agrawal and Amr El Abbadi, Permissioned Blockchains: Properties, Techniques and Applications (SIGMOD '21), 2021.
[94] Maren K. Woebbeking, The Impact of Smart Contracts on Traditional Concepts of Contract Law (2019).

contracts are decentralised and automatically implemented, the need for intermediaries and human intervention is minimal.[95]

In smart contracts, parties do not need to trust each other. Because they are result-oriented mechanisms that work with codes on blockchain networks, closed to external intervention. In traditional contracts, the parties have to trust each other, and in case of a possible mistrust, intermediary institutions will be activated and transaction costs will increase.

Smart contracts are a transparent and auditable system thanks to blockchain technology. Every transaction in the system can be viewed by other users and is recorded in a ledger that can withstand any possible breach. This ensures trust between the parties and encourages their accountability to each other. Traditional contracts are also potentially subject to audit and scrutiny, but without the same level of transparency as smart contracts.

3.11. Conclusions

In this chapter, we have described the characteristics of smart contracts and blockchain technology. We have noted that smart contracts are transparent and irreversible and can be exchanged between parties without the need for trust and intermediary institutions and organisations. We have also examined the advantages and challenges that smart contracts bring. The automated and transparent nature of smart contracts offers a number of advantages over traditional contracting processes. These advantages are to improve business processes such as fast execution, low costs and maximum transparency. However, this innovative technology is not without its challenges. The code-based nature of smart contracts can lead to technical errors and security concerns. In addition, the legal and regulatory framework is still unclear, which may make the adoption of these contracts difficult.

In addition, in this chapter, we have learned what purpose Blockchain technology serves (keeping data records reliably without the need for centralised

[95] Ebru Sensoz Malkoc, Zehra Badak and Selvi Nazli Guvenc, Evaluation of certain problems that may arise with smart contracts from a legal perspective (10th İstanbul Finance Congress, 2021), URL: https://dergipark.org.tr/en/download/article-file/2206910 (accessed 25.02.2024).

structures), that the rules for the data to be recorded are determined from the beginning, that the data progresses depending on a process while the data is recorded in blocks, that all records are distributed to many points, whether it is necessary to obtain permission to access Blockchain networks (open or private), that there are different situations according to the purpose of being involved in the reconciliation process (requiring permission and not requiring permission), that there are four different types in two main groups according to access and reconciliation permissions.

In the next chapter, we will define Ethereum, a decentralized and open source blockchain where smart contracts are most widely used, and the transaction costs of smart contracts.

ETHEREUM, SMART CONTRACTS AND TRANSACTION COSTS

4.1. Introduction

The Blockchain technology and philosophy underlying Bitcoin was developed by software developer Vitalik Buterin in 2013, along with Ethereum, perhaps taking it a step or two further.[96] Thus, Buterin changed the certificate used by Blockchain and developed Ethereum, Blockchain-based software with SHA-256 certificate. Ethereum enabled the production of documents consisting of code, called smart contracts.[97]

Ethereum is an open-source protocol, or more accurately an operating system, that is publicly available and calculates using chain modeling. Ether is the name given to the cryptocurrency produced by this platform, just like Blockchain and Bitcoin. Etherum's structure, which uses the Solidity[98] software language, enhanced with different certificates, has enabled the deployment and operation of pieces of code consisting of software called smart contracts on Ethereum.[99] Ethereum basically

[96] Vitalik Buterin, A Next-Generation Smart Contract and Decentralized Application Platform (Bitcoin Magazine, 2014), URL:https://bitcoinmagazine.com/business/ethereum-next-generation-cryptocurrency-decentralized-application-platform-1390528211 (accessed 02.01.2024).
[97] Stéphane Blemus, Law and Blockchain: A Legal Perspective on Current Regulatory Trends Worldwide (Revue Trimestrielle de Droit Financier, 2017), p.8.
[98] Solidity is an object-oriented, high-level language for implementing smart contracts. Smart contracts are programs that govern the behavior of accounts on Ethereum. For more information: https://soliditylang.org (accessed 02.01.2024).
[99] Vitalik Buterin, Bitcoin Is Not Quantum-Safe, And How We Can Fix It When Needed (Bitcoin Magazine, 2013), URL:https://bitcoinmagazine.com/technical/bitcoin-is-not-quantum-safe-and-how-we-can-fix-1375242150 (accessed 02.01.2024).

consists of three main structures. The main Ethereum blockchain structure, the Ethereum Virtual Machine[100] (EVM) and the side networks owned by third-party applications and the tokens connected to them. The Ethereum platform has its own cryptocurrency called Ether (ETH). Ether is used to run transactions/applications within the Ethereum platform, often associated with the metaphor of an engine needing gasoline to run. This approach is also designed to limit the impact of misuse or malicious use of the Ethereum platform, which can have a negative impact on the operation of the platform.

4.2. Ethereum and Smart Contract Relationship

It is possible to create a smart contract on Ethereum because it is possible to program code on Ethereum. Before the Ethereum blockchain, only cryptocurrency transfers could be made on the Bitcoin blockchain; with Ethereum, users can transfer cryptocurrency called Ether on the blockchain, as well as write new programs on Ethereum. Thus, a program written on Ethereum can work in a distributed manner by showing contractual features.[101] Indeed, smart contracts refer to the realization of transactions based on agreements in distributed ledger recording technology. Even here, the transfer of the asset subject to the programmed contract is performed automatically.

A smart contract is basically a program. It is therefore highly suitable for funding publicly accessible projects that are created and publicized with a simple protocol. This means that smart contracting is suitable not only for typical bilateral contracts, but also for multilateral agreements. Public project financing contracts and crowdfunding applications can be easily realized with this model. This is due to the fact that Ethereum has been providing a structure that lends itself to the concept of self-executing contracts since 2014. Decentralized Autonomous Organizations (DAO),

[100] Ethereum Virtual Machine (EVM): The structure that allows the program sent on Ethereum to run. The program sent on Ethereum is run by EVM in a distributed manner. EVM is the algorithm that connects all computer nodes in the world, known as the operating system of this technology and ensures the decentralization of Ethereum. For more information: https://ethereum.org/en/developers/docs/evm/ (accessed 02.01.2024).

[101] Alex Lipton and Stuart Levi, An Introduction to Smart Contracts and Their Potential and Inherent Limitations (Harvard Law School Forum, 2018)

which emerged in 2016, is a typical example of this.[102] DAO is a self-running smart contract on Ethereum, which is unincorporated, decentralized, without hierarchy or bureaucracy, and can be used for different purposes from project financing to voting by participating with kritpo assets called tokens on Ethereum. Even the deep crisis of confidence brought about by the hacking incident that occurred with the exploitation of a system vulnerability in DAO did not diminish the interest in disintermediated, direct, decentralized, autonomous transactions and contracts, and interest in what smart contracts offer and can offer has continued to grow, as demonstrated by the decentralized finance applications called DeFi (Decentralized Finance) these days.[103]

4.3. Structure, Operation and Sample Applications of Smart Contracts

One of the main features of Ethereum is the transfer of cryptocurrency. However, the function of Ethereum is not just about transferring cryptocurrencies. As in the case of DAO, the Ethereum blockchain can be used for many different purposes. These functions can be designed to include or exclude the transfer of cryptocurrency, or to provide any digital service through computers in different locations. Smart contracts make this possible. This has increased interest in the concept and concept of smart contracts. Computers, each located at a different point in the Ethereum network, are similar to Szabo's vending machines. Here, the computers connected to the Ethereum network are programmed just like automata, ready to perform a predetermined operation in the presence of predetermined conditions. Just like vending machines. What is different from Szabo's point of view is that the contract is established on the network and the contractual work is performed on the network. To explain; devices need to be connected to each other on the Ethereum network. In addition, these devices stand ready to send any information or currency data they contain to the other parties to the contract on predetermined terms and times through

[102] U.S. Securities and Exchange Commission, Report of Investigation Pursuant to Section 21(a) of the Securities Exchange Act of 1934:The DAO (Release No. 81207, July 25, 2017), URL:https://www.sec.gov/files/litigation/investreport/34-81207.pdf (accessed 02.01.2024).
[103] Marcella Atzori, Blockchain Technology and Decentralized Governance: Is the State Still Necessary? (December 15, 2015), p.8. URL: https://associazioneblockchain.it/doc/blockchain-technology-and-decentralized-governance-is-the-state-still-necessary/ (accessed 02.01.2024).

a program running on the network and created according to the will and agreement of the parties.[104] In order for this to be possible, that is, for transactions or payments to be made and recorded between computers on the network, there needed to be a common set of rules, a contract, that the machines agreed to. This is what Ethereum has provided. In other words, Ethereum was developed as a common language and infrastructure platform for transactions between a large number of computers in different physical locations, or any kind of machine with computer capabilities, and the smart contracts that define these transactions.[105]

The functioning of smart contracts running on Ethereum in today's sense is explained by Vitalik Buterin, the developer of Ethereum, as follows: "*Contracts are translated into computer language and stored in blocks. The parties to the contracts, which are copied to distributed ledgers, are kept 100% anonymous. The code snippet is prepared by specifying certain tasks and details (such as time limits, what goes where and where). When the time comes, it takes action to fulfill the transaction, and if the necessary conditions are met, the transaction is either completed successfully or canceled before completion.*[106] With its current structure, it is seen that smart contracts are very convenient to be used in the performance of payment obligation in contracts that create a continuous performance debt relationship, financial leases[107], escrow contracts[108], contracts where the consumer has the right to exercise his/her optional rights[109], online marketplace services[110], mobile application services that bring the parties together for the purpose of providing

[104] Dedeoğlu, A'dan Z'ye Blockchain, p.61.
[105] Turan Sert, Sorularla Blockchain (Türkiye Bilişim Vakfı, 2019), URL:https://bkm.com.tr/wp-content/uploads/2015/06/Sorularlablockchain.pdf (accessed 02.01.2024).
[106] Gianluca Busato, Vitalik Buterin Explaining How Smart Contracts Work (Jun 17, 2022), URL: https://medium.com/enkronos/vitalik-buterin-explaining-how-smart-contracts-work-3d17e5546a80 (accessed 02.01.2024).
[107] Macha Shanker, Use Case: Smart Contract for Lease Agreements using Blockchain Technology (International Journalof Scientific Research in Computer Science and Engineering, 7(6), 2019), p.3-6.
[108] Caroline Banton, How Escrow Protects Parties in Financial Transactions (Investopedia, August 17, 2023), URL:https://www.investopedia.com/terms/e/escrow.asp (accessed 02.01.2024).
[109] Tatiana Cutts, Smart Contracts and Consumers (West Virginia Law Review, 122(2), 2019).
[110] Calvin Pak, A Deep Dive Into Marketplace Smart Contracts (Medium, August 10, 2018), URL:https://medium.com/the-notice-board/a-deep-dive-into-marketplace-smart-contracts-587bbc8e9776 (accessed 02.01.2024).

products or services, transportation[111], insurance[112], banking[113], crowdfunding projects[114] and have already started to be used by being specific to many products and services.[115]

Smart contracts have the transformative power to revolutionize the financial industry. These digital agreements can automate a variety of tasks, such as payments, settlements, and complex derivative trading. By automatically executing predefined conditions when met, smart contracts greatly expedite transactions and cut costs.[116] Additionally, they enhance transparency and security in financial processes, as all executions are recorded on the secure and transparent blockchain network, creating an immutable transaction history. Smart contracts are key tools in finance for automating regulation checks. They work on their own to make sure rules are followed before allowing transactions, lowering the chance of breaking rules and facing fines. Plus, they simplify trade finance. Using these contracts in this field can make the process of getting a letter of credit less complex and quicker, cutting down on paperwork and time in international trade matters.[117]

A real-life example of smart contracting in finance is the use of decentralized finance (DeFi) platforms, which can be exemplified as a decentralized central bank governed by smart contracts, such as MakerDAO, which uses smart contracts to

[111] For a sample application in transportation see. Blockchain in Transport Alliance, URL:https://bita.studio (accessed 02.01.2024).
[112] For an example of Smart Contract implementation in the insurance sector, see. Nexus Mutual, URL: https://nexusmutual.io (accessed 02.01.2024).
[113] Smart Contracts in Financial Services: Getting from Hype to Reality, URL: https://www.capgemini.com/consulting-de/wp-content/uploads/sites/32/2017/08/smart_contracts_paper_long_0.pdf (accessed 02.01.2024); Blemus, Law and Blockchain, p.10.
[114] Mirko Zichichi, Michele Contu, Stefano Ferretti and Gabriele D'Angelo, "LikeStarter: a Smart-contract based Social DAO for Crowdfunding (IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), Paris, France, 2019), URL:https://ieeexplore.ieee.org/document/8845133 (accessed 02.01.2024).
[115] Blemus, Law and Blockchain, p.14.
[116] Zibin Zheng, Shaoan Xie, Hong Ning Dai, Weili Chen, Xiangping Chen and Jian Weng, An overview on smart contracts: Challenges, advances and platforms (Future Generation Computer Systems, volume 105, 2019), URL:https://doi.org/10.1016/j.future.2019.12.019.
[117] Dakota A. Larson, Mitigating Risky Business: Modernizing Letters of Credit with Blockchain, Smart Contracts, and the Internet of Things (Michigan State Law Review, 2019), URL:http://dx.doi.org/10.17613/y0f3-jk78.

provide decentralized lending and borrowing services.[118] MakerDAO allows users to generate DAI, a stablecoin pegged to the US dollar, by locking collateral in the form of Ethereum or other supported cryptocurrencies within a smart contract. Since the system aims for the DAI to always be equal to 1 US dollar, after a certain liquidation price, it will sell the collateral 3% below the market price in order to arbitrage the DAI price to stay close to 1 dollar, and it succeeds. The transaction works as follows: A user who wants to borrow DAI stablecoin deposits Ethereum as collateral into a smart contract on the MakerDAO platform. The smart contract figures out the DAI amount that can be borrowed by considering the present market value of the Ethereum deposited and the loan, to value ratio set by the platform. In case the collaterals worth drops below a level because of market changes the smart contract steps, in to keep the system stable by starting a liquidation procedure to sell off the collateral and guarantee the loan is fully backed.[119] This entire procedure is overseen by contracts starting from granting the loan to selling off collateral all without relying on conventional financial middlemen. It showcases how smart contracts have the potential to enhance the efficiency, transparency and accessibility of services allowing individuals to participate in lending, borrowing and other financial transactions directly on the blockchain.

Improving Supply Chain Management, with Innovative Technology Smart contracts offer advantages in the field of supply chain management. They have the potential to transform how transactions are documented and authenticated throughout the supply chain leading to improved effectiveness and openness.[120] By utilizing contracts individuals involved in the supply chain can automatically uphold agreements and validate transactions based on predetermined rules. This facilitates

[118] The Maker Protocol: MakerDAO's Multi-Collateral Dai (MCD) System, White paper, URL: https://makerdao.com/en/whitepaper#abstract.
[119] Kaihua Qin, Liyi Zhou, Pablo Gamito, Philipp Jovanovic and Arthur Gervais, An Empirical Study of DeFi Liquidations: Incentives, Risks, and Instabilities (IMC '21: Proceedings of the 21st ACM Internet Measurement Conference, 2021), URL:https://doi.org/10.1145/3487552.3487811.
[120] Angwei Law, Smart contracts and their application in supply chain management (Massachusetts Institute of Technology Graduate Theses, 2017), URL:https://dspace.mit.edu/handle/1721.1/114082.

monitoring and tracking of products automatic validation of product quality and adherence to regulations well as more efficient inventory control. Moreover smart contracts can bolster sustainability initiatives, in the supply chain by ensuring transparency and traceability. This enables oversight of standards and advocacy for fair trade practices.

A known real life example of smart contracts, in supply chain management involves the partnership among Walmart, IBM and Tsinghua University to improve the monitoring and safety of food products in China using blockchain technology.[121] This joint effort, which is part of the IBM Food Trust network employs blockchain and smart contracts to establish a record of food product journeys from the farm to the store shelves.[122] Within this framework every participant in the supply chain including farmers, processors, distributors and retailers contributes information about food products on a shared blockchain. Smart contracts are used to automate and uphold agreements between these parties. These agreements can include tasks such as ensuring that a shipment of produce has been stored at the temperature throughout its journey or confirming the legitimacy of certification.[123] For example if a batch of pork is being transported from a farm to a retailer the smart contract might stipulate that the meat must be maintained within a temperature range. Sensors within the shipment can capture temperature data on the blockchain. If this data aligns with the conditions set by the contract then it confirms that the shipment complies with requirements automatically. However if theres any deviation in temperature outside of what was agreed upon range then alerts can be triggered by the contract, for parties

[121] Minky Sharma and Pawan Kumar, Adoption of Blockchain Technology: A Case Study of Walmart (Blockchain Technology and Applications for Digital Marketing, 2021), URL: http://dx.doi.org/10.4018/978-1-7998-8081-3.ch013.
[122] Archana Sristy, Blockchain in the food supply chain - What does the future look like? (Walmart Global Tech, 2021), URL: https://tech.walmart.com/content/walmart-global-tech/en_us/news/articles/blockchain-in-the-food-supply-chain.html. (accessed 24.02.2024).
[123] Rizwan Matloob Ellahi, Lincoln C. Wood and Alaa El-Din Ahmed Bekhit, Blockchain-Based Frameworks for Food Traceability: A Systematic Review (2023), URL: https://doi.org/10.3390/foods12163026.

involved and potentially stop or delay shipment to prevent compromised goods from reaching consumers.

Smart contracts have the potential to bring changes to voting systems by addressing issues, like security, transparency and efficiency. Traditional voting methods often face challenges such as voter fraud tampering with ballots and a lack of transparency. Smart contracts offer a solution by creating an transparent environment, for conducting elections. By utilizing contracts voting systems can guarantee that votes are accurately recorded, securely stored and easily verifiable.[124] For instance smart contracts could facilitate voting allowing voters to cast their ballots remotely through a digital platform that can be verified. With the use of contracts, the credibility and integrity of each vote can be maintained as all votes are logged on an unchangeable blockchain ledger.

An excellent real life illustration of how smart contractsre implemented in voting systems can be seen with Voatz. Voatz serves as a voting platform that harnesses the power of technology and smart contracts to enable secure, transparent and verifiable voting procedures.[125] This platform has been put to the test in trial runs and official elections ranging from primaries and party conventions, to elections at the local level across the United States.[126] Within the Voatz framework voter identities are validated through biometrics and mobile device information. Once verified voters are issued a token that signifies their voting privileges. Whenever a vote is submitted via the app, a contract on the blockchain is triggered to record the vote while guaranteeing its accuracy and irrevocability. The deployment of contracts streamlines the authentication process, for each vote ensuring that only valid votes are tallied while any duplicates or fraudulent attempts are promptly invalidated. This method is designed to make voting easier and more convenient enabling people to cast their

[124] Abhay Singh, Ankush Ganesh, Rutuja Rajendra Patil, Sumit Kumar and Ruchi Rani, Secure Voting Website Using Ethereum and Smart Contracts (Applied System Innovation, 6(4):70, 2023), URL: https://doi.org/10.3390/asi6040070.
[125] Voatz, Whitepaper, URL:https://voatz.com/whitepapers/
[126] Hollie McKay, First presidential vote cast using blockchain technology (Fox News, October 16, 2020), URL: https://www.foxnews.com/tech/first-presidential-vote-cast-using-blockchain-technology.

votes using their smartphones without worrying about tampering or outside influence. Additionally the transparency and permanence offered by technology guarantee that everyone involved can have confidence, in the fairness of the voting process and the correctness of the results. Voatz and similar initiatives represent steps towards modernizing the voting process using smart contracts. It should be noted that for blockchain based voting systems to be widely accepted in the future, they must also overcome challenges such as security, privacy and regulatory compliance.

4.4. Gas Fees on the Ethereum Blockchain

Before addressing the concepts of gas and gaslimit in smart contracts, we should mention the Amazon web service (AWS) business model of "pay as you go".[127] For the use of AWS web services, you do not need to top up your balance at account opening, you pay for the web service you use. In other words, you pay according to the type of Ec2, memory, storage type you use, and if you use api, you pay for the incoming request and sent response.[128] Here, when the Ethereum architecture is designed, the Ethereum virtual machine must take into account predefined rules in order to execute these codes when deploying the installed smart contracts. These rules are equivalent to Amazon pay-as-you-go logic. In the smart contract, the lines of the methods called as transactional operations (database writes and updates) require a payment from the transaction owner for execution by the Ethereum virtual machine. This payment is called the gas price. The gas fee is calculated per instruction. As a result, the value of Ethereum to be paid is calculated by gas*gas price.[129] As rows are executed, the total gas value given for the operation is consumed and its value is decremented. As we mentioned, the payment mechanism is upfront, which is one of the payment methods of Amazon web services. Excess gas value is returned, but if the

[127] How does AWS pricing work?, URL: https://aws.amazon.com/pricing/ (accessed 02.01.2024).
[128] Amazon EC2, URL: https://aws.amazon.com/ec2/ (accessed 02.01.2024).
[129] Jake Frankenfield, Gas (Ethereum): How Gas Fees Work on the Ethereum Blockchain (Investopedia, September 27, 2022), URL: https://www.investopedia.com/terms/g/gas-ethereum.asp (accessed (02.01.2024).

gas value is insufficient, the mining cost is used and the remaining gas is returned.[130] To better understand this complex mechanism, let's write a simple smart contract function.

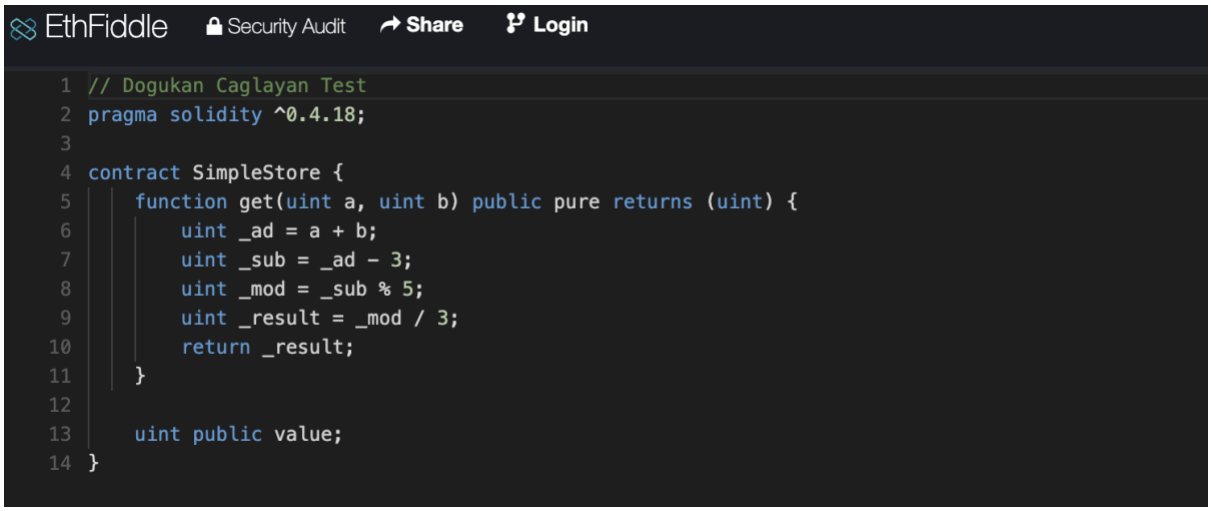

Figure 4.1: Smart contract that performs mathematical operations.

The smart contract shown in Figure 9 is capable of addition, subtraction, mode taking and division. Gas is the cost of the execution steps. In the smart contract above, addition will consume 3 units of gas, subtraction will consume 5 units of gas, mode taking will consume 5 units of gas, and division will consume 5 units of gas, totaling 18 units of gas, which results in the execution cost. Currencies smaller than ether are used to facilitate transactions on the Ethereum blockchain network. Below you can see the currencies between wie and ether.[131]

Unit	Wei Value	Wei
Wei	1 Wei	1
Kwei	10^-3 Wei	1,000
Mwei	10^-6 Wei	1,000,000
Gwei	10^-9 Wei	1,000,000,000

[130] Yakko Majuri, Simply Explained: Ethereum Gas (Medium, Aug 29, 2018), URL: https://yakkomajuri.medium.com/blockchain-definition-of-the-week-ethereum-gas-2f976af774ed (accessed (02.01.2024).
[131] Gwei Calculator and Wei Converter, Alchemy, URL: https://www.alchemy.com/gwei-calculator (accessed (02.01.2024).

Microether	10^-12 Wei	1,000,000,000,000
Milliether	10^-15 Wei	1,000,000,000,000,000
Ether	10^-18 Wei	1,000,000,000,000,000,000

Figure 4.2: Conversion between wei and ether

If we wanted to run the smart contract method in Figure 9, we would have to pay 18*10,000=180,000 wei for the function if the wie expression of each gas value is 10,000 wei. We use a method to determine the gas value required for the smart contract method to work. This method is the gaslimit value given during dissemination. The gaslimit value is deliberately given a large number and the amount required for the functions is met from this value. The excess gas value is returned to the account. This return design makes sense because it is not technically possible to calculate how much gas is required for each smart contract. This is because there is very complex smart contract code.[132] The block size on Ethereum is created by the gaslimit value. Therefore, there is no fixed block structure. On the other hand, if the gas value is not enough to execute the method, the virtual machine executes the method up to the corresponding line of gas ability. At the end of gas, it interrupts the method.

4.5. Smart Contracts and Transaction Costs

Transaction costs are the costs associated with using the market.[133] These costs include search, negotiation, monitoring and auditing. Many factors can affect these costs. Some of these factors are classified as contractual risks, discovery of information problems, opportunism, uncertainty. Contract hazards are one of the main sources of transaction costs. The larger the hazards in the contract, the larger the transaction costs generated by the contract. The selection of governance mechanisms, such as smart contracts in this instance, also plays a role in determining the costs associated with utilizing the market.

[132] Ethereum: A Secure Decentralised Generalised Transaction Ledger, 2023. https://ethereum.github.io/yellowpaper/paper.pdf.

[133] Kenneth Arrow, The Organization of Economic Activity : Issues Pertinent to the Choice of Market versus Non-market Allocation (The Analysis and Evaluation of Public Expenditure: The PPB System, Joint Economic Committee, 1969), p.59.

There are areas where smart contracts reduce the transaction costs of contracting and areas where they increase costs. This analysis is important because it plays a role in determining whether it is economically feasible to use smart contracts. To ascertain this, the initial apparent measure involves evaluating the anticipated value of the transaction (or set of transactions) and balancing it against the expected drafting costs of a smart contract, which represents the most significant transaction cost linked with smart contracts. If we determine that the transaction is sufficiently important economically, then we can conclude whether it makes sense to use smart contracts. We will examine the definition of the costs of using smart contracts in 4 separate categories.

4.5.1. Research Costs

Smart contracts prevent opportunistic behavior by enabling contractual exchange with unknown parties. This diminishes the expenses associated with the thorough investigation that conscientious traders typically undertake regarding their customers prior to entering into risky transactions. Moreover, the prevention of opportunistic behavior can serve as a facilitator for transactions that might have been avoided otherwise, given the absence of trust, elevated costs, and the uncertainty of legal recourse through litigation.

However, it should be noted that smart contracts also have their own transaction costs. Smart contracts are developed using specialized blockchain programming languages. Finding and hiring programmers and developers who specialize in these languages, or training existing staff in them, can incur significant costs. As smart contracts are organized and implemented in a digital environment, it is crucial to ensure their security. Security is crucial as any error or vulnerability can have serious consequences for contracts.[134] Therefore, extra research resources may

[134] Petar Tsankov, Andrei Dan and Arthur Gervais, Securify: Practical Security Analysis of Smart Contracts (Conference on Computer and Communications Security, October 2018). URL: https://dl.acm.org/doi/abs/10.1145/3243734.3243780 (accessed (02.01.2024).

need to be allocated for security audits and thorough testing of smart contracts.[135] The legal validity and regulatory compliance of smart contracts, which we will discuss in the following sections, may vary in different jurisdictions. Understanding these legal and regulatory variations may also require extensive research.

4.5.2. Negotiation Costs

Advocates of smart contracts suggest that this innovative technology will enable the encoding of numerous elements of an agreement into a self-executing smart contract.[136] Consequently, there is a growing apprehension within the legal sector that this rising trend of incorporating technology into the creation and enforcement of contracts could significantly alter the traditional functions of legal professionals.[137]

The inherent need for objectivity and automation in smart contracts may conflict with the typical negotiation processes of business agreements. In real-world negotiations, parties often conduct an implicit cost-benefit analysis, recognizing that there's a point beyond which the effort to anticipate and cover every possible outcome yields diminishing returns. In such circumstances, the parties involved might prefer not to continue spending time on management or incurring legal costs for the negotiation process.[138] They could assess that initiating activities that generate revenue under a signed contract is more advantageous than dealing with any remaining unresolved matters. Therefore, they may choose to handle any unforeseen events as they arise, rather than attempting to resolve all potential issues beforehand. Parties might intentionally leave certain terms in an agreement vague to maintain the flexibility to later argue for an interpretation that benefits them. However, this tactic becomes challenging with smart contracts, as they require precise coding. This level

[135] Kai Peng, Meijun Li, Haojun Huang, Chen Wang and Shaohua Wan, Security Challenges and Opportunities for Smart Contracts in Internet of Things: A Survey (EEE Internet of Things Journal, vol.8, no.15, 2021), URL: https://ieeexplore.ieee.org/abstract/document/9409120 (accessed (02.01.2024).
[136] Nick Szabo, Formalizing and Securing Relationships on Public Networks (First Monday, No.9, 1997), URL:http://firstmonday.org/ojs/index.php/fm/article/view/548/469 (accessed (02.01.2024).
[137] Tai, Challenges of smart contracts.
[138] Xuling Ye, Ningshuang Zeng and Markus König, Systematic literature review on smart contracts in the construction industry: Potentials, benefits, and challenges (Frontiers of Engineering Management, 2022, 9(2), p.208-209.

of exactness is not typically necessary in traditional text-based contract negotiations, where some ambiguity can be strategically used. Smart contracts, by their nature, do not allow for vague terms or the omission of potential scenarios. Consequently, those engaging in smart contracts might discover that the transaction costs involved in negotiating these complex, code-based contracts are higher than those associated with traditional, text-based agreements.[139]

In addition, smart contracts can reduce the need for intermediaries such as lawyers, brokers and agents because they operate in an automated manner. This can lead to a reduction in negotiation and contract enforcement costs. Smart contracts' automation of contract execution can speed up processes, thus saving time and resources needed for negotiations. This efficiency can translate into cost savings for all parties.

4.5.3. Enforcement Costs

The positive and negative effects of smart contracts on enforcement costs are linked to the automation and decentralization that this technology offers to users. Enforcement costs include the costs of checking whether the terms of a contract have been fulfilled, resolving a dispute, and enforcing sanctions in the event of a breach of the terms of the contract. Smart contracts have a significant positive impact on these costs.

Smart contracts are automatically executed if the conditions set when they are created are met. The manual monitoring of terms in traditional contracts is unnecessary in smart contracts. This automatic fulfillment reduces the need for monitoring and enforcement, saving time and cost.[140] With this automated execution that smart contracts have, the contract can include regulatory requirements as part of the code. This helps reduce costs by automating compliance and enforcement

[139] Sklaroff, Smart Contracts And The Cost Of Inflexibility, p.263.
[140] Jelena Madir, Smart Contracts: (How) Do They Fit Under Existing Legal Frameworks? (2018).

processes.[141] In the insurance industry, for example, the terms of policies are often complex and the assessment and processing of potential claims can be time-consuming. Smart contracts offer an advantage to insurers and policyholders by automating this process. A travel insurance policy can provide for automatic compensation in case of possible flight cancellations, etc. Smart contracts, on the other hand, can access information such as the status of the flight, weather conditions and possible reasons for cancellation and automatically pay compensation to the policyholder if the specified conditions are met.

To give a tragicomic example in order to be more understandable, I would like to summarize the problem that a citizen named Mustafa Karasahin, who lives in the Netherlands, had with the city administration of the city of Dordrecht. Karasahin was fined by the municipality for violations in his real estate, and when he did not pay the fines, 2 of his houses were sold by auction method. Karasahin wrote 3500 petitions to the municipality in 2 years for revenge. The city administration, which is obliged by law to respond to the petitions within 4 weeks, could not cope with the 70 to 100 petitions received every day. The municipality took Karasahin to court over costs amounting to 500 thousand euros a year. Faced with the danger of going to jail, Karasahin said he would find more time to write more petitions in prison.[142] Solving this tragicomic example with smart contracts is not only quick and easy, but also almost costless.

4.5.4. Monitoring Costs

While smart contracts automate transactions, they require monitoring and management to ensure that these processes operate in accordance with the terms of the contract. Monitoring costs depend on various factors such as contract execution, security and updating. The creation of smart contracts requires specialized

[141] Naram Mhaisen, Noora Fetais, Aiman Erbad, Amr Mohamed and Mohsen Guizani, To chain or not to chain: A reinforcement learning approach for blockchain-enabled IoT monitoring applications (Future Generation Computer Systems, 2020).
[142] Benjamin Dürr, Der Quälgeist von Dordrecht, DER SPIEGEL, 11.09.2014, URL: https://www.spiegel.de/panorama/niederlande-mustafa-karasahin-kaempft-mit-briefen-gegen-dordrecht-a-990839.html (accessed 17.01.2024).

programming knowledge, which requires more time from developers and therefore increases the cost of the contract. Because smart contracts run on a decentralized network, they are vulnerable to potential vulnerabilities and cyber-attacks.[143] A smart contract with large financial transactions can cause huge losses to the parties due to a potential security vulnerability. Therefore, it is very important to detect and prevent potential vulnerabilities and to conduct security audits. This may increase the transaction cost, as these audits and detections must be performed by experts.[144] In addition, running smart contracts on blockchain networks may also incur network fees for each transaction. These fees can vary depending on the network used, the density of the network and the complexity of the transaction.

But there are ways to reduce these costs. Designing a smart contract as simply and efficiently as possible will both simplify the development process and reduce potential bugs. In the long run, this can reduce the costs of both testing and security audits of the system. Cost savings can be made by using automated testing tools and frameworks in the contract to be coded, allowing bugs to be detected and resolved earlier in the contract development process. To increase security in smart contracts, up to date security and enforcement protocols can be adopted. These protocols reduce potential security vulnerabilities in the contract and reduce monitoring and auditing costs in the long term.

4.5.5. Inflexibility Costs

Smart contracts are inflexible compared to traditional contracts due to the security protocols of blockchain technology. This can create various costs and challenges for the parties to the contract. These costs include potential loss of time and resources. Once the codes that make up the smart contract are placed on the blockchain and the contract is activated, a new smart contract needs to be created for

[143] Sara Rouhani and Ralph Deters, Security, Performance, and Applications of Smart Contracts: A Systematic Survey (IEEE Access, vol. 7, 2019).
[144] Alfonso Panarello , Nachiket Tapas, Giovanni Merlino, Francesco Longo and Alfonso Panarello, Blockchain and IoT Integration: A Systematic Survey(Sensors 2018), URL:https://doi.org/10.3390/s18082575.

any modification or renegotiation of the terms of the contract.[145] This process will require an extra burden and resources even for contracts between 2 parties, and this burden and resource requirement will increase if the contract involves more parties. This inflexibility may lead to the need for legal advice between the parties, and ensuring the compliance of the regulations will also increase costs.[146] This lack of flexibility can also lead to missed opportunities or potential financial losses. For example, a smart contract may be coded to automatically execute a payment on a certain date, and unforeseen circumstances may arise that require the payment to be delayed or not made. This could result in one party breaching the contract and incurring various financial penalties. In such cases, contracting parties would have to terminate the existing contract and create a new one, resulting in additional transaction costs and potential reputational damage.

The inability to renegotiate and inflexibility of smart contracts can hinder innovation and make it difficult to develop more efficient and effective solutions that may emerge. For example, if new technologies, updates and industry standards emerge that could positively impact the performance and functionality of a smart contract or the blockchain on which the contract is built, the parties to the contract may not be able to incorporate these developments into their contract due to contract immutability. This inflexibility may result in missed opportunities for efficiency, cost savings and enhanced capabilities.[147]

The inflexibility and difficult renegotiation of smart contracts can also have negative impacts on businesses. The first of these negative effects is increased transaction costs and potential damages for breach of contract terms.[148] Second, rigid contract terms may limit a company's ability to adapt to rapidly changing market

[145] Adam J. Kolber, Not-So-Smart Blockchain Contracts and Artificial Responsibility (September 21, 2018), URL:https://law.stanford.edu/wp-content/uploads/2018/09/Kolber_LL_20180910.pdf.
[146] Edi Surya Negara and Achmad Nizar Hidayanto, A Survey Blockchain and Smart Contract Technology in Government Agencies (IOP Conference Series Materials Science and Engineering 1071, 2021).
[147] Sklaroff, Smart Contracts And The Cost Of Inflexibility, p.285.
[148] Christopher Clack, Vikram A. Bakshi and Lee Braine, Smart Contract Templates: foundations, design landscape and research directions (August 4, 2016), URL: https://arxiv.org/abs/1608.00771

conditions or unforeseen circumstances. For example, in the case of a supply chain related smart contract between the parties, in the event of a disruption in raw materials or a change in customer demand patterns, a company may want to modify the terms of the smart contract to adapt to these changes, but this may be difficult, and as a result, the company may incur additional costs, such as finding alternative suppliers or dealing with excess inventory. In addition, the inflexibility of smart contracts can hinder innovation and collaboration. Companies may be hesitant to enter into agreements that cannot be easily modified, as this lack of flexibility limits their ability to discover new partners or adapt their business models to capture potential opportunities in new business models.

Finally, the inflexibility of smart contracts can lead to legal and regulatory challenges. A smart contract between the parties may cease to be legal under new regulations, leading to legal disputes or penalties.[149] For example, let's consider a smart contract that pays with cryptocurrencies. A company has created a smart contract to facilitate and speed up payments to suppliers. This smart contract is programmed to automatically pay the supplier in cryptocurrency upon verification of receipt of a particular service or product. But if the government passes a law prohibiting or restricting the use of cryptocurrencies in commercial transactions, the smart contract that was legal before the new law is no longer in compliance with the new government regulations. However, due to the inflexible nature of smart contracts, it would be cumbersome for the company to update the contract to comply with the new prohibited requirements. This could expose the smart contract counterparty to legal risks and possible penalties.

4.6. Hazards Arising from Smart Contract

The innovations offered by smart contracts on blockchain technology, there are also risks and security vulnerabilities brought by this technology. Security vulnerabilities are the most prominent of these risks. The programming languages in

[149] Clifford Chance, Smart Contracts: Legal Framework and Proposed Guidelines for Lawmakers, p.12.

which smart contracts are written may contain bugs and vulnerabilities.[150] These vulnerabilities can be exploited by malicious people and the contract can be manipulated. For example, the DAO (Decentralized autonomous organization) attack on June 17, 2016 is an important example of how a vulnerability in a smart contract can be exploited.[151] Using Ethereum technology, DAO was conceived as an investment fund governed by complex smart contracts that aimed to make it possible for investors from around the world to pool their resources and then vote to direct how that money was used.[152] It was the world's first open global investment fund that anyone could join. The goal was to invest and manage funds in a decentralized way. The balance inside the DAO amounted to 150 million dollars. The attack started with a "reentrancy" vulnerability in DAO's smart contracts.[153] This vulnerability was caused by a bug in the smart contract's process of managing Ether transfers. When the hacker initiated an Ether withdrawal from the DAO contract, a loop was created that triggered a re-withdrawal before the contract updated the balance. With this method, the hacker managed to withdraw close to 3.6 million Ethereum from the DAO balance. This attack, which was worth 150 million dollars at the time, is worth around 12 billion dollars at the time of this study.

[150] Muhammad Usama Akhtar, Ethereum Smart Contract Analysis through Chat-GPT and other NLP Techniques (Master Thesis, March 2023), URL:https://webthesis.biblio.polito.it/26527/1/tesi.pdf.
[151] Charlie Shier, Alana Giambattista, Elgar Gong, Gabrielle Fletcher and Ryan Sanayhie, Understanding a Revolutionary and Flawed Grand Experiment in Blockchain: The DAO Attack (Journal of Cases on Information Technology 21(1) 19-32. 2017), URL:http://dx.doi.org/10.2139/ssrn.3014782.
[152] Ellen Naudts, The future of DAOs in finance (Occasional Paper Series of European Central Bank no 331, 2023), URL:https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op331~a03e416045.en.pdf.
[153] Noama Fatima Samreen and Manar Alalf, Reentrancy Vulnerability Identification in Ethereum Smart Contracts (IEEE International Workshop on Blockchain, 2020), URL: https://doi.org/10.1109/IWBOSE50093.2020.9050260.

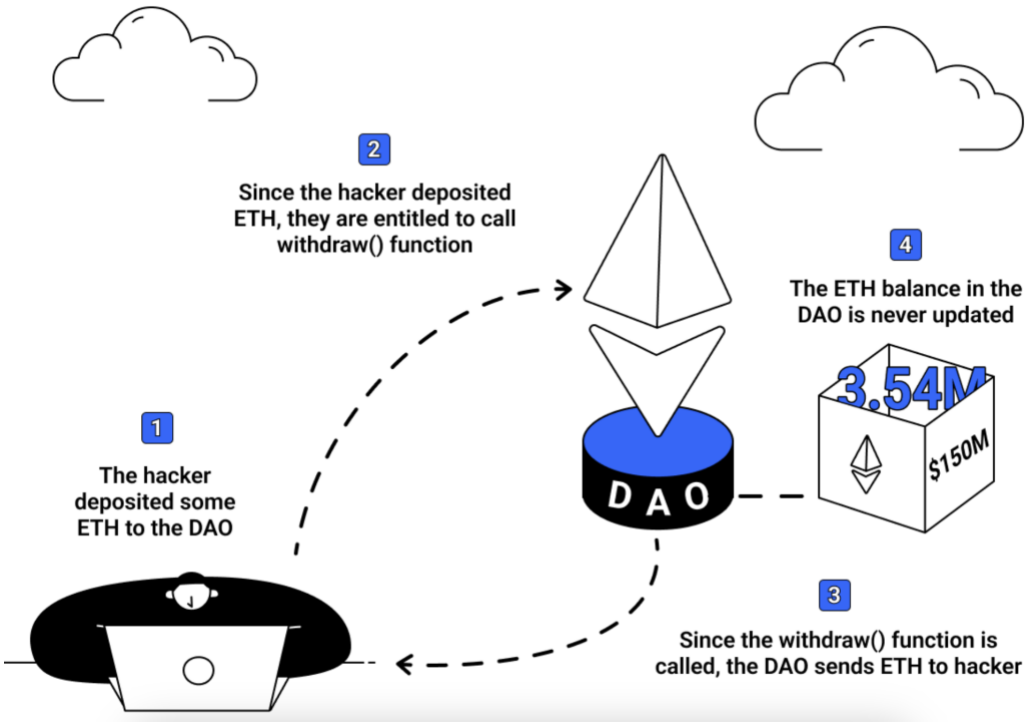

Figure 4.3: Illustration on the re-entrancy attack[154]

Let's give an example for better understanding: Let's consider a bank with total liquidity of 18 billion dollars. But the bank's accounting system waits until 12 midnight to update the balances. This flaw of the bank is noticed by someone with bad intentions named X, who opens an account with the bank and deposits 100 million dollars. Shortly afterwards, X comes back and withdraws his 100 million dollars. However, since the balances are updated at midnight, he still has 100 million dollars in his account. In this way, X withdraws 18 billion dollars, the total liquidity of the bank. The bank will realize that the money has been stolen at midnight, when the balances are updated. Let's see the reentrancy attack on a smart contract on Figure 4.4.

[154] Etherscan, Re-entrancy Attack (May 2023), URL: https://info.etherscan.com/re-entrancy-attack/ (accessed 20.11.2023).

Vulnerable contract with a reentrancy vulnerability

```
pragma solidity ^0.8.0;

contract VulnerableContract {
    mapping(address => uint256) private balances;

    function deposit() public payable {
        balances[msg.sender] += msg.value;
    }

    function withdraw(uint256 amount) public {
        require(amount <= balances[msg.sender], "Insufficient balance");
        (bool success, ) = msg.sender.call{value: amount}("");
        require(success, "Transfer failed");
        balances[msg.sender] -= amount;
    }
}
```

Figure 4.4: An example of a reentrancy attack

In Figure 4.4, users can deposit Ether into the contract through the smart contract's deposit function. The same contract allows users to withdraw the deposited Ether through the withdraw function. However, there is a re-centering vulnerability in the contract's withdrawal function. Because of this vulnerability, when a user attempts to withdraw funds, the contract sends the requested amount to the user's address before it updates the account balance. The attacker's contract will look like this:

Attacker's contract to exploit the reentrancy vulnerability

```
pragma solidity ^0.8.0;

interface VulnerableContractInterface {
    function withdraw(uint256 amount) external;
}

contract AttackerContract {
    VulnerableContractInterface private vulnerableContract;
    address private targetAddress;

    constructor(address _vulnerableContractAddress) {
        vulnerableContract = VulnerableContractInterface(_vulnerableContractAd
        targetAddress = msg.sender;
    }
    Function to trigger the attack
    function attack() public payable {
        Deposit some ether to the vulnerable contract
        vulnerableContract.deposit{value: msg.value}();
        Call the vulnerable contract's withdraw function
        vulnerableContract.withdraw(msg.value);
    }
    Receive the function to receive funds from the vulnerable contract
    receive() external payable {
        if (address(vulnerableContract).balance >= 1 ether) {
            Reenter the vulnerable contract's withdraw function
            vulnerableContract.withdraw(1 ether);
        }
    }
    Function to steal the funds from the vulnerable contract
    function withdrawStolenFunds() public {
        require(msg.sender == targetAddress, "Unauthorized");
        (bool success, ) = targetAddress.call{value: address(this).balance}(""
        require(success, "Transfer failed");
    }
}
```

Figure 4.5: The attacker's smart contract exploiting the vulnerability

This attack has raised concerns about smart contracts and Ethereum's security. The DAO attack exposed potential vulnerabilities in the nascent smart contract and blockchain technology. This attack has shown smart contract developers that they need to code more carefully and take security audits into account.

One of the biggest obstacles to the widespread use of blockchain technology, where smart contracts are also created, is scalability issues.[155] Scalability is the rate at which users in a blockchain network are able to fulfill their requests to perform a transaction.[156] The scalability of blockchain networks is that every transaction in the network is verified by every node in the network. This increases the security and transparency of the network and is the foundation of blockchain technology, but it also limits transaction capacity and speed. For example, Bitcoin can typically process around 7 transactions per second (TPS), while Ethereum can process between 15 and 30 transactions per second.[157] For comparison, Visa can process around 65,000 TPS transactions per second.[158] This scaling problem in blockchain networks leads to delays in transactions and high transaction fees, especially during periods of high network utilization.

Another hazard that awaits smart contracts is a fraud method called "rug pulls" on the blockchain. The emerging cryptocurrency market has provided more innovative and high-yielding investment opportunities. Various projects have emerged in this innovative and investment ecosystem. In order for these projects to be realized, investors need to be found. However, some projects have disappeared by

[155] Adrian Hofmann, Challenges and Solution Approaches for Blockchain Technology (Doctoral Thesis, 2022), p.69. URL: https://doi.org/10.25972/OPUS-28261.
[156] Nikolay Ivanov, Qiben Yan and Qingyang Wang, Blockumulus: A Scalable Framework for Smart Contracts on the Cloud (July 2021), URL: https://arxiv.org/pdf/2107.04904.pdf.
[157] Chonghe Zhao and Shengli Zhang, Bodyless Block Propagation: TPS Fully Scalable Blockchain with Pre-Validation (19 April 2022), URL:https://arxiv.org/pdf/2204.08769.pdf.
[158] Visa Fact Sheet, URL: https://www.visa.co.uk/dam/VCOM/download/corporate/media/visanet-technology/aboutvisafactsheet.pdf (accessed 12.02.2024).

taking investor funds and this is called "rug pulls".[159] While the growing interest in cryptocurrencies and blockchain technology has spurred financial innovation in the space, this surge in interest has also been a boon for potential fraudsters. With the anonymity provided by blockchain technology, fraudsters have abused this anonymity through rug pulls. This method is often used for new cryptocurrency launch projects or liquidity pools. After a certain amount of funds have been invested in the project, the developers withdraw the liquidity from the project and disappear. This causes the value of the project to drop or even disappear, causing investors to suffer losses. Fraudsters can use this method to withdraw funds from the smart contract, undermining trust in blockchain technology and smart contracts and preventing new participants from entering the market.

Another hazard is oracle manipulation. Smart contracts are self-executing, but they require real-world data to perform this execution. This data, which is vital for smart contracts, is provided by oracles. Oracles carry data from the outside world to the blockchain system.[160] In line with this data, smart contract functions are realized and the transaction is completed. However, this data can be manipulated and can cause the smart contract to make incorrect transactions due to manipulated data. This manipulation can occur by misleading the consensus-based oracle system with false information, and by feeding false information about oracle data into smart contracts. This can influence the actions of the contract in the wrong direction and lead to misleading transactions. This can lead to possible minor or life-threatening financial losses. To prevent possible manipulation, multiple oracles can be used to provide independent data. However, this can also increase transaction costs.

4.6. Transaction Cost Economics Approach in Smart Contracts

Governance studies based on economics are developing every year and transaction cost economics has emerged as one of these governance studies.

[159] Trishie Sharma, Rachit Agarwal and Sandeep Kumar Shukla, Understanding Rug Pulls: An In-depth Behavioral Analysis of Fraudulent NFT Creators (ACM Transactions on the Web, Volume 18, 2023), URL:https://doi.org/10.1145/3623376.

[160] Giulio Caldarelli and Joshua Ellul, The Blockchain Oracle Problem in Decentralized Finance—A Multivocal Approach (Applied Sciences. 2021), URL: https://doi.org/10.3390/app11167572.

According to transaction cost economics, companies exist to minimize transaction costs, which are the costs that affect the exchange of goods and services in the market.[161] These costs do not only include goods and services. They also include the cost of negotiating, implementing, monitoring and monitoring contracts and resolving disputes that may arise from potential conflicts.[162] The position of the economics of transaction costs in smart contracts is very important when considered in terms of blockchain technologies. The emergence of smart contracts aims to be fast, secure, transparent and, most importantly, more cost-effective than traditional contracts. Smart contracts are designed to reduce the need for intermediaries that waste time and cost in traditional contracts and to reduce transaction costs.

Transaction cost economics has several basic principles. The first is the concept of bounded rationality, which, according to transaction cost economics, refers to the difficulty for individuals and firms to access perfect information due to their limited information processing capacity.[163] This lack of information hinders the ability of individuals and firms to analyze and leads to bounded rationality where they make decisions based on the information they are given. Another principle is opportunism. According to transaction cost economics, individuals and organizations think primarily about their own interests.[164] Their priority is to maximize their own profits, not to harm others. This behavior leads parties to take measures to protect themselves against opportunism, which leads to additional costs.

The final principle is asset specificity and contractual hazards. Transaction cost economics emphasizes the importance of asset specificity when assets are dedicated

[161] Maria E. Maher, Transaction cost economics and contractual relations (Cambridge Journal of Economics, Volume 21, 1997), URL:https://doi.org/10.1093/oxfordjournals.cje.a013664.
[162] Robert Gibbons, Transaction-Cost Economics: Past, Present, and Future? (The Scandinavian Journal of EconomicsVol. 112, No. 2, 2010), URL:https://doi.org/10.1111/j.1467-9442.2010.01609.x.
[163] Chihiro Suematsu, Transaction Cost in Economics (Springer, 2014), p.194.
[164] Rodrigo Martins, Fernando Ribeiro Serra and André da Silva Leite, Transactions Cost Theory influence in strategy research (Working paper no:61/2010), URL:https://core.ac.uk/download/pdf/9306341.pdf.

to a specific use and their value diminishes or disappears in alternative uses.[165] When assets are specific to a particular transaction, there is a risk that one party will unfairly benefit from the specialized investments made by the other party. This raises contractual risks and potential theft issues.

Transaction Cost Economics principles can help to understand the potential challenges and limitations of implementing smart contracts. For example, in the context of the concept of asset specificity, smart contracts often involve the use of specific assets, such as unique digital identifiers, that are dedicated to a specific transaction and have limited or exclusive uses. The unique nature of assets involved in smart contracts creates a reliance between the parties. This dependency can result in increased expenses if those assets need to be customized or moved to other options.[166] Additionally, when designing and putting smart contracts into practice, it is crucial to take into account the limitations of human rationality and the potential for opportunistic behavior. When designing smart contracts, developers and organizations must consider the cognitive limitations and self-serving nature of involved parties. They need to predict possible opportunistic actions and include safeguards like reputation systems or conflict resolution strategies to reduce potential risks. The design of smart contracts, including the contractual agreements and how they are enforced, is critical for achieving cost-effectiveness.[167] In cases where there is a lot of uncertainty or the situation is complex, it might be more efficient to have a clear hierarchy in decision-making rather than relying only on market forces to resolve disputes. To choose the best smart contract platform and provider, businesses can use transaction cost economics. By looking at how reliable, flexible, and secure the platform is, companies can choose the one that best meets their specific transaction needs and keeps transaction costs low.

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[165] Jean-Francois Hennart and Brian Silverman Transaction Cost Theory: Past Progress, Current Challenges, and Suggestions for the Future (The Academy of Management Annals 15(1), 2020), URL: http://dx.doi.org/10.5465/annals.2019.0051.

[166] Clifford Chance, Smart Contracts: Legal Framework and Proposed Guidelines for Lawmakers, p.33.

[167] Nzuva, Smart Contracts Implementation, Applications, Benefits, and Limitations, p.72.

When using Transaction Cost Economics, choosing the right smart contract platform and provider is critical. Organizations should evaluate factors like platform reliability, scalability, and security to reduce transaction costs and align with their specific transaction needs. By applying TCE principles to the selection process, stakeholders can strategically choose platforms that align with their economic organization and minimize the risks associated with platform adoption. By incorporating principles of TCE into smart contracts and their governing mechanisms, we can transform economic structures and simplify transaction handling. Understanding the implications of TCE allows stakeholders to make strategic choices, leverage blockchain's capabilities, and enhance economic efficiency.[168] This integration creates opportunities for better decision-making, optimizing blockchain applications, and boosting the overall efficiency of economic systems.

4.7. Conclusions

Ethereum has empowered the creation of decentralized applications, allowing for blockchain-based distribution and automated execution with smart contracts. These contracts offer advantages like increased efficiency and transparency over traditional contracts. However, high gas fees and transaction costs associated with smart contracts have become barriers to wider adoption and effective utilization of this technology.

Research costs involve acquiring knowledge about smart contracts and the Ethereum platform, which includes understanding how the platform functions, writing smart contracts, and implementing best practices. Negotiation costs stem from establishing the terms of smart contracts and ensuring agreement between parties. This process can be time-consuming and complex, especially for intricate transactions or those involving multiple parties. Implementation costs refer to the execution of smart contracts and the achievement of their intended outcomes. In Ethereum, the expenses associated with executing smart contracts depend on the amount of

[168] Alex Murray, Scott Kuban and Matt Josefy, Contracting in the Smart Era: The Implications of Blockchain and Decentralized Autonomous Organizations for Contracting and Corporate Governance (Academy of Management Perspectives, 2019), URL:http://dx.doi.org/10.5465/amp.2018.0066.

computational resources utilized, which is reflected in the gas fees for each transaction. Keeping track of whether the specified requirements of a smart contract have been fulfilled over time adds to the monitoring costs. While the automated nature of smart contracts can drastically lower these costs compared to conventional contracts, ongoing monitoring of contract performance and results is still necessary. Using innovative technologies like Ethereum and smart contracts comes with a cost: inflexibility. This is because they can't be easily changed to meet new market conditions, technology advancements, or unexpected events. Smart contracts follow a set workflow and are hard to modify. This can make it difficult for contracts to adapt to changing requirements or circumstances. Inflexibility costs play a critical role in identifying the potential challenges and limitations of smart contracts and the Ethereum platform. When adaptation to changing market conditions is required, it is often not possible to update or replace smart contracts. This prevents traders or investors from being flexible in the face of unexpected situations and can lead to potential losses or opportunity costs.

Ethereum and smart contracts can streamline and make transactions processes more efficient and transparent. However, to harness their potential, it is crucial to manage gas fees and transaction costs effectively. Legal, technological, and regulatory frameworks need to be taken into account. To make these technologies accessible and useful, it is essential to optimize gas fees, design adaptable smart contracts, and plan processes strategically. Understanding Ethereum and smart contract transaction costs is vital for their widespread use and success.

In the next chapter, we will look at the legal aspects of smart contracts, which may also affect transaction costs, and how smart contracts are regulated in major countries (especially in European countries).

SMART CONTRACTS AND THE LAW

5.1. Introduction

In the changing world of technology smart contracts have emerged as a groundbreaking tool that is set to transform traditional legal agreements and how they

are enforced. These self executing contracts are coded with the terms of the agreement promising to automate and simplify transactions and processes across industries. This advancement not brings about efficiency and transparency but also poses challenges to the existing legal frameworks governing contracts and transactions, in this digital era.

However like any technology integrating contracts into society at large raises important legal issues. The decentralized and unchangeable nature of blockchain provides security and trust. Complicates matters such as jurisdiction, contract enforceability, dispute resolution and regulatory compliance. Moreover the technical intricacies and potential coding errors in contracts introduce risks and liabilities that current legal frameworks may not be prepared to handle.

This chapter aims to explore how contracts fit within the law by exploring how existing legal principles apply to these digital agreements, while identifying gaps and uncertainties that legislators and legal experts need to address. We will examine how smart contracts can enhance and even substitute instruments in specific scenarios, highlighting their limitations and the importance of grasping the necessary legal framework for their wide adoption.

5.1. Legal Approaches to Smart Contracts

Smart contracts are considered as a legal concept due to the term "contract" in the concept. Legal scholars understand contracts as legally binding agreements. Indeed, smart contracts have similar functions to agreements that are legally characterized as contracts. Smart contract code may specify the acts to be exchanged between the parties and how they are exchanged. Moreover, smart contracts may be considered as a suitable instrument to guarantee the exchange of performances thanks to the facilities provided by the underlying distributed ledger technologies.[169] Smart contracts are agreements or parts of agreements that resemble contracts in the traditional sense, but are embedded in computer code.[170] Lessig's rule that "code is

[169] Florian Möslein, Smart Contracts im Zivil- und Handelsrecht (Zeitschrift für das gesamte Handelsrecht und Wirtschaftsrecht, Vol.183, 2019), p.29.
[170] Mirjam Eggen: 'Chain of Contracts' (Aktuelle Juristische Praxis, 1/2017), p.6.

law" can also be understood as "code is contract".[171] However, the phrase "code is law" should not be interpreted to mean that the execution of contract clauses by software alone gives them legal validity. In this context, it is not true that a smart contract always qualifies as a contract in law.[172] It should be noted that smart contracts are actually a piece of code. In order to determine whether this piece of code can be legally qualified as a contract, an evaluation should be made within the framework of legal rules.[173]

According to one legal approach, in smart contracts, which are software, legally significant acts are managed, controlled and documented based on digitally controllable results, and if the necessary conditions are met, the same and obligatory contracts can be established with them.[174] However, there are those who prefer a broad definition under the legal approach, taking into account that blockchain technology may have different applications and is in development. In these cases, it is seen that the difference between the definitions of technical and legal approaches becomes relative. According to another definition, smart contracts are computer-aided protocols that can digitally control at least one result by applying the content of the program code and bind it to the realization of a certain condition.[175]

According to another definition of a smart contract, it is understood as software that is linked to data sources in the blockchain base, and the contractual rights and obligations arising from the contract within it are automatically fulfilled when certain (predetermined) conditions are met.[176]

According to a sub-view that emphasizes the formation of contracts in the legal sense, smart contracts are in fact internet-based contracts, the terms of which are

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[171] Lawrence Lessig, Code: And Other Laws of Cyberspace (Basic Books, 1999).
[172] Merit Kõlvart, Margus Poola and Addi Rull, Smart Contracts (The Future of Law and eTechnologies, 2016), URL:http://dx.doi.org/10.1007/978-3-319-26896-5_7.
[173] Mateja Durovic and André Janssen, Formation of Smart Contracts under Contract Law (The Cambridge Handbook of Smart Contracts, Blockchain Technology and Digital Platforms, 2019), p.753.
[174] Kaulartz and Heckmann, p.618.
[175] Hanzl, p.42.
[176] Lukas Müller and Reto Seiler, Smart Contracts aus Sicht des Vertragsrechts - Funktionsweise, Anwendungsfälle und Leistungsstörungen (AJP, 3/2019), p. 318.

defined in advance by a code.[177] In addition, the smart contract independently and regularly checks whether its predefined conditions are met, and if they are met, the smart contract fulfills and enforces them. Therefore, a smart contract is characterized as a self-executing contract. As can be seen, the term self-executing contract is frequently used in legal approaches. However, according to some views under the legal approach, smart contracts may in fact only be related to the implementation phase of the contract in a legal sense.[178] Accordingly, smart contracts, defined as computer controlled protocols, guarantee that the contract will be automatically executed in accordance with a mathematical procedure.[179] In other words, smart contracts are not intended to cause a change in the legal sense, but to actualize this change. The records that are important for the contractual relationship are not contained in the software that implements the contract, but in the text of the classical contract or in the oral agreement.

5.2. Legal Nature of Smart Contracts

Smart contracts are programs that run independently and carry out tasks based on predetermined conditions. Despite their advantages and growing popularity smart contracts pose difficulties. Identifying the root cause of non performance is a hurdle, in smart contracts. In contract law it is essential to pinpoint the party in case of a breach. However the automated nature of contract execution makes it challenging to determine the reason for non performance. Moreover using automated oracles to collect information and initiate contract execution raises concerns about their reliability and accuracy. The issue of consent in automated agreements is another obstacle. Consent plays a role in contracts by ensuring that all parties comprehend and

[177] Alexander Djazayeri, Rechtliche Herausforderungen durch Smart Contracts (jurisPR-BKR, 12/2016), p.127.
[178] Philipp Sandner, Ina Kristen Voigt and Martin Fries, Distributed-Ledger-Technologie und Smart Contracts im Finanzumfeld: Automatisierung von Darlehesverträgen (Rechtshandbuch Legal Tech, 2018), p.30.
[179] Martin Müller, Bitcoin, Blockchain und Smart Contracts: Technische Grundlagen und mögliche Anwendungsbereiche in der Immobilienwirtschaft (ZfIR, 2017), p.609.

agree to the terms and conditions. Yet, in contracts consent can be more uncertain since the contracts execution relies on code and automated procedures.[180]

One of the issues related to smart contracts is their enforceability. Smart contracts are created to execute themselves and be enforced using technology. This raises concerns, about how these contracts can be enforced within systems. Presently there is a lack of established precedents and regulatory guidelines on enforcing contracts. While smart contracts are intended to be binding agreements, the decentralized nature of technology complicates their enforceability.[181] Unlike contract enforcement methods that rely on authorities like courts or arbitration panels smart contracts function on a decentralized network without a central governing body to monitor and enforce contract terms. This poses a challenge to the understanding of enforceability in existing frameworks. Efforts have been made to tackle these challenges by adjusting structures to accommodate smart contracts, which involves considering specialized legislation for smart contracts such, as recognizing digital signatures and electronic records.

Smart contracts pose challenges in terms of jurisdiction. Traditional contract laws rely on the notion of boundaries, where the regulations of a region dictate how a contract is established, validated and executed. On the smart contracts function, within an decentralized framework creating complexities in identifying the relevant jurisdiction when disputes or breaches occur. This ambiguity surrounding jurisdiction can result in uncertainties and obstacles when it comes to enforcing contracts across diverse legal frameworks. One potential resolution involves incorporating choice of law and jurisdiction provisions into contracts, where the involved parties mutually decide on a jurisdiction to oversee their agreement.[182] Another strategy, under

[180] Loi Luu, Duc-Hiep Chu, Hrishi Olickel, Prateek Saxena and Aquinas Hobor, Making Smart Contracts Smarter (CCS '16: Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security, 2016), URL: https://doi.org/10.1145/2976749.2978309.
[181] Alex Lipton and Stuart Levi, An Introduction to Smart Contracts and Their Potential and Inherent Limitations (Harvard Law School Forum on Corporate Governance, 2018).
[182] Marco Dell'Erba, Demystifying Technology. Do Smart Contracts Require a New Legal Framework? Regulatory Fragmentation, Self-Regulation, Public Regulation (New York University School of Law; The Wilson Center, 2018), URL: https://dx.doi.org/10.2139/ssrn.3228445.

discussion is the creation of accords or alignment of regulations to set up a legal structure, for smart contracts worldwide.[183]

The use of smart contracts also raises concerns about regulatory oversight. Smart contracts can automate processes and transactions, including those covered by regulations. This creates challenges, in making sure that smart contracts adhere to the guidelines, such as laws for consumer protection, anti money laundering rules and securities regulations.[184] To tackle these issues legal experts and regulators are looking into ways to integrate compliance measures into contracts. This could involve including requirements directly in the code of the contract establishing self executing compliance protocols or creating external systems for monitoring and enforcing compliance. Additionally there are efforts being made to set up sandboxes where innovators and developers can test contracts in a controlled setting while collaborating with regulators to ensure compliance, with relevant laws.[185] Work is also ongoing to develop frameworks and standards specifically designed for contracts. These frameworks aim to clarify how existing legal principles and regulations relate to contracts while taking into account the features of decentralized blockchain technology.

5.3. Legal Issues Raised by Smart Contracts

The legal issues raised by smart contracts are as complex as they are critical and mark a crucial intersection between technology and law. Although a smart contract is software code, the agreed contract ultimately creates a legal situation. It is therefore important to understand how this legal language is interpreted by the legal system. While we will see more and more of these contracts in the near future, it is important

[183] Kristian Lauslahti, Juri Mattila, Taneli Hukkinen and Timo Seppälä, Expanding the Platform: Smart Contracts as Boundary Resources (Translational Systems Sciences, TSS,volume 11, 2018), URL:https://doi.org/10.1007/978-981-10-8956-5_4.

[184] Andrew Agapio, Overcoming the Legal Barriers to the Implementation of Smart Contracts in the Construction Industry: The Emergence of a Practice and Research Agenda (Buildings, 13(3), 2023), URL: https://doi.org/10.3390/buildings13030594.

[185] Council of Arab Central Banks and Monetary Authorities Governors, Guidance Note on Adopting Smart Contracts and Smart Contracts Legal Enforceability in Arab Countries (2022), URL: https://www.amf.org.ae/en/news/20-12-2022/arab-monetary-fund-publishes-guidance-note-adopting-smart-contracts-and-their-legal.

to remember that the "written laws" and legislation limiting these contracts will continue to evolve.

5.3.1. Smart Contracts and Personal Data Protection

The use of smart contracts might raise concerns regarding privacy. Safeguarding personal information. This is particularly relevant, in transactions where maintaining confidentiality's crucial as the presence of smart contracts on the blockchain could potentially compromise this confidentiality.[186] While users and transactions are typically considered pseudonymous research indicates that individuals and entities can still be identified through data points.[187] Moreover the nature of a distributed ledger makes it challenging to delete data or exercise the right to be forgotten on the blockchain structure. Nevertheless in contracts there may be ways to control access to data and encrypt content to prevent viewing by others. This approach could serve as a method, to deletion of personal data.

On February 23, 2022, the draft EU Data Act was published.[188] The main objective is to give users (consumers and companies) control over the data generated when using a product or service, i.e. more control over what can be done with their data. The draft defines smart contracts as "computer programs in electronic ledgers that execute and complete transactions according to predetermined conditions".[189] Smart contracts have the potential to guarantee to data owners and data recipients that the conditions for data sharing are complied with. In this context, smart contracts are considered to be useful in facilitating seamless data sharing.

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[186] Matthias Artzt and Thomas Richter, Handbook of Blockchain Law: A Guide to Understanding and Resolving the Legal Challenges of Blockchain Technology (Kluwer Law International, 2020), p.164.
[187] Daniel Drummer and Dirk Neumann, Is code law? Current legal and technical adoption issues and remedies for blockchain-enabled smart contracts (Journal of Information Technology, Vol. 35, 2020), p.346. URL:https://doi.org/10.1177/0268396220924669.
[188] European Commission, Data Act: Commission proposes measures for a fair and innovative data economy (23 February 2022),URL:https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1113.
[189] The European Data Act, URL: https://www.eu-data-act.com. (accessed 03.03.2024).

In this framework Article 30(1) of the Draft Data Bill outlines four requirements, for contracts.[190] Firstly smart contracts need to ensure a level of protection against errors and unauthorized changes by external parties (referred to as "robustness"). Secondly they should include features that allow for resetting the contract or halting its operation when necessary (known as " termination and suspension"). Moreover there should be provisions, for storing transaction data smart contract logic and code to maintain a record of data operations carried out in the past (referred to as "data archiving and persistence") once a smart contract is terminated (referred to as "auditability"). Lastly access control mechanisms must safeguard the contract at both governance and operational levels ("access control").

The experts involved viewed these suggested modifications, as an contentious shift. The proposed amendment is seen as questioning the core unchangeability of architecture with a focus on the need to revamp all oracles.[191] If this legislation is approved countless online smart contracts, in the intended jurisdiction would become illegal.[192] There appears to be no method to adjust them to comply with the provisions outlined in the Draft Data Law.

Using smart contracts presents a number of obstacles, in maintaining data privacy. One significant issue is related to storing data. Since smart contracts reside on the blockchain all information contained in the contract is accessible to every network participant.[193] This could lead to the exposure of confidential data that requires safeguarding. Another challenge is data access. Because smart contracts operate independently on the blockchain regulating or restricting access to data

[190] Council of the European Union, LIMITE EN - Data, p.73. URL: https://data.consilium.europa.eu/doc/document/ST-7413-2023-INIT/en/pdf. (accessed 03.03.2024).
[191] Frederik Gregaard, About Article 30 of the Data Act (Linkedin, 2023), URL: https://www.linkedin.com/posts/gregaard_eu-parliament-passes-bill-requiring-smart-activity-7052269734704091136-6Nkj/. (accessed 03.03.2024).
[192] Jack Schickler, EU Parliament Passes Bill Requiring Smart Contracts to Include Kill Switch (Coindesk, Mar 14, 2023), URL: https://www.coindesk.com/policy/2023/03/14/eu-parliament-passes-bill-requiring-smart-contracts-to-include-kill-switch/. (accessed 03.03.2024).
[193] Hamed Taherdoost, Smart Contracts in Blockchain Technology: A Critical Review (Information, 14(2), 2023), URL: https://doi.org/10.3390/info14020117.

within the contract may prove challenging. This situation can give rise to worries, about entry or inappropriate handling of information.

Furthermore, the right to be forgotten established by the European Court of Justice poses a significant challenge when it comes to smart contracts and data privacy.[194] The immutable nature of blockchain data contradicts the erasure and deletion principles set out in the General Data Protection Regulation (GDPR). Therefore, reconciling this contradiction requires innovative approaches, such as the use of off-chain storage for personal data or the development of decentralized identity solutions that enable revocation of access to certain data.Some potential solutions to address the challenges of data privacy in smart contracts include the following:[195] The first solution is to use Encryption. Encrypting personal data stored in smart contracts can add an extra layer of protection. The other solution is to implement access controls. Implementing access controls in smart contracts can ensure that only authorized persons can access and view personal data. Another solution is to implement privacy preserving techniques. New privacy preserving solutions based on cryptographic privacy techniques are emerging to address the privacy issues associated with smart contracts. However, none of these solutions have fully addressed the right to be forgotten problem. The applicability and effectiveness of these solutions depends on the characteristics of the blockchain platform used and the specific requirements of the application.

5.3.2. Smart Contracts and Private International Law

Smart contracts are far from perfect and do not guarantee that the contract will be performed as the parties intended. Consequently smart contracts are likely to spark disagreements, between the parties. Unlike agreements there is a challenge for the parties in such scenarios. Due to the nature of technology particularly in public

[194] General Data Protection Regulation (GDPR), Everything you need to know about the “Right to be forgotten”, URL: https://gdpr.eu/right-to-be-forgotten/. (accessed 25.02.2024).
[195] Alfredo J. Perez and Sherali Zeadally, Secure and privacy-preserving crowdsensing using smart contracts: Issues and solutions (Computer Science Review Volume 43, 2022), URL: https://doi.org/10.1016/j.cosrev.2021.100450.

blockchains unless both parties reveal their identities to each other explicitly they remain unaware of each others true identity and location.[196] They can only recognize each other by their pseudonymous. This lack of transparency can pose challenges in cases of disputes as it raises uncertainties about whom to take action, against which countrys courts have jurisdiction and which legal framework will govern the dispute.[197]

One of the remedies for disputes arising from smart contracts is to have the dispute resolved by state courts outside the blockchain. However, as mentioned above, in cases where such a dispute exists, it is both difficult to identify the parties and unrealistic to enforce the decisions of the court within the framework of blockchain principles.[198] To reduce the risk of pursuing a party in the middle of a real-life dispute, parties could integrate automated third-party verification tools into a smart contract, such as background checks on the other party.[199] The results of the check could be made available to both parties so that there is full transparency about who the parties are. This mechanism would also allow the location to be recorded so that a case can actually be filed. However, it should be noted that the addition of identity verification may discourage some parties from entering into smart contracts. This is because one of the most important features and reasons for using the public blockchain in particular is that the system is trusted, not the individual.[200] As can be seen, possible solutions to such a problem are not very suitable for the decentralized structure that is the basis of blockchain technology. In order to resolve smart contract

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[196] Galia Kondova and Jörn Erbguth, Self-Sovereign Identity on Public Blockchains and the GDPR (ACM/SIGAPP Symposium on Applied Computing, 2020), URL: http://dx.doi.org/10.1145/3341105.3374066.

[197] Freedom, Security & Justice: European Legal Studies, URL: http://www.fsjeurostudies.eu/files/FSJ.1.2022.7.LOPEZ-RODRIGUEZ.pdf. (accessed 27.02.2024).

[198] Pietro Ortolani, Chapter 21 Recognition and Enforcement of the Outcome of Blockchain-Based Dispute Resolution (Blockchain and Private International Law, 2023), URL: https://doi.org/10.1163/9789004514850_023.

[199] Bin Hu, Zongyang Zhang, Jianwei Liu and Yizhong Liu, A comprehensive survey on smart contract construction and execution: paradigms, tools, and systems (Patterns volume 2, issue 2, 2021), URL:https://doi.org/10.1016/j.patter.2020.100179.

[200] Scott A. McKinney, Rachel Landy and Rachel Wilka, "Smart Contracts, Blockchain and the Next Frontier of Transactional Law (Washington Journal of Law, Technology and Arts, Vol. 13, 2018), URL: https://digitalcommons.law.uw.edu/wjlta/vol13/iss3/5/.

disputes less costly and faster, dispute resolution mechanisms programmed in the on-chain method blockchain have started to be developed.[201] Some alternative dispute resolution organizations and companies have even started to create model rules for resolving smart contract disputes.

The application of contracts, across countries brings about several hurdles in the field of international private law. Since smart contracts function in an globally connected setting the usual legal methods for ensuring contract obligations may encounter difficulties in adapting to the characteristics of smart contracts. A key obstacle involves harmonizing the self executing aspect of contracts with the established criteria for creating and fulfilling contracts under legal frameworks. The automated execution and irreversible nature of contract terms could clash with contract law principles, in regions giving rise to uncertainties regarding enforceability and legal legitimacy.[202] Enforcing smart contract terms, in cross-border deals can be difficult because there are no consistent global standards for validating and upholding digital agreements. The different legal approaches to smart contracts in regions make it hard to ensure fair outcomes in international disputes involving these contracts.[203] Figuring out which laws apply to smart contracts across borders can also be unclear adding another layer of complexity to enforcing them. With smart contract technology evolving and intersecting with private international law it is important to carefully consider how to determine the applicable law and ensure enforceability, in situations involving multiple jurisdictions.[204]

[201] JAMS Rules Governing Disputes Arising out of Smart Contracts, URL: https://www.jamsadr.com/smartcontracts?tab=overview. (accessed 25.12.2023).
[202] Raskin, The Law and Legality of Smart Contracts, p.328-329.
[203] Gabriel Goh, Smart contract disputes and public policy in the ASEAN+6 region (Digital Law Journal, 3(4), 2022), URL: https://doi.org/10.38044/2686-9136-2022-3-4-32-70.
[204] Sean Murphy and Ronald David Smith, Can smart contracts be legally binding contracts? (Norton Rose Fulbright, November 2016), URL: https://www.nortonrosefulbright.com/en-gb/knowledge/publications/a90a5588/can-smart-contracts-be-legally-binding-contracts. (accessed 05.03.2024).

5.3.3. Smart Contracts and Tax Law

Transactions that have an impact, on investors and consumers such as smart contracts are of interest to tax laws. When transactions with economic effects occur, the tax system is affected, even if there is no explicit regulation on this issue.[205] Given that our tax system revolves around income, spending and assets any smart contract related to these areas also draws the interest of tax laws. Whether its a contract involving income one involving an expenditure, by a party or one involving the transfer of wealth all fall within the purview of tax laws. The transactions facilitated by smart contracts where cryptocurrencies are exchanged for goods or services could lead to varying taxation implications. Examples include profits from the change in value of cryptocurrencies; income from transaction-related fees; and tax on goods or services sold.[206]

For tax authorities, the taxation process becomes particularly difficult when transactions are carried out through virtual processes that do not have a single owner or responsible party. There may be thousands of anonymous transactions linked to a single smart contract. For example, from an income tax perspective, this challenge is evident when the taxpayer of taxable income is a foreign, virtual or unknown person.[207] On the other hand, smart contracts have the potential to facilitate the taxation process. When the tax due to the state is paid automatically with smart contracts, tax losses and evasion can be prevented and tax collection can be efficient.[208]

5.3.3.1. The Impact of Smart Contracts on the Taxation Process

Governments have to collect taxes to finance public expenditures. It is vital for governments to realize the collection of taxes, which is an important item in public revenues. When collecting taxes, it is important to minimize the cost of the tax to be

[205] Allison Christians, Taxation in the Age of Smart Contracts: The CryptoKitty Conundrum (Ohio State Tech Law Journal 91, 2020), URL: https://ssrn.com/abstract=3570717.
[206] Jimmy Royer and Alan G. White, Smart Contracts and Their Potential Tax Implications (October 24, 2018), URL: https://www.lawyer-monthly.com/2018/10/smart-contracts-their-potential-tax-implications/. (accessed 05.03.2024).
[207] Christians, p.92.
[208] Price Waterhouse Coopers, Two practical cases of blockchain for tax compliance (April 23, 2019), URL:https://www.pwc.nl/nl/tax/assets/documents/pwc-two-practical-cases-of-blockchain-for-tax-compliance.pdf. (accessed 05.03.2024).

collected and to consider efficiency. When these are taken into consideration, the priority will be that the public interest is observed. Therefore, tax collection has a key role for both developed and developing countries. For this purpose, there have been new searches in tax collection with the development of technology. Today, artificial intelligence aims to minimize the existing problems in tax collection.[209]

Thanks to digital technologies, public sector decisions and services can be enhanced through a new generation of open, accountable, transparent and collaborative e-government services. The UK's Chief Scientific Adviser recently published a report outlining how blockchain-based technologies can provide new tools for reducing fraud, preventing errors, reducing operating costs, increasing efficiency, promoting compliance and accountability in most public services.[210] Possible applications include tax collection, identity management, local or national digital currencies, property and land records, and government records of all kinds. The same technology also opens up opportunities for non-state actors to provide state-like services, from notary services to global citizenship.

For example, the Estonian government has experimented with permission-based blockchain-based applications that allow citizens to use their ID cards to obtain prescriptions for medicines, vote, make monetary transactions, claim benefits, register jobs, pay taxes, and access nearly three thousand other digital services.[211] This approach also allowed civil servants to encrypt their documents, review and approve permits, contracts and applications, and request information to other services. Of course, some access data is protected and restricted to protect users' privacy.[212]

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[209] Orçun Avcı, Vergi Tahsilatında Yapay Zekânın Kullanımı ve Önemi (Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi, 22(1), 2021), p.51.

[210] UK Government Chief Scientific Adviser, Distributed Ledger Technology: beyond block chain (January 19, 2016), URL:https://assets.publishing.service.gov.uk/media/5a818d6fe5274a2e87dbe3dd/gs-16-1-distributed-ledger-technology.pdf.

[211] PricewaterhouseCoopers, Estonia – the Digital Republic Secured by Blockchain (2019), URL:https://www.pwc.com/gx/en/services/legal/tech/assets/estonia-the-digital-republic-secured-by-blockchain.pdf.

[212] Philip Boucher, How Blockchain Technology Could Change Our Lives (European Parliamentary Research Service, European Parliament, 2017),

On the other hand, the "Gachain" public blockchain technology, which the People's Republic of China, one of the world's most populous and most developed economies, implemented in October 2017, was developed to accelerate tax collection and prevent tax evasion through verification and electronic invoice system.[213]

Another example of the impact of smart contracts on the taxation process is the case of Russia, which requires electronic value added tax refunds. On 01.01.2015, it started to submit all transactional value added tax data electronically. This infrastructure has created a national smart contract that allows the Russian Federal Tax Service to track goods via blockchain and see possible systematic evasion and tax evasion. As a result of this experiment, value added tax revenues increased by 12% that year.[214]

The blockchain structure, which forms the infrastructure for smart contracts, offers a combination of cost-effectiveness and fast processing. As advances in information technology continue, these costs are expected to decline further in the coming years. Improvements in the chaining process could also lead to faster speeds. The absence of intermediaries and the self-authenticating nature of blockchains contribute to transaction speeds. Incorporating the technology will facilitate real-time audits when tax authorities inspect companies. The transparency automation of blockchain technology will lower tax compliance costs and reduce staffing.[215]

The use of blockchain technology in taxation brings many advantages. However, in addition to these advantages, as a result of the increase in the share of cryptocurrencies in the economy, new problems that can be considered illegal in the field of taxation have also emerged. Cryptocurrencies are based on blockchain technology. As a result of the elimination of intermediaries by this technology,

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URL:https://www.europarl.europa.eu/RegData/etudes/IDAN/2017/581948/EPRS_IDA(2017)581948_EN.pdf.

[213] Bei Xi Xu, Government to Use Blockchain to Prevent Tax Evasion (Tax Notes International 87, 2017).

[214] Simon Jenner, Blockchain: The Digital Tax Function's Leading-Edge Technology (Tax Notes International 88, 2017), p.1088-1089.

[215] Piotr Jurowiec, Blockchain Applications in the World Tax Regime (GoodAudience, 2018), URL:https://blog.goodaudience.com/blockchain-applications-in-the-world-tax-regime-ea2111741f0b.

anonymity between transactions is ensured. This situation causes uncertainty for many regulatory bodies, including tax authorities. In this regard, the Central Banks of England and Canada, the U.S. Federal Reserve Bank and many other central banks have launched investigations into cryptocurrencies.[216] Considering that the global cryptocurrency market capitalization is approximately 2.84 trillion dollars, it can be said that central banks take this situation very seriously.[217]

As we mentioned in the previous sections, the blockchain, in addition to recording every single transaction, also verifies and records every single transaction between cryptocurrency users. However, it does not contain identifying information. From the transactions in the chain, the parties only verify the address and the amount of coins that users transfer. That is, the owner of the address, the geographical location of the wallet or other important identifying information is not recorded. Thus, unlike other electronic transactions, cryptocurrencies allow users to send and receive money and valuable property anonymously. Because cryptocurrency transactions are inherently anonymous, users who want to avoid taxation can invest large amounts in cryptocurrencies instead of stocks, bonds or other investments.[218] This leads to tax evasion.

The fact that cryptocurrency transactions are difficult to identify causes tax authorities to fail to determine taxable income and cause loss of revenue. In addition, blockchain technology also imposes certain obligations on tax administrations. As a result of the increase in business models and the speed of market entry with the development of technology, the legislator cannot keep up with this speed and tax administrations cannot update tax rules. In this context, tax administrations may have problems in keeping up with the changing technology and implementing tax rules. In

[216] International Monetary Fund - IMF, How Should Central Banks Explore Central Bank Digital Currency? (Fintech Notes, 2023/008), URL:https://www.imf.org/en/Publications/fintech-notes/Issues/2023/09/08/How-Should-Central-Banks-Explore-Central-Bank-Digital-Currency-538504.
[217] Forbes, Cryptocurrency Prices Today By Market Cap, URL: https://www.forbes.com/digital-assets/crypto-prices/. (accessed 11.03.2024).
[218] International Monetary Fund - IMF, Taxing Cryptocurrencies (WP/23/144, 2023), URL: https://www.imf.org/en/Publications/WP/Issues/2023/06/30/Taxing-Cryptocurrencies-535510.

addition, the legal infrastructure is not sufficient for smart contracts and cryptocurrency transactions. There is also the possibility that the professional qualifications of the staff or expert teams may not be sufficient for blockchain technology, and there are budget constraints for advanced training and high start-up costs.[219]

5.3.4. Smart Contracts and Contract Law

The convergence of smart contracts and conventional contract law brings up a range of legal and practical considerations that require thorough attention. A primary hurdle involves establishing the validity of smart contracts within the realm of traditional contract law. Despite the benefits of automation and effectiveness offered by smart contracts they still need to align with the core tenets of contract law such, as offer, acceptance, consideration and intent to form binding relationships.[220] Additionally issues concerning smart contract formation, execution and remedies in the context of contracts necessitate an examination, within the existing legal structure.

5.3.4.1. Freedom of Contract

One of the fundamental principles of contract law is the principle of freedom of contract. The principle of freedom of contract is an umbrella concept that includes many different freedoms within itself. Within this framework, there is the freedom to decide whether or not to conclude a contract, to choose the counterparty to the contract, to freely determine the content of the contract and freedom of form.[221] Freedom of contract in the context of smart contracts presents both new opportunities and challenges. By enabling the automatic enforcement of contract terms, smart contracts not only allow parties to complete transactions faster and with fewer errors, but can also provide advantages for complex and multilateral agreements. In addition,

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[219] Tim Niesen, Martin Scheid and Peter Fettke, Getting Ready for the Future of the Tax Function - Global Survey on Digital Tax Maturity and AI Readiness (WTS Global, 2018), URL:https://wts.com/wts.de/insights/kuenstliche-intelligenz/wtsai_brochure_getting-ready-for-the-future-of-the-tax-function.pdf.

[220] Mykyta Sokolov, Smart Legal Contract as a Future of Contracts Enforcement (26 Jul 2018), URL:https://dx.doi.org/10.2139/ssrn.3208292.

[221] Tedoradze Irakli, The Principle of Freedom of Contract, Pre-Contractual Obligations Legal Review English, EU and US Law (European Scientific Journal February 2017 edition Vol.13), URL: http://dx.doi.org/10.19044/esj.2017.v13n4p62.

the elimination of unnecessary bureaucracy for intermediaries will significantly reduce transaction costs, and the transparency provided by blockchain technology will build trust between the parties.

The freedom of contract in smart contracts has disadvantages as well as advantages. The most important disadvantages include inflexibility, technical issues and, most importantly, uncertainty about the legal status of smart contracts and their compatibility with traditional contract law. For example, it is unclear whether a smart contract is considered a legal contract or how to determine the will of the parties. Smart contracts therefore have the potential to expand the concept of freedom of contract, but this technology also has legal and practical challenges. In order for smart contracts to be used effectively and fairly, it is important to develop legal frameworks and standards that are compatible with technological developments. This will create a balanced approach that will both encourage innovation and help parties protect their rights.

5.3.4.2. Can Willpower be Expressed in a Programming Language?

Within the framework of the principle of freedom of contract and especially the principle of freedom of form, the parties may express their will in the languages of their choice, in natural languages, even in dead languages, or as symbols or signs.[222] The principle of freedom of will prevailing in private law allows the parties to determine the language of the contract as they wish. Within this framework, there is no obstacle for the parties to express their will in smart contract code. Expressions of will may be created or communicated using technical means.[223] This also applies to the "offer and acceptance" method, which is generally used for the conclusion of a contract.

Translating the concept of willpower, from psychology into a programming language or smart contracts presents challenges due to the differences between human

[222] Alexander Wilhelm, Smart Contracts im Zivilrecht – Teil 2“ (Wertpapier-Mitteilungen, Zeitschrift für Wirtschafts- und Bankrecht (WM), 2020), p.1808.
[223] Möslein, p.36.

cognition and computer code.[224] Willpower encompasses functions such as motivation, self regulation and the capacity to resist immediate gratification making it difficult to replicate in a programming setting. Nevertheless certain elements of decision making processes influenced by willpower in humans can be. Enforced in contracts, through predefined rules and conditions. Smart contracts operate automatically based on their coded logic ensuring that specific actions occur when designated conditions are satisfied resembling a way to instill discipline or dedication. For instance consider a smart contract designed to assist an individual in reaching their savings or investment aspirations; it can be viewed as a tool that bolsters determination. This type of smart contract automates fund transfers based on criteria thereby facilitating the attainment of long term objectives by the individual. To sum up while willpower itself may not be directly encoded in a programming language, the design and execution of programming languages and smart contracts can be tailored to aid individuals in accomplishing their objectives through determination. This serves as an illustration of how technology can reinforce conduct and decision making processes.

5.3.4.3. Freedom of Form

Another pillar of the principle of freedom of contract is freedom of form. The basic elements of the simple written form are text and signature. The text element reflects the will of the person making the declaration of will to the legal transaction. It does not matter what the text is written in or in which language it is written after it reflects the will of the legal transaction.[225] Classically, the declaration carrier is physically present and is characterized as a paper document.[226]

Regarding the requirement of the textual element of the simple written form, the language used in the text is not important. We have mentioned in the previous

[224] Evelina Fedorenko, Anna Ivanova, Riva Dhamala and Marina U. Bers, The Language of Programming: A Cognitive Perspective (Trends in Cognitive Sciences 23(7), 2019), URL: http://dx.doi.org/10.1016/j.tics.2019.04.010.
[225] Claire Huguenin, Obligationenrecht Allgemeiner und Besonderer Teil (2.A. Zurich 2014), p.349.
[226] Ingeborg Schwenzer, Schweizerisches Obligationenrecht Allgemeiner Teil (7. Auflage, Bern 2016), p.13.

sections that smart contracts are composed of programming languages. In this sense, since programming language is also a language, it can be argued that it is within this scope in the first place.[227] However, since the textual element reflects the legal transaction awareness of the declarant, it is stated in the doctrine that the writing and language used here should at least be understandable for the persons protected by the formal provisions.[228]

Accordingly, it is stated that this condition will be met if the addressee of the declaration of will is a person who understands the programming language.[229] However, if the addressee is a person who does not know the programming language, it is debatable whether a concrete person or a customer model to be determined according to the principle of trust will be taken as the basis for the intelligibility and whether this condition is met.[230] In the blockchain network, electronic declarations of will are stored securely against external interventions in such a way that they cannot be changed, and there is no possibility of loss or forgery of the text. Considering these conditions, it can be said that smart contracts provide the function of the textual element of the simple written form.[231]

The general situation in the world is that contracting parties do not need to create the declaration content with a specific authoring tool, and the declaration content can be created by utilizing technological tools. It is generally considered sufficient if the obligations contained in the smart contract code ("source code") can be displayed in typeface.[232] However, the signature requirement is problematic in many countries. For example, in Europe, the use of electronic signatures is regulated by the

[227] Ute Bertram, Smart Contracts. Praxisrelevante Fragen zu Vertragsabschluss, Leistungsstörungen und Auslegung (MDR, 23/2018), p.1418.
[228] Ernst Kramer and Bruno Schmidlin, Allgemeine Einleitung in das schweizerische Obligationenrecht und Kommentar zu Art. 1-18 (Bern 1986), p.12-15.
[229] Bertram, p.1418.
[230] Florian Möslein, Rechtsgeschäftslehre und Smart Contracts, Rechtshandbuch Smart Contracts (München 2019), p.88.
[231] Hanzl, p.205.
[232] Pınar Çağlayan Aksoy and Zehra Özkan Üner, NFTs and copyright: challenges and opportunities (Journal of Intellectual Property Law & Practice 1115, 2021), URL: https://dx.doi.org/10.1093/jiplp/jpab104.

"European Union Regulation on Electronic Authentication and Trust Services" (eIDAS).[233] eIDAS divides electronic signatures into three different categories: Simple Electronic Signature (SES), Advanced Electronic Signature (AES) and Qualified Electronic Signature (QES). For our example, QES is legally equivalent to handwritten signatures in the European Union. However, this is not common in the world. The double key system used in the blockchain allows to check that the integrity of the message is preserved, but does not guarantee the identity of the public key holder. However, in order to be able to speak of a secure electronic signature, a trusted third party, i.e. an approval institution, must intervene when establishing the identity link between the key used and the key holder, and the transaction must be based on a certificate provided by this institution. Since there is no such approval institution in the blockchain, the electronic signatures used in the blockchain are not suitable for meeting the simple written form requirement.[234]

5.3.4.4. Unlawful and Immoral Contracts

The principle of freedom of content allows the parties to freely determine the content of their contracts. One pillar of this is the freedom of the parties to determine the means by which their contracts will be enforced. Nevertheless, contracts that are objectively impossible to perform at the time of their conclusion; whose subject matter, the present content or the implied object contravene a mandatory, objective, written or unwritten rule of private or public law; which are contrary to personal rights due to the subject matter of the obligation or the excessive obligations they contain; which have a content or object contrary to the general rules of morality prevailing in a given society; and which are contrary to public order are void in most Italian and most European countries.[235]

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[233] eIDAS Regulation, URL: https://digital-strategy.ec.europa.eu/en/policies/eidas-regulation. (accessed 07.03.2024).
[234] Rolf H Weber, Smart Contracts and What the Blockchain Has Got to Do With It (Bern 2019), p.365.
[235] Paolo Franceschetti, Nullità del contratto (Altalex, 2016), URL:https://www.altalex.com/documents/altalexpedia/2016/05/05/nullita#_Toc449546012. (accessed 07.03.2024).

It is not possible to eliminate the nullity regulated by law by inserting a contractual provision contrary to public order or law or morality into a smart contract.[236] The fact that the parties to a smart contract are pseudonymous also does not save contracts that are contrary to law or morality from being null and void.[237] In this framework, even if the parties agree that the smart contract will be used for the realization of an unlawful or immoral purpose or that the smart contract will be used in the execution of such a contract, this agreement is not legally valid. For example, the sale or importation of narcotics is prohibited in Italy.[238] Selling or importing drugs on the blockchain does not make this transaction valid. This transaction is still prohibited by law. As a matter of fact, whichever country's law is the law applicable to the smart contract, the transaction must be carried out in accordance with the rules of law in that country.[239] While this is the legal situation, inconsistencies between the law and the information technology system can occur, which can lead to the execution of illegal smart contracts, as the smart contract code will not take into account the possible invalidity of a legal contact unless instructed to do so.[240]

At this point, the following situation should also be mentioned: Smart contracts cannot control whether the parties have the capacity to contract. Within this framework, it is technically possible for a minor child or a person who lacks the capacity to distinguish due to intoxication or mental illness to be a party to a smart contract. A person may unwittingly enter into a smart contractual relationship with a person who lacks the capacity to have knowledge of the contract or with a child. From a legal perspective, the contracts established by these persons may face invalidity

[236] Andreas Sesing and Jonas S. Baumann, Automatisierung von Vertragsbeziehungen in der Industrie 4.0 (Zeitschrift zum Innovations- und Technikrecht 2020), p.235.
[237] Blaise Carron and Valentin Botteron, “How smart can a contract be?”, Blockchains, Smart Contracts, Decentralised Autonomous Organisations and the Law (Cheltenham/Northampton 2019), p.86.
[238] Altalex, Testo unico sulla droga - Titolo V - Dell'importazione, dell'esportazione e del transito, URL: https://www.altalex.com/documents/news/2014/05/28/testo-unico-sulla-droga-titolo-v-dell-importazione-dell-esportazione-e-del-transito. (accessed 07.03.2024).
[239] Kolber, p.198.
[240] Schrey and Thalhofe, p.1436.

sanctions. In order to prevent this problem, it is stated that the identity control methods to be realized in the blockchain are important.

5.3.4.5. Performance and Breach of Performance in Smart Contracts

Blockchain technology is utilized in the execution of contracts. Within the framework of the distinctions we have adopted regarding smart contracts, performance may first come to the fore in the narrow sense of smart contracts. However, what is important here is that the establishment of the contract takes place in the blockchain network, and the performance of the obligation can also take place outside the blockchain network with external data providers.[241] On the other hand, in smart contracts for the implementation of contracts, the contract is established outside the blockchain. The performance of this contract is carried out automatically and directly through smart contracts in the blockchain network.[242] In this case, if it is accepted that Ether is used as a means of payment, the contract may become null and void. This process starts with a smart contract trigger when a customer sends Ether to a smart contract.[243] More concretely and technically, the "if" premise in the smart contract code is realized and the consequence associated with the "then" is implemented.[244]

We can exemplify the situation with car rental. If a person needs a car, they can use smart contracts to ask if a car is available for rent. In such a case, the system takes the customer's information, checks the payment status and availability of a suitable car against the criteria in the pre-coding, and finally makes it possible to use a suitable candidate car if all the conditions for renting are met. The customer in turn sends Ether to the smart contract. A pre-programmed password that can unlock a parked car with a shared location is then sent to the customer's mobile phone via a computer program that provides external data. With this password, a compatible application on the

[241] Lukas Gottardis and Raimund Pittl, Smart Contracts – An Analysis from the Perspective of Austrian Law (Journal of European Consumer and Market LawVolume 8, Issue 5, 2019), p.194.
[242] Martin Heckelmann, Zulässigkeit und Handhabung von Smart Contracts (NJW, 2018), p.305.
[243] Kaulartz and Heckmann, p.618.
[244] Berk Kapancı, Özel Hukuk Penceresinden Blokzincir: "Sanal Para" Değerleri ve "Akıllı Sözleşmeler" Üzerine Değerlendirmeler (Gelişen Teknolojiler ve Hukuk 1, 2020), p.115.

customer's mobile phone, such as a QR code, can unlock the vehicle's door and then its engine, making it usable. Especially with the development and widespread use of electronic and smart vehicles, we may encounter such examples in the near future. Programming smart contracts in compliance with legal regulations is important due to the meaning we give to the primacy of code approach.[245] In a smart contract regime that is programmed in compliance with legal regulations, if the tenant has problems in payment, the smart contract protocol prevents the car from starting by locking the car door and engine.

As a result of the immutability and self-execution features of smart contracts, the ideal situation is that the performance of the contract takes place automatically and without any legal or factual problems. Because smart contracts are composed of digitally controllable events, they are independent of the parties' will to perform or not to perform. The parties do not execute the smart contract, the smart contract code executes itself on the blockchain. From this point of view, performance is virtually guaranteed, meaning that the principle of pacta sund servanda[246], one of the fundamental principles of contract law, is absolute.

Even if the smart contract code is transparent, it is possible to miss bugs even in simple smart contracts. Especially in the complex smart contract networks that underpin DeFi applications, understanding and verifying the code can be difficult even for users who can read and understand the source.[247] Those who don't understand the source code build their expectations based on information provided by third parties or professional code auditors who lay out smart contract transactions in understandable language. In recent years, a multi-million dollar code auditing industry has emerged to provide independent security for this sector, but even such

[245] Heckelmann, p.509.
[246] Britannica, pacta sunt servanda, URL:https://www.britannica.com/topic/pacta-sunt-servanda. (accessed 08.03.2024).
[247] Daniel Macrinici, Cristian Cartofeanu and Shang Gao, Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study (Telematics and Informatics 35(8), 2018), URL:http://dx.doi.org/10.1016/j.tele.2018.10.004.

audited contracts can be hacked, resulting in huge losses for investors.[248] Therefore, the concepts of breach of obligation and non-performance of the contract will also be encountered in smart contracts.[249] For example, default may arise if the performance of the contract is temporarily prevented due to program failure or technology failure. If there is an off-chain smart contract and the underlying natural language contract is vague, ambiguous or open to interpretation, the smart contract may not perform as the parties intended.[250]

5.4. Different Uses and Legal Reflections of Smart Contracts

The introduction of smart contracts into commercial operations and personal transactions presents a unique set of opportunities and challenges for legal experts, legislators and regulatory entities. On one hand, the autonomy and self-executing nature of smart contracts can reduce the complexity and costs associated with traditional contract formation, execution, and enforcement. On the other hand, the integration of these digital agreements into existing legal frameworks raises critical questions about jurisdiction, dispute resolution, contractual validity, and the protection of consumer rights.

5.4.1. In terms of Consumer Law

The free market economy and developments in economic and social areas have brought about the need to raise awareness, protect and organize consumers, who are in a weaker position against powerful sellers. Therefore, states have made regulations in their domestic laws to guarantee these fundamental rights.[251] In contractual relationships, one party often acts as a consumer while the other party is a more powerful party than the consumer party, such as a bank or a seller. Therefore, it is

[248] Balázs Bodó and Primavera De Filippi, Trust in Context: The Impact of Regulation on Blockchain and DeFi (Amsterdam Law School Legal Studies Research Paper No. 2022-07), URL:https://dx.doi.org/10.2139/ssrn.4051842.
[249] Fikriye Ceren Sadioğlu, Borçlar Hukuku Çerçevesinde Akıllı Sözleşmenin İşlevleri ve İşlevlerin Yerine Getirilmesi Sı-rasında Karşılaşılan Sorunlar (Ankara Hacı Bayram Veli Üniversitesi Hukuk Fakültesi Dergisi, 2021), URL: https://doi.org/10.34246/ahbvuhfd.1018674.
[250] Markus Kaulartz, Jonas Gross, Constantin Lichti ve Phillip Sandner (Legal Aspects of Blockchain Technology for Industrial Use Cases,2022), p.6.
[251] European Commission, Consumer rights directive, URL:https://commission.europa.eu/law/law-topic/consumer-protection-law/consumer-contract-law/consumer-rights-directive_en. (accessed 08.03.2024).

clear that the consumer party needs more protection in the process from the negotiation of the terms of the contract to the execution of the contract. When we look at the laws on consumer protection, it is seen that some conditions such as the preparation of contracts in a certain font size to facilitate the reading, understanding and judgment of the consumer; giving a copy to the consumer and providing preliminary information to the consumer, who is a party to the contract, before the contract is signed, have been introduced in order to protect the consumer.

It is controversial how the regulations introduced in the consumer legislation to protect the consumer can be applied to smart contracts. This is because it is not technically possible to deliver a copy of a smart contract to the consumer "physically" or via e-mail as stipulated in the consumer legislation. In the event of a technical error or omission on the part of the seller, who is the counterparty of the consumer, during the establishment of the smart contract, it will not be possible for the consumer to prove the correct transaction and/or term agreed between the parties.[252] Therefore, in the event of a technical error or breach of contract that may arise in the smart contract, the consequences of the error or breach of contract will have occurred without the contracting party notifying the other party.

The incorporation of smart contracts, into the Consumer Protection Framework of the European Union (EU) specifically regarding the right to withdraw creates a blend of technology and consumer rights. Smart contracts, known for their capacity to execute and contract terms automatically according to predetermined criteria bring advantages in efficiency and security. Nonetheless they pose difficulties, in harmonizing with established consumer protection entitlements like the right to withdraw as outlined in the Consumer Rights Directive (2011/83/EU).[253] Consumers have the option to cancel a contract within a 14 day period after making a purchase

[252] Mateja Durovic and Chris Willett, A Legal Framework for Using Smart Contracts in Consumer Contracts:Machines as Servants, Not Masters (Modern Law Review Volume 86, 2023), URL:https://doi.org/10.1111/1468-2230.12817.

[253] Eur-Lex, Directive 2011/83/EU of the European Parliament and of the Council of 25 October 2011 on consumer rights, URL:https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011L0083.

without needing to give a reason.[254] This measure is, in place to safeguard consumers who make purchases off site. It gives them the chance to rethink their doorstep purchases especially when they haven't had the opportunity to examine the products or grasp the services beforehand.

When smart contracts are automatically executed, it becomes difficult for consumers to exercise their right of withdrawal. Once the contract is up and running, it independently enforces the terms, which can limit the consumer's chances of withdrawing in time.[255] The immutable nature of the technology, which prohibits modification or removal of data, adds complexity to the provision of withdrawal privileges. This immutable nature raises questions about reversing transactions or adjusting contract terms when a consumer chooses to exercise withdrawal rights.[256] The Consumer Rights Directive requires clear and understandable information on the right of withdrawal between sellers and consumers. Another challenge is to ensure that consumers are adequately informed about their rights in the context of smart contracts, which can be complex and technical.[257]

Aside from the view that smart contracts may create problems in consumer protection, another view is that smart contracts may support consumer protection. Accordingly, regulators or legislators will be able to standardize some terms by enabling parties to encode certain contracts or regulatory conditions in a way that cannot be changed in smart contracts. For example, in order to prevent unlawfulness in credit transactions, the legislator may require the parties to a credit contract to code maximum interest rates into smart contracts.[258]

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[254] European Union, Guarantees and returns, URL:https://europa.eu/youreurope/citizens/consumers/shopping/guarantees-returns/index_en.htm.
[255] European Law Institute, ELI Principles on Blockchain Technology, Smart Contracts and Consumer Protection (2022), URL:https://www.europeanlawinstitute.eu/fileadmin/user_upload/p_eli/Publications/ELI_Principles_on_Blockchain_Technology__Smart_Contracts_and_Consumer_Protection.pdf.
[256] Lucas Forbes, Consumer Protection In the Face of Smart Contracts (Loyola Consumer Law Review Volume 34, 2022), URL:https://lawecommons.luc.edu/lclr/vol34/iss1/3.
[257] Son T Nguyen, Consumer Protection Against Unfair Contract Terms in the Age of Smart Contracts (Federal Law Review, Volume 51, 2023), URL:https://doi.org/10.1177/0067205X231205048.
[258] Chamber of Digital Commerce, Smart Contracts: 12 Use Cases for Business & Beyond; A Technology, Legal & Regulatory Introduction — Foreword by Nick Szabo(2016),

5.4.2. In terms of Commercial Law

Smart contracts can be used in almost any commercial activity that commits to the purchase or exchange of goods and services. Smart contracts are particularly advantageous when there are frequent transactions within a network, and each transaction involves the performance of certain tasks between the parties on an ongoing basis. For this reason, it is possible to see smart contracts in many different sectors and services.

As mentioned in the previous chapters, smart contracts are actively used in areas such as financial services, internet of things, insurance, real estate and supply chain. While smart contracts can be found in all areas of commercial life, they also provide convenience in corporate governance and secretarial work. For example, the bankruptcy of a company can be filed directly with a smart contract without the need for a court.[259] In addition, shareholder agreements, where human intervention is not very necessary, can also be realized through smart contracts under certain conditions.

As I know, monitoring costs can be reduced to almost zero in transactions and activities within commercial law, as an automatic result is achieved if the smart contract is entered with the right codes.[260] This may be particularly advantageous in voting clauses and share sale regulations. For example, if a voting clause is set on a smart contract, the smart contract will automatically set the debtors' voting token to one of the creditors. If the creditors use their tokens to vote in favor, the smart contract will then use the debtors' tokens to vote. In this way, the contracting parties will not have to follow the terms of the contract and the smart contract will work by itself. Secondly, a smart contract can prevent the parties in a company from acting with different interests. However, in order for the smart contract to be implemented

URL:https://www.perkinscoie.com/images/content/1/6/v2/164979/Smart-Contracts-12-Use-Cases-for-Business-Beyond.pdf.

[259] Carter D. Wietecha, The Impending Collision of Smart Contracts and the Automatic Stay (Notre Dame Law Review Volume 97, 2022), URL:https://scholarship.law.nd.edu/cgi/viewcontent.cgi?article=5011&context=ndlr.

[260] James Grimmelmann, All Smart Contracts Are Ambiguous (Journal of Law & Innovation, 2019), URL:https://www.law.upenn.edu/live/files/9789-jli-volume-2.

effectively, the conditions to be set within the smart contract should be drafted in a clear manner that leaves no room for interpretation. As it is known, smart contracts do not have the ability to interpret. It is important to note that a contract on a blockchain system also protects against the risk of fraud, unless one of the contracting parties owns more than 50% of the mining power.[261]

5.4.3. In terms of Capital Market Law

Distributed ledger technology has the potential to significantly reduce the complexity of the relationships between the parties to capital market transactions.[262] Capital market transactions involve many participants such as buyers, sellers, brokers, regulatory authorities and require additional procedures such as obtaining permits. In terms of the execution of capital market transactions, smart contracts are expected to provide some benefits.

At the beginning of the 20th century, capital markets, which were dispersed and unorganized, took on a centralized structure due to financial crises and bad experiences.[263] The centralized structure includes safe mechanisms in terms of functioning. For instance stock markets support price determination while centralized clearing and settlement processes lower the risk of defaults. This setup has promoted the growth and smooth operation of markets by instilling confidence, in traders. Recently advancements like technology and smart contracts have prompted a shift from centralized to decentralized structures. In this transition institutions among market participants and the design of instruments will undergo changes due, to the adoption of smart contracts. Accordingly, in the coming period, intermediaries,

[261] Fredy Andres Aponte-Novoa, Ana Lucila Sandoval Orozco, Ricardo Villanueva-Polanco and Pedro Wightman, The 51% Attack on Blockchains: A Mining Behavior Study (Institute of Electrical and Electronics Engineers IEEE Volume 9, 2021), URL: https://doi.org/10.1109/ACCESS.2021.3119291.
[262] Global Financial Markets Association, Impact of Distributed Ledger Technology in Global Capital Mark(2023),URL:https://www.gfma.org/wp-content/uploads/2023/05/impact-of-dlt-on-global-capital-markets-full-report.pdf.
[263] Ha-Joon Chang, Bad Samaritans: The Myth of Free Trade and the Secret History of Capitalism (Bloomsbury Pub Plc USA, 2008),p.15.

exchanges, clearing houses and custodians operating under the current structure will need to redefine their activities.[264]

Procedures that are completed in stages in capital markets can be made more efficient and faster with the use of blockchain and smart contracts.[265] Similarly, the use of smart contracts can reduce the possibility of error by automating corporate transactions. When smart contracts are used in capital market transactions, it is possible to make the exchange of assets much faster by instantly transferring a token to the beneficiary's wallet. Moreover when institutions and organizations participate in these transactions data can flow rapidly throughout the database. In this way, the procedures to be followed can be fulfilled more quickly. Especially if regulatory and supervisory institutions have direct access to the blockchain and smart contract, this system will progress faster.[266] For this, it would be more appropriate to make transactions on private/permitted blockchains.

As is known, products that fall under the definition of capital market instruments are traded in organized markets or over-the-counter (OTC) markets.[267] Collateralization of OTC contracts by investment institutions, collateral monitoring, and collateral completion notifications involve manual processes.[268] The increasing adoption of smart contracts, in over the counter (OTC) transactions will lead to the development of smart contracts particularly in specific categories. This will help reduce inaccuracies in contract terms and confirmation documents prepared during the contract setup phase in OTC transactions. Automated procedures, such, as monitoring collateral and ensuring its completion will be executed seamlessly.

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[264] Mahir Kubilay Dağlı, Akıllı Sözleşmeler ve Sermaye Piyasalarına Etkisi (Blokzincir, Kripto Paralar ve Akıllı Sözleşmelerde Güncel Gelişmeler, 2021), p.57-58.
[265] Mohd Javaid, Abid Haleem, Ravi Pratap Singh, Rajiv Suman and Shahbaz Khan, A review of Blockchain Technology applications for financial services (BenchCouncil Transactions on Benchmarks, Standards and Evaluations Volume 2,2022), URL:https://doi.org/10.1016/j.tbench.2022.100073.
[266] Bank for International Settlements, The future monetary system (BIS Annual Economic Report, 21 June 2022), URL:https://www.bis.org/publ/arpdf/ar2022e3.htm. (accessed 04.03.2024).
[267] International Monetary Fund, Financial markets: Exchange or Over the Counter, URL:https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/Financial-Markets.
[268] International Swaps and Derivatives Association, Collateral Management Suggested Operational Practices, URL:https://www.isda.org/collateral-management-sop/.

Subsequently asset transfers will be automatically facilitated upon contract maturity. In other words, a kind of code libraries will emerge and anyone who wants to use a smart contract will be able to select and use it according to the contract terms that suit them. In this way, especially capital market instruments traded in the OTC market will have a more transparent structure.[269] In addition to all these advantages, the inability to perform the necessary controls in cases such as coding errors in smart contracts may create additional risks.[270]

The application of smart contracts is not limited to bilateral agreements. Smart contracts can also help create agreements involving people, in a network.[271] In this scenario smart contracts could be used to form partnership agreements or set up an organization by connecting many individuals working together on a project. In the global context, equity issuances ("IPOs") and crowdfunding are regulated by regulatory authorities.[272] Initial coin offering (ICOs), on the other hand, have some different features compared to equity issues.[273] Countries such as the US, Switzerland, Canada and Hong Kong have scrutinized the issue on the grounds that some ICOs may violate capital market regulations.[274] It is clear that ICOs are very high-risk and speculative investment instruments for investors. In addition, it is unclear whether "token sale" practices, which have similar aspects and differences to public offerings and crowdfunding activities, will fall within the scope of state regulation. Indeed, the tokens offered through ICOs do not fully overlap with the definitions such as shares, stocks, securities, capital market instruments in classical legal regulations, and have

[269] Dağlı, p.56.
[270] Burak Görmez, Finansal Sektörde Yıkıcı Yenilik: Dağıtılmış Defter Teknolojisi ve Türkiye Sermaye Piyasalarının Durumu (Distributed Ledger Technologies/Blockchain) (SPK Etüdü, 2017), p.39.
[271] Jens Frankenreiter, The Limits of Smart Contracts (Columbia Law School, 2019), URL:https://doi.org/10.1628/jite-2019-0021.
[272] European Eommission, Understanding Crowdfunding and its Regulations, URL:https://publications.jrc.ec.europa.eu/repository/handle/JRC92482.
[273] European Parliament, Understanding initial coin offerings, URL:https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/696167/EPRS_BRI(2021)696167_EN.pdf.
[274] U.S. Securities and Exchange Commission (SEC), Cryptocurrency/ICOs, URL:https://www.sec.gov/securities-topics/ICO.

some unique characteristics.[275] It is of great importance for the growth of capital markets that countries play an active role in the developments in smart contracts and blockchain technology and make the necessary legal and technical infrastructure arrangements.

5.4.4. In terms of Intellectual Property Law

The connection, between smart contracts and intellectual property law can be viewed from two perspectives. Firstly smart contracts play a role in transactions related to property whether contractual or non contractual. Secondly smart contracts themselves are subject to rights, within the realm of intellectual property law.[276]

Intellectual property rights are generally protected under European law through certain categories of rights. An element of an intellectual property right may be subject to protection under a protection regime that has its own legislation and is determined under special regulations, such as copyright and related rights or trademarks, geographical indications, industrial designs, patents, utility models, domain names, plant species, integrated circuit topographies, trade secrets under the industrial property branch of intellectual property law.[277] This protection provided by intellectual property rights ensures through legal means that the right holder has certain exclusive powers over the relevant right and that others cannot exercise such powers over that intellectual property right element.

The instances where smart contracts could potentially be protected by intellectual property rights include copyright related to the source code and object code used in contracts copyright linked to the design of the user interface facilitating interactions, with contracts, industrial property rights concerning the algorithm or

[275] Hulusi İlker Evin, Sermaye Piyasalarında Yeni Uygulamalar: Kripto Para Arzları (Türmob XX. Türkiye Muhasebe Kongresi, 2018), URL:https://www.researchgate.net/publication/328492416_Sermaye_Piyasalarinda_Yeni_Uygulamalar_Kripto_Para_Arzlari.

[276] Alexander Savelyev, Contract law 2.0: 'Smart' contracts as the beginning of the end of classic contract law (Information & Communications Technology Law Volume 26, 2017), URL:https://doi.org/10.1080/13600834.2017.1301036.

[277] European Commission, Intellectual property rights, URL:https://commission.europa.eu/business-economy-euro/doing-business-eu/intellectual-property-rights_en.

user interface of smart contracts or safeguarding through laws, against unfair competition.[278] When considering the safeguarding of computer programs, as pieces, within the realm of contracts it can be inferred that the binary code or the programming language based source code of smart contracts may be safeguarded as creative works provided they stem from an authentic and intellectual endeavor. However there is some debate surrounding the issue of intellectual property protection, for elements such as program flows, algorithms and interfaces that form the stages of smart contracts, within computer programs. Some argue that copyright protection should extend to program flows (often depicted as flowcharts) considering them as a work that contributes to the outcomes of computer programs in later stages.[279]

Its widely believed that algorithms on the hand don't have the benefits of intellectual property protection because they're based on ideas waiting to be translated into code forming the fundamental framework and core essence of a computer program.[280] Some argue that algorithms could be seen as a creation if they go beyond concepts and become "forms translated into instructions, for organizing computer commands" displaying characteristics unique, to their creators.[281] If we take into account the characterization of "protocols and user interfaces for securing and shaping relationships in common networks and the promises expressed through these interfaces" presented by Nick Szabo,[282] who first introduced the term smart contracts in the world, it is possible to protect a user interface consisting of audiovisual elements with which the parties to smart contracts interact as users as a work of science and literature under the scope of a computer program as a design.

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[278] Michèle Finck and Valentina Moscon, Copyright Law on Blockchains: Between New Forms of Rights Administration and Digital Rights Management 2.0 (IIC 50, 77–108,2019), URL:https://doi.org/10.1007/s40319-018-00776-8.
[279] Şener Dalyan, (Bilgisayar Programlarının Fikri Hukukta Korunması (Doktora, Ankara, Ankara Üniversitesi, 2008), p.78-79.
[280] Dalyan, p.82.
[281] Pelin Özkaya and Refik Samet, Yazılım Ürünlerinin Telif Hukuku Kapsamında Korunması (Uluslararası Bilgi Güvenliği Mühendisliği Dergisi 6), p.25.
[282] Nick Szabo, Formalizing and Securing Relationships on Public Networks (First Monday, 2(9), 1997), URL:https://doi.org/10.5210/fm.v2i9.548.

5.4.4.1. Protecting Intellectual Property Rights Using Smart Contracts

Smart contracts could potentially serve as a tool to safeguard property independently of their functions. The definition of contracts plays a role, in understanding their widespread application. If we define smart contracts within the context involving aspects like contract formation, performance of obligations monitoring obligations fulfillment and managing contingent contractual terms blockchain applications might not fit the criteria, for non contractual legal transactions or similar legal acts. An example of this is time stamping, which is not directly related to a transaction such as the conclusion of a contract and the performance of its obligations, but which has recently become widespread in intellectual property law, especially for the purpose of proving the creation of copyright, almost as a means of attestation. When a piece of work is dated using timestamps and linked to the blockchain platform it holds significance as evidence, in proceedings against individuals who infringe upon the intellectual property rights associated with that work. This timestamp can be utilized both before and after actions, as proof of ownership and usage. However simply time stamping, in this manner would not comply with contract law. In reality this approach does not pertain to finalizing or carrying out a contract. Its purpose is to record and prove the establishment of an entitlement.

Hence it is crucial to consider whether a smart contract aligns, with the notion of a contract, in terms and if a blockchain application extends beyond contractual transactions to offer advantages in non contractual legal dealings. In the area of contracts, it is considered that IPRs owned by enterprises may be more amenable to protection in this way, in particular because traditional methods of obtaining IP protection incur significant costs for small and medium-sized enterprises (SMEs). One

such method is the conclusion of non-disclosure agreements (NDAs) via a smart contract upon login to networking platforms.[283]

In addition, smart contracts can also be useful in the application and registration processes of rights such as patents, utility models, trademarks and industrial designs.[284] For example, in jurisdictions such as the United States,[285] where it is important to document the first use of a trademark, a blockchain-based trademark registry may be useful in proving first use, or a time-stamping method may be used, which may allow the creator of a work to prove this fact.[286] Whether smart contract applications are legally "valid" and will yield the same result as traditional methods such as attestation will depend on the strength of the evidence that law enforcement (e.g. courts or arbitration panels) will attribute to blockchain-based certificates, if not clarified by legislators' acceptance of blockchain-based methods. It is also possible that smart contracts can be used in the field of intellectual property law to combat counterfeit products, supply chain management and the separation of original products and counterfeit products by ensuring the traceability and transparency of original products through blockchain-based methods.[287] Since smart contracts have a digital content, it is considered possible to regulate contracts whose subject matter is the transfer or licensing of intellectual property as smart contracts.[288] When considering each intellectual property right it is important to check if the law mandates a written form, for the contract involved.

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[283] Lutz Maicher, On Intellectual Property in Online Open Innovation for SME by means of Blockchain and Smart Contracts (World Open Innovation Conference 2016), URL:http://dx.doi.org/10.13140/RG.2.2.27099.57124.

[284] Thomas Heinz Meitinger, Smart Contracts (Informatik-Spektrum,2017), URL:https://doi.org/10.1007/s00287-017-1045-2.

[285] Congressional Research Service CRS, An Introduction to Trademark Law in the United States (July 24, 2023), URL:https://crsreports.congress.gov/product/pdf/IF/IF12456.

[286] World Intellectual Property Organization (WIPO), Blockchain and IP Law: A Match made in Crypto Heaven?, URL:https://www.wipo.int/wipo_magazine/en/2018/01/article_0005.html.

[287] Mohammed Ali Alqarni, Mohammed Saeed Alkatheiri ,Sajjad Hussain Chauhdary and Sajid Saleem, Use of Blockchain-Based Smart Contracts in Logistics and Supply Chains (Electronics, 12(6), 2023), URL:https://doi.org/10.3390/electronics12061340.

[288] Gaétan de Rassenfosse and Kyle Higham, Decentralising the Patent System (Social Science Research Network, 2020), URL:https://dx.doi.org/10.2139/ssrn.3446337.

5.5. Legal Regulations on Smart Contracts in Comparative Law

A smart contract, which is a use case of blockchain technology, is not actually designed as a contract in the legal sense. Even Vitalik Buterin, who first coined the term "smart contract", has expressed regret over his choice of the term "smart contract" because people perceive it as a contract in the legal sense.[289] Smart contracts are also involved in relationships serving various purposes such, as tokens and automated systems. For instance escrow agreement[290] that entail value and asset transfers along with smart contracts can be executed using smart contracts through coded contracts, between the involved parties. In these days of new technologies, new conditions, new values, new ideas and even new currencies, it is inevitable that new legal problems will arise in the future.

Smart contracts, being built upon the parties intentions will naturally fall under the rules of contract law to traditional agreements. However the unique technological aspects and coding inherent, in contracts necessitate an approach when establishing contracts using this technology. Currently, there is not an encompassing framework that governs smart contracts globally. The legal standing, implementation and oversight of contracts lack a standard or widely recognized regulation. Instead different countries address the utilization and governance of contracts through their existing laws and unique regulatory methods. Today, there are no regulations on smart contracts both in the legal systems that have determined the Anglo-Saxon legal system, which interprets the freedom of contract broadly, and in the legal systems that have adopted the Continental European legal system.

Smart contract codes introduce methods, for regulation making it easier to envision how contract law could be implemented if individuals opt to utilize the code, for enforcing contracts. As a result of overseeing smart contracts or the fundamental

[289] Vitalik Buterin, Twitter: “To be clear, at this point I quite regret adopting the term "smart contracts". I should have called them something more boring and technical, perhaps something like "persistent scripts". (October 2018), URL: https://twitter.com/VitalikButerin/status/1051160932699770882?s=.
[290] Corporate Finance Institute, Escrow Agreement, URL:https://corporatefinanceinstitute.com/resources/valuation/escrow-agreement/. (accessed 11.03.2024).

blockchain technology many nations have primarily focused on integrating smart contracts into the current framework of contract law legislation.[291] However, when a purely codified contract is before a court, the contracting parties will certainly face difficulties in applying contract law to assess whether that contract was validly formed and whether the parties have fulfilled their obligations or whether there has been a breach of contract. In order to address these challenges, the application of existing contract law to smart contracts will be guided by the regulations on contracts concluded electronically. For example, the European Union Directive 1999/93/EC of December 13, 1999 on Common Framework Requirements for Electronic Signatures[292] and Directive 2000/31 of June 8, 2000 on Electronic Commerce,[293] the Federal Electronic Signature Act[294] and the Single Electronic Transaction Act[295] adopted in 2000 in the United States of America and the UNCITRAL Model Law on Electronic Commerce[296] prepared by the United Nations International Trade Law Commission and adopted by the United Nations General Assembly will guide courts and practitioners in the interpretation of the formation, performance and validity of smart contracts.

5.6. Smart Contract Laws in Major Countries

Smart contracts have been getting a lot of attention lately for their potential to change the way traditional contracts work. They offer advantages like being more efficient, transparent and secure. However incorporating them into systems comes with its own set of challenges. These include issues, like how enforceable they're which jurisdiction they fall under and ensuring they comply with existing laws. The United States, the European Union, China, Japan and other countries have found it

[291] Savelyev, p. 119-120.
[292] EUR-Lex, Directive 1999/93/EC of the European Parliament and of the Council of 13 December 1999 on a Community framework for electronic signatures, URL: https://eur-lex.europa.eu/eli/dir/1999/93/oj.
[293] EUR-Lex, e-commerce directive, URL: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32000L0031.
[294] Federal Electronic Signature Law (ESIGN), URL:https://www.fdic.gov/resources/supervision-and-examinations/consumer-compliance-examination-manual/documents/10/x-3-1.pdf.
[295] Uniform Electronic Transaction Act (UETA), URL:https://www.cga.ct.gov/2000/rpt/2000-R-1076.htm.
[296] UNCITRAL Model Law on Electronic Commerce (1996) with additional article 5 bis as adopted in 1998, URL:https://uncitral.un.org/en/texts/ecommerce/modellaw/electronic_commerce.

necessary to regulate or take steps to address the legal aspects of smart contracts. In the European Union there is a growing interest in regulating contracts. The European Commission has been publishing reports and guidelines on this topic. Countries such as Germany, France and the United Kingdom are also actively participating in shaping regulations, around contracts.

The legal standing and court documentation of smart contracts, in the United States is an evolving field that is still being clarified. In general according to US law smart contracts are viewed as written agreements. Essentially a smart contract may be seen as a pact between parties; however this hinges on the contracts legal validity and enforceability. Although there have been court rulings far certain cases have tackled crucial questions concerning the legal status of smart contracts. For instance a Wyoming court has ruled that other parties can terminate a smart contract though such rulings are mostly limited and contentious.[297] The implementation and oversight of contracts in the US are overseen by legislation and regulatory entities at state and local levels. While some states have enacted laws recognizing smart contracts generally speaking new regulations and guidelines are needed to harmonize with the legal framework. Guidance from bodies like the US Securities and Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC) has been pivotal in providing clarity on the structure for smart contracts in the US. These regulators have offered insights into how existing regulations relate to using smart tcontracts, in specific situations. For instance the SEC has released guidelines, on how digital assets fall under securities laws.[298] These guidelines carry implications for smart contracts involved in issuing, selling or trading tokenized securities on blockchain networks. They have played a role in clarifying the legal landscape concerning the application of current regulations to smart contracts and digital assets.

[297] Morgan N. Temte, Blockchain Challenges Traditional Contract Law: Just How Smart Are Smart Contracts? (Wyoming Law Review: Vol. 19: No. 1, 2019), URL: https://scholarship.law.uwyo.edu/wlr/vol19/iss1/7.

[298] US Securities and Exchange Commission (SEC), Framework for “Investment Contract” Analysis of Digital Assets, URL: https://www.sec.gov/files/dlt-framework.pdf.

Likewise the CFTC has issued advice on handling assets, especially cryptocurrencies and virtual commodities according to the Commodity Exchange Act (CEA).[299] This guidance covers aspects of smart contracts utilized in derivatives markets decentralized finance (DeFi) platforms and other blockchain applications. By offering directives on responsibilities and standards for smart contracts in these sectors the CFTCs guidance has fostered the establishment of proper and legally compliant practices within the industry. In essence the regulatory instructions from both the SEC and CFTC have been instrumental in shaping the framework for smart contracts in the United States. These clarifications aid market participants in comprehending their duties and adhering to existing regulations, amidst the swiftly evolving realm of blockchain technology and digital assets.

Germany has been working on clarifying the standing of smart contracts, in line with its 2019 Blockchain Strategy.[300] Regulatory bodies like the Federal Financial Supervisory Authority have been actively providing guidance to ensure that smart contracts comply with existing regulations especially when it comes to securities, financial instruments and digital assets.[301] The German government has also been collaborating with industry experts to gather insights on shaping smart contract regulations.[302] This joint effort aims to promote innovation while safeguarding consumer interests and market stability. Businesses and individuals engaging in smart contract transactions in Germany should stay informed about the changing landscape and adhere to the governments guidelines and compliance standards. By doing they

[299] Commodity Futures Trading Commission (CFTC), Digital Assets, URL:https://www.cftc.gov/digitalassets/index.htm. (accessed 11.03.2024).
[300] Bundesfinanzministerium, German government adopts blockchain strategy (18 September 2019), URL:https://www.bundesfinanzministerium.de/Content/EN/Pressemitteilungen/2019/2019-18-09-joint-release-with-bmwi.html. (accessed 14.03.2024).
[301] Federal FinancialSupervisory Authority (BaFin), Services relating to DLT, blockchain and crypto assets, URL:https://www.bafin.de/EN/Aufsicht/FinTech/Geschaeftsmodelle/DLT_Blockchain_Krypto/DLT_Blockchain_Krypto_node_en.html. (accessed 14.03.2024).
[302] Philipp Sandner, Germany on Chain: Die Blockchain-Strategie der Bundesregierung — Bitcoin ja, Libra nein (September 19, 2019), URL:https://philippsandner.medium.com/germany-on-chain-die-blockchain-strategie-der-bundesregierung-bitcoin-ja-libra-nein-bfe8cb77af36.

can effectively navigate the environment and leverage the advantages offered by smart contracts, within Germanys regulatory framework.

In France, the government has demonstrated a proactive approach to addressing smart contract regulation. The introduction of the Action Plan for Business Growth and Transformation (PACTE) law in 2020 is a significant step towards recognizing the importance of smart contracts in modernizing financial transactions.[303] This legislation contains rules, for issuing and registering securities through distributed ledger technology recognizing the importance of smart contracts in shaping financial transactions. Additionally the French government has been actively involved in talks with industry players to fully grasp the impact of smart contracts and establish regulatory steps.[304] This collaborative approach aims to create a structure that meets industry requirements while providing clear legal guidelines, for smart contract dealings.

In Italy, smart contracts have been legally recognized and defined through Law No. 12/2019, which formalized the definitions and applications of Distributed Ledger Technologies (DLTs) and smart contracts.[305] This legislation, known as the "Decreto Semplificazioni," outlines that DLTs include technologies and IT protocols that utilize a shared, distributed, replicable, and simultaneously accessible ledger. These systems are decentralized in structure based on cryptography enabling the recording, validation updating and secure storage of data in both encrypted and cryptographically protected formats. The information stored is verifiable, by each participant cannot be altered or tampered with. According to this legislation smart

[303] International Bar Association, A French law perspective on blockchain technology (September 20, 2021), URL:https://www.ibanet.org/french-law-blockchain. (accessed 14.03.2024).
[304] D. V. Chub, Legal regulation of smart contracts in France (Actual Problems of Russian Law, 2019), URL:http://dx.doi.org/10.17803/1994-1471.2019.105.8.151-158.
[305] Diritto Mercato Tecnologia: DIMT, Commento in materia di Blockchain e Smart contract alla luce del nuovo Decreto Semplificazioni (February 26, 2019), URL: https://www.dimt.it/news/breve-commento-alla-legge-11-febbraio-2019-n-12-di-conversione-del-decreto-legge-14-dicembre-2018-n-135-recante-disposizioni-urgenti-in-materia-di-sostegno-e-semplificazione-per-le-imprese-e-per-la-pu/. (accessed 08.03.2024).

contracts are computer programs that function on DLTs.[306] They automatically bind two or more parties based on predetermined conditions. An important aspect of this law is that it confirms smart contracts meet the requirement for written form if there is identification of the involved parties. This holds significance for transactions that necessitate written documentation for validity or proof purposes. The Agency for Digital Italy (AgID) is responsible for establishing standards for DLTs and outlining identification requirements, for parties involved in smart contracts within ninety days from when the law takes effect. This legal framework aims to promote the adoption of blockchain and smart contract technologies by offering legal validity and clarity. It recognizes the potential of these technologies to digitize and automate agreements across various industries, thereby reducing costs and creating new opportunities.

The European Union is actively working on aligning the regulations, for smart contracts as part of the draft Data Act, which specifically addresses these digital contracts.[307] One notable feature of the proposed legislation is the introduction of four criteria for contracts; robustness, safe termination and interruption, auditability, and access control. These requirements aim to ensure that smart contracts protect against errors and third-party manipulation, can be terminated securely, keep records of transactions and are protected through access control mechanisms. Furthermore, there is a significant focus on the interoperability of smart contracts, emphasizing the need for these contracts to meet harmonized standards or relevant parts of the Standardisation Regulation.[308] Another significant aspect of the EUs strategy for regulating smart contracts involves incorporating a "kill switch" in them.[309] This

[306] Firenze Legale, Smart contracts and Italian regulations (May 2019), URL: https://www.firenzelegale.it/en/smart-contracts-and-italian-regulations/. (accessed 08.03.2024).
[307] European Commission, Data Act, URL:https://digital-strategy.ec.europa.eu/en/policies/data-act. (accessed 03.03.2024).
[308] Alexander Schmalenberger, Smart contracts in the Data Act (TaylorWessing, 2022), URL:https://www.taylorwessing.com/en/interface/2022/smart-contracts/smart-contracts-in-the-data-act.
[309] Legal Army, The new approved text of the Data Act clarifies the obligation to include the “Kill Switch” in smart contracts (November 30, 2020), URL:https://www.legalarmy.net/en/blog/el-nuevo-texto-aprobado-de-la-data-act-aclara-la-obligacion-de-incluir-el-kill-switch-en-los-smart-contracts#:~:text=The%20last%20draft%20of%20the,blockchain%20ecosystem%20and%20its%20configuration..

feature is part of the updates to the EUs Data Act. Allows for terminating or resetting smart contracts under specific circumstances. The EU Council has reached an agreement on this provision underscoring the EUs commitment, to mitigating risks associated with contract operations while promoting their secure and effective use. Another step towards the recognition and dissemination of smart contracts within the European Union is the establishment of The European Blockchain Partnership (EBP).[310] EBP is a collaboration between all EU member states, Norway, and Liechtenstein, alongside the European Commission, to build the European Blockchain Services Infrastructure (EBSI).[311] EBSI, which started in 2018 aims to leverage technology for improving cross-border services, for public administrations, businesses and individuals. The goal is to enhance information verification and build trust in services.

5.7. The Future of Smart Contracts

It is still early for smart contracts to be used and widely adopted in complex commercial relationships. But they have the potential to transform the way people make smart contractual agreements in the future. Time will tell the impact on society and use cases as their development progresses. The evolution of smart contracts is expected to continue to shape the technological and regulatory landscape in important ways. Predictions can be made about how smart contracts will develop and be adopted in the future.

As smart contracts become more common, in industries there is a growing recognition of the importance of incorporating them into established frameworks. This incorporation will entail creating systems that blend the self executing features of contracts with the adaptability and subtleties of traditional legal agreements.

[310] European Commission, European Blockchain Partnership, URL:https://digital-strategy.ec.europa.eu/en/policies/blockchain-partnership.
[311] European Commission, European Blockchain Services Infrastructure, URL: https://ec.europa.eu/digital-building-blocks/sites/display/EBSI/Home.

Achieving this integration will necessitate cooperation, between professionals and technology experts to ensure that smart contracts align with existing principles.[312]

Smart contracts are expected to expand their application beyond finance and supply chain management to include sectors such as real estate, healthcare and intellectual property. These sectors are expected to discover the benefits of smart contracts in improving efficiency and streamlining deal processes. To support this expansion, they should also take initiatives to customize contracting platforms to the demands and regulations of each sector.[313]

The rules and regulations governing smart contracts are expected to evolve as more people begin to use the technology. Authorities are expected to aim to set the stage by encouraging innovation while protecting the rights of consumers and investors. This maturation will include establishing guidelines for disclosing, policing and resolving disputes related to smart contracts to ensure transparency and legal certainty in their use.[314]

Considering the vulnerabilites linked to smart contracts it is anticipated that advancements, in security and privacy measures will take center stage in their development.[315] The primary goal will be to enhance the robustness of contract platforms against cyber risks and safeguard the privacy of data. This could involve incorporating methods and enforcing standardized security protocols throughout smart contract environments. By focusing on vulnerability issues, the advancement of smart contracts can move towards creating secure and privacy-conscious platforms. This growth will not only reduce the dangers associated with smart contracts. It will

[312] Aaron Wright, Priyanka Desai, Freeman Lewin and Benjamin L. Van Adrichem, "Smart Contracts" & Legal Enforceability (Yeshiva University, Cardozo School of Law o School of Law, 2018), URL: https://larc.cardozo.yu.edu/blockchain-project-reports/2/.
[313] Nzuva, p.66-67.
[314] Cheng Lim, TJ Saw and Calum Sargeant, Smart Contracts: Bridging the Gap Between Expectation and Reality (11 July 2016), URL: https://blogs.law.ox.ac.uk/business-law-blog/blog/2016/07/smart-contracts-bridging-gap-between-expectation-and-reality.
[315] Yajing Wang, Jingsha He, Nafei Zhu, Yuzi Yi, Qingqing Zhang, Hongyu Song and Ruixin Xue, Security enhancement technologies for smart contracts in the blockchain: A survey (Emerging Telecommunications Technologies Vol 32, Issue 12, 2021), URL: https://doi.org/10.1002/ett.4341.

also increase trust among users and expand the technology's usefulness in different fields.

The future development of smart contract compatibility, across blockchain networks and platforms is set to make significant progress. Efforts to establish standards aim to simplify communication and interaction between smart contract environments enabling transactions across different protocols and interoperable decentralized applications.[316] These advancements in interoperability standards will enhance the scalability and effectiveness of smart contract implementations marking an advancement for the blockchain industry. This progress in interoperability standards for contracts signifies a leap forward in the field offering new opportunities for decentralized technologies by making them more accessible, adaptable and robust. As these developments take shape they are likely to fuel innovation and promote adoption of technology and smart contracts, across multiple industries.

Smart contracts have gained popularity in years, for their potential to revolutionize how transactions and agreements are carried out. In the context of public administration, smart contracts offer benefits such as streamlining processes cutting costs and boosting transparency and accountability. Smart contract can also automating routine processes, reducing the potential for human error and improving the overall transparency and accountability of government operations.[317] By utilizing smart contracts public administration can improve procurement processes, optimize service delivery and ensure compliance with regulations. However a major obstacle to smart contract adoption in public administration is the requirement for a strong and secure digital infrastructure. Insufficient digital systems could pose challenges and security threats during contract implementation.[318] Despite their potential it's essential to acknowledge the barriers associated with integrating smart contracts into public

[316] Shafaq Naheed Khan, Faiza Loukil, Chirine Ghedira-Guegan, Elhadj Benkhelifa and Anoud Bani-Hani, Blockchain smart contracts: Applications, challenges, and future trends (Peer-to-Peer Netw. Appl. 14, 2021), URL: https://doi.org/10.1007/s12083-021-01127-0.
[317] Negara and Hidayanto, p.5.
[318] Negara and Hidayanto, p.6.

administration. The presence of a infrastructure secure data management systems and skilled personnel capable of overseeing smart contract usage is crucial. Additionally legal frameworks must adapt to accommodate the intricacies of smart contracts, in the sector. The legal and regulatory frameworks governing public administration need to evolve to accommodate the complexity of smart contracts. Clear guidelines and regulations on the use of smart contracts in public operations are essential to ensure compliance and mitigate potential risks.

The influence of artificial intelligence (AI), on smart contracts presents a complex issue with important impacts on technology, law and commerce particularly in light of recent regulations in the EU. AI has the ability to streamline and improve the management and implementation of contracts by automating processes. By analyzing data and recognizing patterns AI can enhance decision making by predicting outcomes. As AI continues to advance it can enable smart contracts to adjust based on external inputs or past performance making them more adaptable to changing circumstances.[319] Additionally AI is capable of handling decisions that involve data analysis, a task that smart contracts may struggle with due to their fixed nature. Furthermore one significant aspect is how AI enhances the security features of contracts by identifying irregularities or suspicious patterns in smart contract interactions to prevent misuse beforehand. The European Union may need to take new steps to regulate technologies such as artificial intelligence and blockchain. For instance integrating AI systems into smart contracts could require testing and risk evaluation to ensure their reliability and security. There may also be mandates for transparency in AI decision making processes when those decisions carry financial implications. Another possible regulation could establish standards for AI usage, within contracts to prevent unfair or biased outcomes. Finally, compliance with the General Data Protection Regulation (GDPR), of which the European Union is the

[319] Pınar Aksoy, AI & Smart Contracts: Future of Digital Deals (Arksinger, 2022), URL:https://blog.arksigner.com/en/smart-contracts-leveraging-artificial-intelligence, (accessed 14.04.2024).

strictest, is crucial. AI systems will need to ensure data confidentiality and integrity, especially when processing personal data through smart contracts.

5.8. Conclusions

Smart contracts challenges from both legal standpoints. On the side creating secure and reliable smart contracts necessitates expertise, in programming languages like Solidity and a grasp of technology. Legally there are uncertainties surrounding the nature and enforceability of contracts. Questions arise about how smart contracts affect taxation processes due to their automation and standardization potentially altering tax calculations and collections. Moreover, smart contracts have implications in various areas of law. For consumers they can enhance transparency and efficiency in transactions reducing fraud risks. In business settings smart contracts can streamline operations by automating tasks and cutting infrastructure costs. In markets they can facilitate more secure transactions by lessening reliance on intermediaries. Concerning intellectual property law smart contracts offer a record of ownership and licensing rights that cannot be altered. Across systems globally the regulation of smart contracts is still evolving with varying degrees of clarity in legal frameworks, among countries. Despite these challenges the future looks promising for contracts as they bring efficiency, transparency and security benefits.

The acceptance and validity of contracts, under the law differ greatly across countries highlighting the need, for a legal structure to deal with issues concerning jurisdiction, conflict resolution and safeguarding consumer rights. It is essential for upcoming studies to concentrate on creating procedures that blend obligations with technological progress guaranteeing that smart contracts adhere to legal standards while remaining technologically sound.

CONCLUSIONS

We started this research with the aim of shedding some light on the unexplored area of the legal and economic approach to smart contracts. Our main question was whether and when smart contracts should be preferred to traditional contracts. To answer this question, we looked at traditional contracts and why we need them.

6.1. Traditional Contracts, Transaction and Costs

Contracts play a role, in building trust and certainty in dealings. By defining the responsibilities and entitlements of all parties involved contracts establish a framework for operations minimizing uncertainties and potential conflicts. Additionally contracts help parties manage risks set performance expectations and enforce rights and remedies if agreements are not met. Well-structured contracts support efficient economic interactions, promoting stability and growth in the economic environment. Trust, predictability and efficiency are elements facilitated by contracts in transactions. Hence grasping the significance of contracts in reducing transaction expenses is essential, for nurturing an framework. Beyond their role in establishing trust and predictability, contracts also carry a moral obligation. Compliance with contractual agreements is not only a legal obligation but also a reflection of ethical principles. When entering into an agreement individuals commit to fulfilling their commitments thus maintaining the integrity of the contract. This ethical dimension of contracts goes beyond legality highlighting the significance of honesty, integrity and responsibility, in transactions. Ultimately acknowledging the foundation of agreements strengthens trust and ethical behavior, in the economic landscape. Ensuring that parties honor their commitments and follow the contract terms is crucial, for contract enforcement. Legal systems are vital in this process providing a structure for resolving disputes and enforcing contract obligations. A operating legal system can offer the tools to settle conflicts and uphold contractual agreements when issues arise. Additionally the effectiveness of enforcing contracts relies on how contracts can be enforced. Legal frameworks with enforceable contract laws promote predictability and stability in transactions. Parties can trust that their

rights will be safeguarded, with remedies if obligations are not met. The success of enforcing contracts hinges on institutions role. A well-functioning legal system is crucial to protect the integrity of contracts and ensure that economic transactions proceed smoothly and efficiently.

Transaction costs play a role in understanding the efficiency and sustainability of transactions. These expenses cover a spectrum of costs linked to carrying out business activities, such as negotiation, monitoring and enforcing contracts. Essentially transaction costs represent the resources utilized to overcome the obstacles and challenges inherent in interactions. Grasping and handling transaction costs is essential for attaining market efficiency and sustainability. By reducing these expenses parties can simplify their operations encourage market involvement and allocate resources efficiently. Effectively managing transaction costs enhances the competitiveness of the market. Enables businesses to leverage growth opportunities effectively. Additionally cutting down on transaction costs can facilitate the establishment of partnerships and foster innovative business approaches. Lowering barriers created by high transaction costs promotes entrepreneurship, nurtures ingenuity. Creates avenues, for collaboration and trade. This process ultimately boosts the vibrancy and resilience of the market while propelling progress.

6.2. Smart Contracts on Blockchain Technology

In Chapter 3, we discussed smart contracts and blockchain technology, the definition, implementation and key features of smart contracts, as well as the advantages and disadvantages of smart contracts over traditional contracts.

Smart contracts are contracts that execute themselves using code to define the terms agreed upon by buyers and sellers. They automatically enforce and execute themselves when certain conditions are met. This innovation relies on blockchain technology, a digital ledger that securely records transactions across multiple computers ensuring that recorded transactions cannot be changed retroactively. The decentralized nature and transparency provided by blockchain technology make it an ideal foundation, for smart contracts. By eliminating the need for intermediaries,

smart contracts can automate processes in finance, real estate, supply chain management and more. The potential uses of contracts and blockchain technology are extensive with their impact, on businesses and society projected to be substantial. As these technologies progress and see acceptance understanding their capabilities and implications is crucial for businesses and individuals to adapt in todays evolving digital environment. Smart contracts function by following a set of "if-then" conditions, where specific actions are triggered when certain criteria are met. These criteria are embedded in the smart contract. Are verified automatically by the blockchain network beneath. This automated process reduces errors and simplifies operations and minimizes the need for participation. A significant aspect of smart contracts is their ability to self execute; once the specified conditions are satisfied the contract is enforced automatically without interference. This not only speeds up the execution of the contract but also saves the parties resources and increases the security of the contract. Additionally the decentralized structure of guarantees that all parties engaged in a contract have equal access, to an unchangeable record of transactions promoting trust and transparency.

The implementation of smart contracts involves a series of steps. To start the terms and conditions of the contract must be accurately translated into code to reflect the intended outcomes and actions. This requires an understanding of the business needs and legal aspects involved in the agreement. Once the smart contract is developed it must be deployed onto the network. During this deployment process interaction, with the network is necessary to confirm and finalize the contract integrating it into the system. Typically there is a transaction fee associated with this process referred to as "gas" within the Ethereum blockchain realm. Once deployed the smart contract becomes operational continuously monitoring conditions and executing programmed actions when those conditions are met. The decentralized structure of blockchain ensures that the contract is spread across nodes, for added security.

Smart contracts offer benefits compared to traditional contracts, which is why they are increasingly being embraced across different industries. Smart contracts executed on the blockchain offer a high degree of security and transparency. The decentralized and immutable nature of the blockchain ensures that all participants have access to the same tamper-proof record. This reduces the risk of fraud and manipulation. Smart contracts automate the execution of contracts, eliminating the need for intervention and reducing the time and resources needed to manage contracts. This automation simplifies and speeds up the fulfillment of obligations. By eliminating middlemen and automating execution smart contracts lower expenses. Reduce reliance on third party verification and validation. This leads to cost reductions compared to contract management methods. The automation and self execution features of contracts lessen the risk of errors in executing and enforcing contracts. Conditions embedded in the contract ensure that actions are appropriately triggered when specific criteria are met. Finally, smart contracts are not constrained by borders and enable cross-border interactions and agreements. This global accessibility creates opportunities for trade and commerce.

While smart contracts offer benefits it's crucial to consider their drawbacks when compared to traditional contracts. Developing and executing contracts demands an understanding of blockchain technology and a high level of technical skill. This complexity can be daunting for individuals and organizations lacking the required expertise and resources often necessitating guidance which can increase contract costs. Once a smart contract is deployed on the blockchain its operations become irreversible. This rigid nature means that rectifying coding mistakes or unforeseen issues can be intricate and may involve time and money. The legal framework governing contracts is still evolving, resulting in uncertainties regarding enforcement and conflict resolution. The absence of established precedents could lead to challenges, in jurisdictions potentially sparking disputes between parties. Smart contracts are vulnerable to flaws and bugs in their code that could be exploited by entities. Ensuring the security and resilience of contract code is paramount to

minimize these risks. Additionally since smart contracts may depend on data sources, for triggering actions there exists a risk of vulnerability if these data feeds are compromised or manipulated. Due to the scalability issue in blockchain networks, as the network becomes more complex and dense, smart contract transactions may become more costly. This limitation in scalability could result in added expenses, for transactions involving volumes.

6.3. Ethereum and Smart Contracts: A Symbiotic Relationship

In part 4 of the study, we discussed Ethereum, the infrastructure and technology used by smart contracts, gas fees and the transaction costs of smart contracts.

Ethereum serves as a platform that empowers users to create and manage smart contracts and decentralized applications free from disruptions, fraud or outside interference. Smart contracts work as self-executing agreements where terms are encoded directly into the system, facilitating transactions without relying on intermediaries. The Ethereum cryptocurrency Ether is used to reward network participants for their efforts and verification tasks. Transaction fees within the Ethereum network are influenced by the complexity of executing contracts and computational demands. Gas, a unit of measurement for the work involved in transactions or operations, plays a role in determining transaction costs on the Ethereum network. Gas plays a role, in the Ethereum network determining the expenses associated with running contracts and transactions. Each operation carried out on the Ethereum network necessitates a gas amount with its price denominated in Ether. The overall cost of a transaction is computed by multiplying the gas price by the gas limit, which signifies the gas amount a user is ready to allocate for a transaction. The intricacy and computational demands of a contract directly impact the gas needed for its execution. Consequently complicated operations and computations will result in transaction costs due, to increased gas consumption.

Even considering these transaction costs, Ethereum-based smart contracts have found application in a variety of real-world scenarios and have been deployed in the

finance, real estate, supply chain management sectors. In the world of finance, smart contracts have paved the way for innovative solutions for making and executing automated financial agreements and lending opportunities for crowdfunding and asset tokenization. These smart contracts offer secure ways, for peer to peer transactions removing the need for middlemen and cutting down on transaction expenses. Another field where smart contracts are making a mark is in streamlining real estate deals by automating tasks like property transfers escrow arrangements and rent payments. By utilizing Ethereum based contracts efficiency has been boosted, transparency enhanced and administrative burdens lightened in the real estate industry. The realm where smart contracts shine the brightest is in managing supply chains. Through smart contracts supply chain processes have been optimized with automated tracking of goods, verification of origins and execution of binding supply chain agreements that uphold themselves. This advancement has improved visibility and responsibility, within supply chains while simplifying operations and reducing activities.

As Ethereum and its related technologies progress and undergo advancements it becomes essential to take into account the costs linked to smart contracts and transaction procedures. Apart, from the gas fees involved in executing contracts there are other costs at play, such as research, negotiation, enforcement and flexibility costs. These costs hold sway over the efficiency and usability of smart contracts within the Ethereum ecosystem. Crafting and putting into action contracts often demand research to ensure that their logic and functionality align with the intended objectives. Research expenses encompass the time and resources invested in grasping the intricacies of contract code pinpointing vulnerabilities and assessing how effective the contract is in fulfilling its designated purpose. With smart contracts growing more complex and varied, in their applications the research expenses tied to devising dependable contracts become notably substantial. Negotiating the terms and conditions of smart contracts can lead to negotiation costs, especially in scenarios involving multiple parties. These costs include the time and resources needed to

outline and finalize the contract terms as agreeing on the precise conditions and parameters embedded in the smart contracts. Therefore it's essential to take into account the negotiation costs linked to contracts as they play a role in the transaction expenses and need thoughtful consideration for successful implementation of contractual agreements, on Ethereum network. After smart contracts are deployed, the enforcement costs related to verifying and executing the contractual obligations come into play. These expenses cover the computing resources needed to authenticate and implement the stipulations and conditions embedded in the contracts along, with the procedures for settling disagreements and guaranteeing adherence to the terms. With a rise in both the volume and complexity of smart contracts these enforcement costs emerge as an element in assessing how efficient and sustainable the Ethereum network is, for processing transactions involving smart contracts. Smart contracts despite being praised for their efficiency and automation come with drawbacks related to inflexibility that could hinder their acceptance and functionality. The issue arises from the execution of code that becomes unchangeable once it is deployed on a blockchain. This lack of flexibility means that any mistakes, omissions or unexpected situations, in the coding cannot be easily corrected, potentially leading to disputes or financial losses. Moreover the rigidity may impede the ability to adjust agreements to changing circumstances a practice in contracts through negotiation and modifications. Due to this lack of adaptability it is essential to test and validate contract code, before implementation, which can increase initial costs and demand specialized expertise.

6.4. A Legal Perspective of Smart Contracts

In the last part of the study, chapter 5, we focused on the legal status of smart contracts, legal regulations on smart contracts and smart contract laws in major countries.

The application of smart contracts, in traditional legal systems poses a complex issue. Typically contracts are binding agreements between parties that can be enforced by law. They must meet criteria to be considered valid such as offer, acceptance intent to establish relationships and consideration. These agreements are typically

documented in written or spoken form. Require judgment for implementation and enforcement. In contrast smart contracts are self executing agreements where the terms are encoded directly into lines of code. They function on technology ensuring that once conditions are satisfied the contracts automatically execute without intervention. This automation and reliance on code, for contract execution raise inquiries and obstacles.

Data protection is another critical area of concern when it comes to smart contracts. Using information in smart contracts raises issues related to complying with data protection laws like the General Data Protection Regulation (GDPR) in the European Union. Incorporating data into smart contracts requires adherence to regulations such as GDPR, which gives individuals rights like access, correction, deletion and limiting data processing. Protecting these rights can be difficult in contracts because the immutable nature of blockchain technology contradicts the modification or removal of data once it has entered the blockchain. To process data lawfully there must be a legal reason, such as consent or legitimate interest. Obtaining clear and informed consent, in contract scenarios can be tricky especially when transactions are automated without involvement.

The global aspect of smart contracts presents obstacles regarding jurisdiction and applicable law primarily because of their capacity to function seamlessly across borders on blockchain platforms. Blockchain, the technology underlying smart contracts, is decentralized and global in nature. A single smart contract can involve parties, from countries conduct border transactions and be stored on servers situated globally. This decentralization makes it challenging to determine a location or legal jurisdiction governing the contract. In contracts jurisdiction typically hinges on factors like the parties locations, where the contract was signed or where contractual obligations are fulfilled. However for smart contracts these criteria may lack clarity or relevance leading to uncertainty about which countrys courts hold jurisdiction over dispute resolution. Determining the applicable law is another complex issue. Conventional legal frameworks often rely on principles such as party choice of law or

the law closely tied to a contracts context. Yet smart contracts may not explicitly designate a law and their digital nature without borders can complicate establishing ties, to a particular countrys laws. Even if a court successfully claims jurisdiction and applies its laws enforcing its decision presents hurdles. The decentralized and anonymous aspects of technology can make it challenging to determine the identities and whereabouts of individuals organizations or nodes, on the blockchain, which can complicate enforcement efforts.

To overcome the problem of uncertainty surrounding jurisdiction over smart contracts and to maximize the benefits of the contracts, different countries have introduced various regulations. When looking into how smart contracts are regulated in jurisdictions it's essential to delve into the approach adopted by the United States. The US has seen advancements in how smart contractsre legally handled, with regulatory agencies, like the Securities and Exchange Commission offering guidance on categorizing digital assets generated through smart contracts. Moreover legal precedents involving contracts, such as court rulings on disputes regarding contract terms are shaping the environment. In the European Union regulations concerning contracts have been influenced by laws like the General Data Protection Regulation and oversight entities such as the European Securities and Markets Authority. Understanding how these rules impact the use and implementation of smart contracts is vital, for businesses operating within EU borders.

Despite the applications and potential of smart contracts it is evident that they currently lack the capability to address various issues present, in traditional contractual relationships, such as breaches of contract and contract modifications. The inherent immutability of blockchain network structures poses challenges for smart contracts. In order for traditional contractual relationships to be transferred to smart contract technology, first of all, horizontal and vertical relations and collective work between blockchain participants and players developing blockchain technology and regulatory bodies are needed. Without collaborations smart contracts may not function effectively within the existing framework or render efforts by regulatory

bodies to safeguard consumers and commercial activities futile. The inevitable uncontrolled advancement of technology will pave the way for contracts particularly utilizing blockchain technology; however regulations are imperative to facilitate the integration of traditional contractual relationships into this technological landscape. Failure to disclose real world implications of transactions on blockchains or provide protection, for these transactions could significantly diminish the benefits offered by this innovative technology.

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