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„The Economics of Blockchain. Transformation of Companies and Changing the Role of Institutions by Means of Application of Blockchain Technology"

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Zusammenfassung

Die Blockchain-Technologie gewinnt immer mehr an Aufmerksamkeit und wird von den Institutionen immer mehr angenommen anerkannt. In den letzten Jahren hat das Thema Dezentralisierung durch verschiedene Bereiche der Wirtschaft und des Finanzwesens immer weiter durchdrungen.

Auch wenn Blockchain vor allem mit Kryptowährungen und Mining in Verbindung gebracht wird, hat sich die Technologie in der Tat weit über diese Phänomene hinaus verbreitet und wird voraussichtlich viele Vorgänge und Transaktionen in verschiedenen Institutionen auf der ganzen Welt abdecken.

Da es sich um eine neue Technologie handelt, befindet sie sich noch im Anfangsstadium der wissenschaftlichen Forschung und infolgedessen besteht es ein erheblicher Mangel an Wissen über die Technologie. Diese Masterarbeit versucht, eine Forschungslücke im Zusammenhang mit der Blockchain und Smart Contracts zu schließen.

In der vorliegenden Arbeit werden die wissenschaftlichen Artikel systematisch analysiert, um die bestehende Forschung auf diesem Gebiet zusammenzufassen. In der Arbeit wird die allgemeine Funktionsweise von intelligenten Verträgen und verteilten Ledgern erläutert, um dann untersuchen zu können, in welchem Maß diese Technologie für Operationen und Transaktionen diverser Institutionen einsetzbar ist. Der letzte Teil der Arbeit bietet einen Rahmen für Unternehmen mit möglichen Blockchain-Anwendungen für ihre Aktivitäten.

Abstract

Blockchain technology is gaining more and more attention and wider adoption by the institutions nowadays. For the last few years the topics of decentralization has been perveating different sectors of the economy and finance wider and wider.

Even though blockchain is mostly associated with cryptocurrency and with mining, the technology in fact has managed to spread wide beyond those phenomena and is projected to cover many operations and transactions in various institutions across the world.

Due to the fact that technology is new, it still remains at the early stage of the scholarly research and moreover, there is a significant lack of knowledge about it. This master thesis tackles to fill a research gap related to blockchain and smart contracts.

The present paper will be systematically analyzing the scholarly articles to summarize the existing research in the field. The thesis is presenting the general explanation on how the smart contracts and distributed ledgers operate, and later, it moves to explore how the institutions can potentially apply the technology to their operations and transactions. The final part of the thesis provides a framework for the companies with possible patterns of blockchain applications in their activities.

Introduction

Blockchain is understood to have been invented and publicly released by Satoshi Nakamoto in 2008 as the underlying technology for Bitcoin, the peer-to-peer cryptocurrency which was originally launched as an experiment but later garnered the support of the internet community. Cryptocurrency has attracted plenty of attention from governments, various actors in the financial industry as well as from many scientists and economists. There were many discussions of the cryptocurrency boom in the media and plenty of attempts to regulate crypto on governmental and intergovernmental levels. However, until recently hardly any government or big company perceived cryptocurrency as a serious thing. Only when the price started increasing rapidly and more liquidity started to be poured into the crypto market by both financial institutions and individuals, bitcoin and crypto-assets became one of the hottest topics in the EU and in the whole world. In different resources, cryptocurrency is defined in different ways. In 2019 European Central Bank defined crypto-assets as "a new type of asset recorded in digital form and enabled by the use of cryptography that is not and does not represent a financial claim on, or a liability of, any identifiable entity".

As the technology behind Bitcoin, the blockchain attempts to solve the problem of double-spending and eliminate intermediaries in the transaction process. Based on peer-to-peer principles, blockchain doesn't require any institution, be it a corporation or government, or bank to audit and confirm the transactions in its system. The records kept on the blockchain are impossible to change, they are transparent and accessible by anyone. The mechanisms of consensus make blockchain trustless, as the algorithm ensures that no single participant to the system tampers with the records and the data in the system is kept honest. Due to this case, blockchain is also often referred to as Distributed Ledger Technology (DLT).

Despite being primarily associated with cryptocurrency in general and with Bitcoin in particular, the DLT technology is already expanding far beyond the field of finance and is already being widely used in supply chain management, legal sector, gaming and art. Moreover, taking into account the developments of this technology over the last 2-3 years, it can be said that there will be more and more real use cases of blockchain in different sectors of the economy within the coming years.

Blockchain technology is the underlying instrument for such things as smart contracts, digital tokens for various assets and decentralized applications (DApps). They have the potential to cause a multitude of alterations in approaches to business processes, propose the emergence of new business models, disrupt the workflow of different institutions, and even change people's routine lives.

Most of these changes have to do with the decentralization of transactions, partial automation of some processes (or, more accurately, their algorithmization), and may result in substantial cuts in transaction costs for companies.

Distributed ledger technologies are a good example when it comes to showing the limitations of traditional approaches of institutional analysis, especially in cases of complex infrastructure' research. Complexity is one of the central problems for modern institutional economic theory because it is focusing on "pre-digital" capitalism (Frolov D., 2019). One should bear in mind that theories of transaction costs and of institutions were created at the turn of the 1980s and 1990s. (Williamson, 1985; North, 1990). This means that they are unlikely to take into account the latest technological developments.

The purpose of the master thesis is to analyze the possible implications of the distributed ledger technology by SMEs and institutions for cutting their costs, limiting the opportunism and eliminating the intermediary from the transactional process. In the course of the research, blockchain technology and smart contract underpinned by it will be analyzed from the perspective of transaction cost theory, theory of transactional value and incomplete contract theory. The master thesis will also provide a synthesis of the existing scholarly knowledge about the technology analyzed through the lens of the above theories. The research will also include a framework with suggestions for the companies planning to use blockchain or smart contracts in their operations.

The central question of the research carried out in the course of working on the master thesis will be: *"Will distributed ledger technology and smart contracts be able to change the current state of companies, by making them more transparent as a result of reducing their costs and eliminating the middlemen?"*

In order to answer the research question, the following hypotheses will be checked in course of the research:

(H1): If blockchains can reduce the transaction costs in different sectors of the economy, they will make the transaction process more transparent and clear by eliminating the intermediaries from the process.

(H2): If the contracts of the company are complete, the applications of blockchain are likely to reduce costs of writing and enforcing contracts, whereas the costs of bargaining and renegotiation are unlikely to be affected.

(H3): Smart contracts as a new form of contracting are similarly applicable to all types of contracts within the context of the traditional transaction cost typology: classical, neoclassical, behavioural.

(H4): The application of smart contracts in economic practice is institutionally neutral, as it only changes the form of conclusion and execution of the contract.

The hypotheses will be explored using thematic analysis and by splitting the scholarly articles selected for the research into themes. A more detailed description of the themes and methodological approach will be provided in the following section.

Methods

In the course of the research a systematic review of the existing scientific literature in the field of blockchain and smart contracts was carried out in order to investigate and answer the research question. This method will serve as a good explanatory method for the key elements of blockchain technology. The systematic review of the literature will also constitute the basis for the further analysis and synthesis of scholarly articles.

The synthesis method will be used to summarize the material used for preparing the research. At the same time, synthesis will help to combine the results of the research of contract theory and transaction cost theory with the existing knowledge of smart contracts and blockchain. The method of interpretation will allow to make some new propositions to the existing knowledge.

One of the main problems with scholarly research of blockchain technology is that the technology is developing and changing a lot. As a result, scholar researchers are failing to keep up with the practical implications of blockchain. Hence lots of the existing research has a number of limitations. Nevertheless, the selected methods will also help to integrate the studies into the practical field.

The synthetic approach is not only a summary of the existing knowledge of smart contracts and blockchain; it is also a way to understand the level of the existing knowledge around the technology. Moreover, an analysis like this will also help to determine the limitations of the previous studies as well as to define the knowledge gaps that need to be filled. A part of the research will be dedicated to explaining and reviewing the main principles of the technology. Later there will be a deeper synthesis of the theories which will help to better comprehend the subject of the research.

The process of the systematic literature review consisted of the following steps:

Formulating the research question

Before conducting any kind of research it is important to formulate the research question. At the very beginning of the research, the original purpose was to analyze how the blockchains could potentially impact the governance in the company. However, in the course of the research, the main goal slightly changed and it was decided to analyze how blockchain technology can be

used by companies to increase the level of trust, eliminate opportunism and to minimize the companies' transaction costs.

Relying on this purpose, there were 4 hypotheses mentioned above, introduced and explored during the research.

Collecting data

While selecting and collecting the materials for the literature review there was a focus on both: primary and secondary sources.

- The primary data was mainly collected from the official websites of different blockchain protocols, like Ethereum, Solana, etc. Among the primary data, there were also articles and whitepapers prepared by the founders of different blockchains (for example by Vitalik Buterin, by Satoshi Nakamoto etc.), that were explaining the way the technology works in detail. The technical materials were collected from the websites like GitHub, Soliditylang, Hyperledger Fabric, Solana Foundation, etc.
- The secondary data were mainly scholarly articles found via different databases. The scholarly databases selected for the research were Google Scholar, JSTOR, and DOI.

Screening and evaluating the data

In the course of looking for the articles mainly across the above-mentioned databases, the following keywords were used in the beginning: ‘blockchain’, ‘smart contracts’. However, the large amount of the results in the databases has shown that there is a need for additional keywords to narrow down the number of materials for the analysis. For this reason, there were also added such keywords as: ‘transaction cost’, ‘transaction cost theory’, ‘trust’, ‘contract theory’, ‘opportunism’. Other criteria of inclusion of articles into the analysis were the fact that it is focused on blockchain, the availability of the full text of the article.

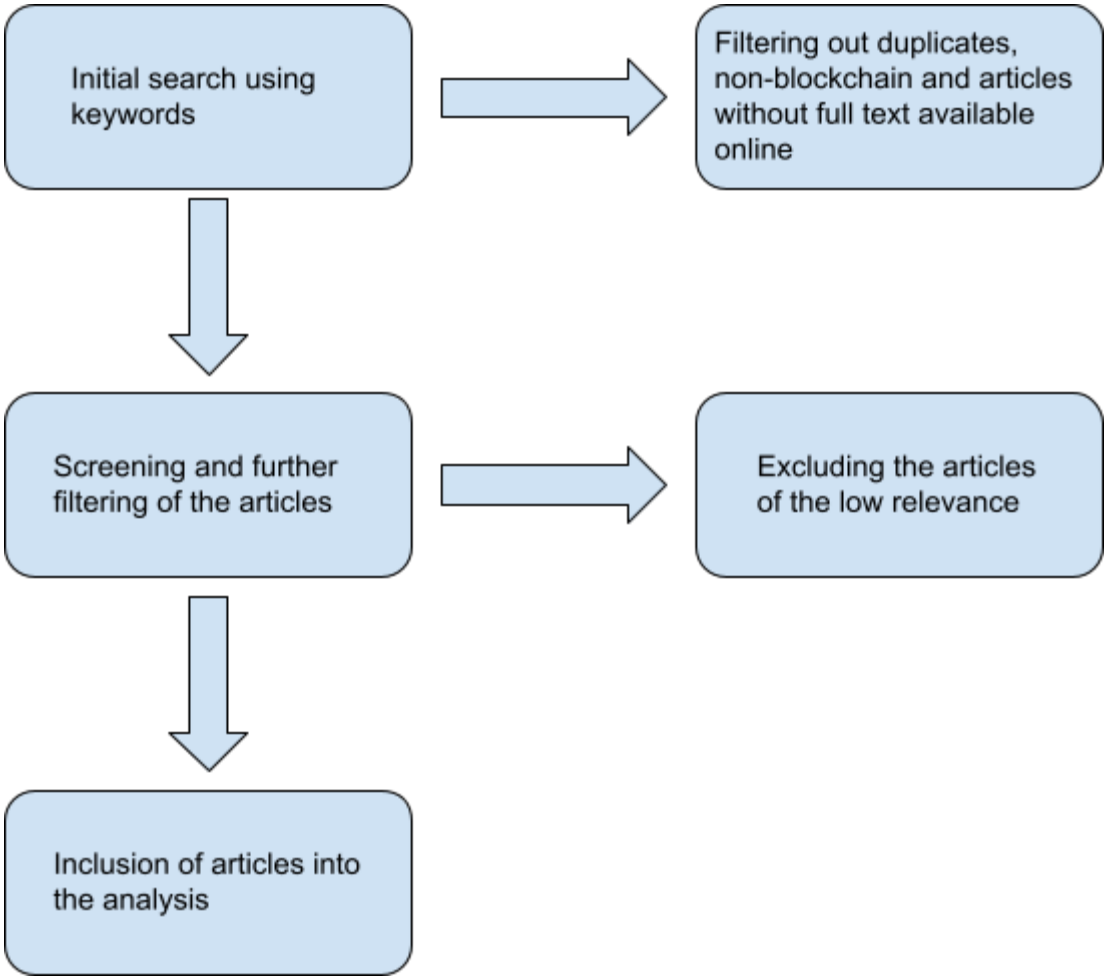

Fig 1. The process of screening and including the articles.

After the first stage, there were more than 200 scholarly articles found and downloaded. The procedure of their review and inclusion can be seen in Fig.1. The duplicates were not included in this number. Based on their titles and abstracts, articles were then filtered out by their relevance. There were those of the high, the medium, and the low relevance. The latter ones were removed. The main reasons for the low relevance of the articles were that they were concentrated on cryptocurrency in the first place, or too technical and mainly consisted of the pieces of code, or that they were not in the first place focused on the distributed ledger technologies. The articles that were mainly describing blockchain not from the economic perspective, were also removed after screening.

Following this stage, there was another stage of a more detailed screening of articles in accordance with their relevance. During this stage, each article was read and summarized.

Another thing that was done on this step was defining a theme to which a particular article can be related as well as the main results of the article.

Coding and analyzing the results

The coding procedure was performed in the Excel sheets by creating a table with the following columns for each article:

- Name
- Authors
- Year
- Database
- Journal
- Link
- Type of the article
- Methodology
- Geography
- Topics
- Relevancy
- Challenges

First of all, the codification allowed us to define the main thematic concepts to be analyzed during the research. Although at the screening stage some articles were excluded from the research, they were still added to the codification procedure. Moreover, the technical and crypto-focused articles appeared to be useful for the explanation of the main concepts of blockchain and smart contracts.

Among the literature analyzed, there were plenty of articles focused on the application of blockchain technologies to financial and logistics companies. Another big part of the articles was focused on smart contracts and their applications for SMEs. It is also interesting to note that the vast majority of researchers were considering blockchain as a technology that has the potential to outcompete the existing intermediaries in the future.

For the more structured analysis of the paper thematic analysis was applied. This method does not rely on any theoretical framework unlike content analysis or grounded theory, which also looks for repeating patterns in the information that is included in the analysis (Braun and Clarke, 2006). This method is flexible and allows analyzing different types and amounts of data in a handy manner. Thematic analysis can be usually carried out by using an inductive or a deductive approach. In this case, the deductive approach was originally used, however following a detailed reading supported by taking notes and codification of the material in scholarly articles which later were combined into themes, the initial themes were reviewed once again. Those, which were not fully covered in the articles were excluded, whereas some new themes which were more relevant for the research were added.

In the course of combining the existing codes into the themes, there could be seen a clear hierarchy of those. There were the central themes in the research which could be divided into subsections of the themes.

The themes and their purposes were the following:

Theme	**Overview**	**Hypothesis**
Blockchain	General concept Principles of functioning of the blockchain Use-cases of the technology	Basis for the research
Consensus mechanisms	Definition of the consensus and analysis of the need for it Overview of the pros and cons of the existing consensus mechanisms Overview of the existing blockchains and their consensus mechanisms	Basis for the research
Blockchain and transaction costs	What role can blockchain play in reducing the transaction costs for the firms? The possible use cases of blockchain for cutting transaction costs and eliminating the middlemen	*(H1): If blockchains can reduce the transaction costs in different sectors of the economy, they will make the transaction process more transparent and clear by eliminating the intermediaries from the process.*

Smart contracts	Definition of smart contracts The types of smart contracts The costs of using smart contracts Flexibility to changes in such contracts	Basis for the research
Smart contracts and incomplete contract theory	Which contracts have more opportunity to be finalized as a smart contract? Mechanisms of enforcement of smart contracts	*(H2): If the contracts of the company are complete, the applications of blockchain are likely to reduce costs of writing and enforcing contracts, whereas the costs of bargaining and renegotiation are unlikely to be affected.*
Smart contracts and legal contracts	Where can smart contracts be suited? Smart contracts VS. classical, neoclassical and relational contracts	*(H3) Smart contracts as a new form of contracting are similarly applicable to all types of contracts within the context of the traditional transaction cost typology: classical, neoclassical, behavioral.*
Smart contracts and institutions	Smart contracts and the existing legal system Smart contracts and dispute resolution Approaches to integrating smart contracts into the existing civil law system	*(H4) The application of smart contracts in economic practice is institutionally neutral, as it only changes the form of conclusion and execution of the contract.*

Table 1. The link between themes and hypotheses.

The more detailed connection between the themes as well as their overview can be found in the Appendix 1.

From the table above it can be also noticed that these themes are in hierarchical relation towards each other. Nevertheless, in this research, they were approached as the ones on the same level with a separate analysis and overview of literature for every theme.

The following chapter is going to present the general results of the literature overview and the second part of the thesis will be concentrated on the analysis of the relevant themes.

Once again it should be noted that the current research not only aims to describe the blockchain technology, it also aims to analyze it from the perspective of the existing economic theories, thus testing whether they are also applicable to the newer formats of operations of companies.

Results

Literature overview

After the screening procedure, 95 articles were selected in total. This chapter will provide an overview of grouping the articles by different parameters selected in the course of the coding process.

All publications were published from 2016. Nevertheless, there was one publication about the functioning of blockchain and bitcoin published by Satoshi Nakamoto in 2009 and another one by Vitalik Buterin, the founder of the Ethereum network in 2014. The short overview of the scholarly articles by dates is represented in Fig.2.

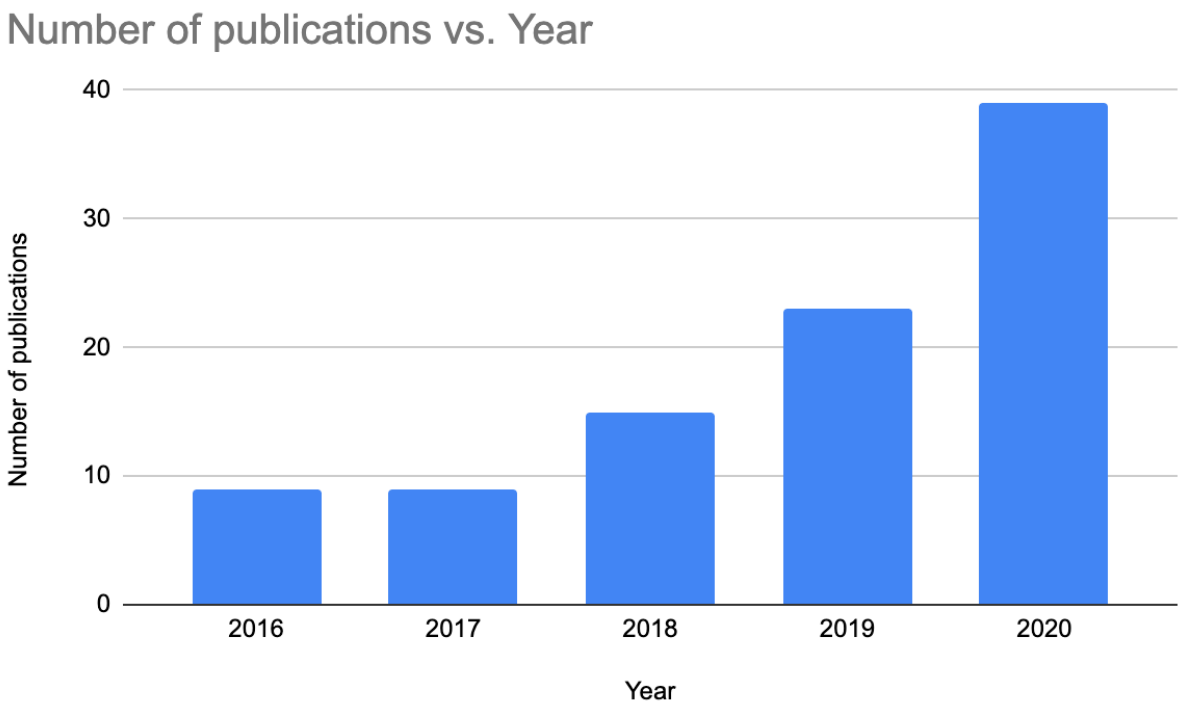

Fig 2. Distribution of publications by years

Such a rapid upgrowing trend in the number of scholarly publications is something expected. This is caused by the fact that the distributed ledger technology is relatively new and it has not been sufficiently researched yet. Moreover, in the nearest future, there will be even higher

percentage of publications, and that will be caused by the speed of the development of the technology.

As for the geography, the regions with the highest number of articles issued were Europe (44%) North America (36%), Asia (18%) and Oceania (2%). A more detailed review of the geography of the articles can be seen below in Fig.3.

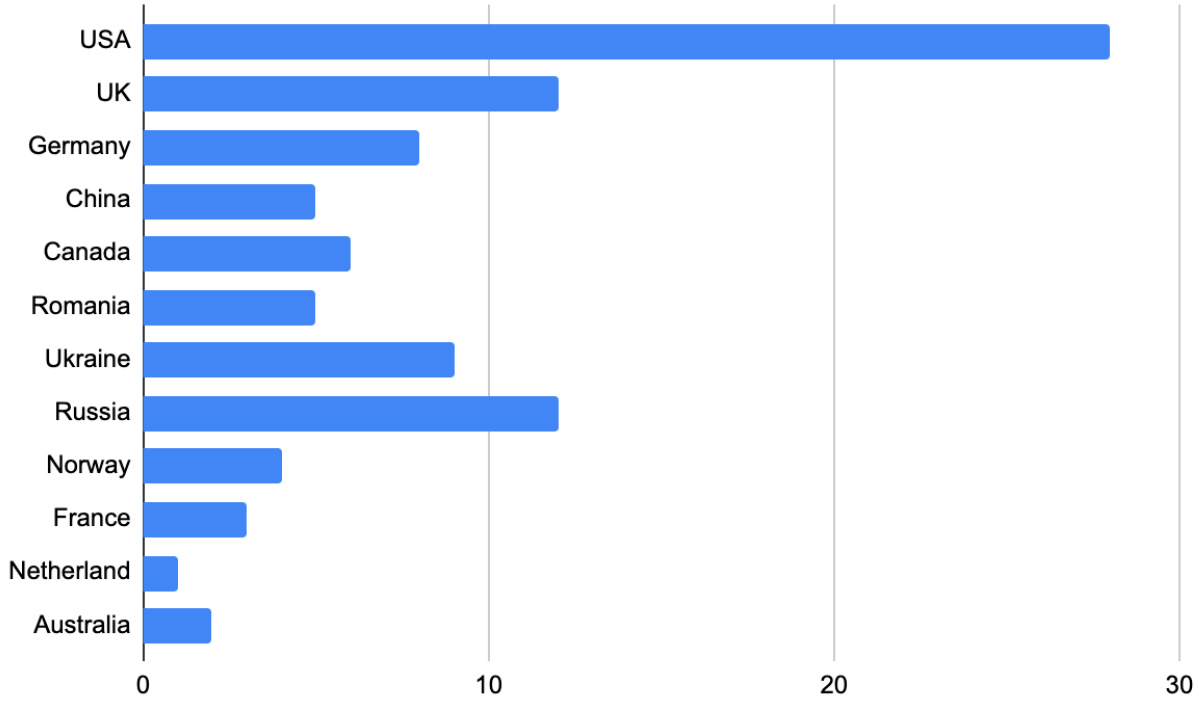

Fig 3. Geographical distribution of publications.

The research methods in the articles were not evenly distributed, most of the articles were using the exploratory methods (61%), where they were trying to define the main concepts like blockchain, consensus and smart contracts as well as explore what effect the application of the distributed ledger technology might have on a particular type of business or institution. The second most popular research method was the analysis via theoretical framework, i.e analyzing the technology from the economic or legal perspective, etc. (19%)

The case studies and interviews were less popular and constituted about 8% and 7% respectively. Systematic literature review in its turn amounted to only 3% of the analyzed articles and a few

other methods were among the remaining 2%. This is caused by the lack of literature available for the researchers.

In addition, it is worth saying that the articles had 2 main focuses as for the general themes: these were either blockchain-focused or smart contract focused articles.

The results of the synthetical analysis in accordance with the thematic domains described in the methodology section will be described in the following parts of the research. It is important to mention that the last chapters describing the transaction value, contract theory and contract types were also relying on the articles that were not grouped into the current literature review. The main purpose for this was to see if these theories are applicable to the new technologies.

Results.

Description of Themes

The concept and general characteristics of blockchain technology.

Blockchain technology was first applied in 2009 as a registry for bitcoin transactions. Initially, blockchain was most actively used in the financial and banking sectors. However, the flexibility of the technology allows it to expand its applications to potentially include numerous other areas as well.

Blockchain technology outside the context of cryptocurrencies began to be actively discussed in 2014. This was caused by the fact that people paid attention to the potential of the decentralized approach and the use of such consensus-building mechanisms, where the final state of the database of the accounting system would be sufficiently well protected from changes. Blockchain, as a way of organizing data storage, allowed accounting systems with many independent validators to achieve not only secure synchronization of a joint database, but also the immutability of this data, taking into account some assumptions (Genkin, A., Mikheev, A 2017).

Before Bitcoin, all financial systems were closed and protected by "traditional" methods of screens (firewalls), access control systems, etc. The options - with the help of other firewall methods of ensuring database protection were seriously considered by organizations for practical application. Bitcoin has proved that a financial system can exist without a decision-making

centre, moreover it can also be transparent to everyone and audited, at the same time offering a high level of privacy to the parties (Beck, R et al, 2017). However, for businesses where internal business data is present, full transparency is not acceptable. Later, methods were proposed to ensure a higher level of user privacy, as well as implemented in projects of some cryptocurrencies. These techniques effectively dealt with the privacy issues of business transactions, while leaving them publicly verified and not irrevocable (Beck, R et al, 2017).

In a direct sense, blockchain is a way of storing and synchronizing data between participants who do not trust each other. The system assumes that all data about existing transactions is grouped into blocks, whereby each is linked to the other one in a cryptographic way.

As for the concept of "blockchain" itself, there is no legal definition of the term at the moment. The literal translation of the word "blockchain" is defined in the Dictionary of the English language as follows: "distributed ledger technology", "distributed storage of trusted records", "platform for creating new cryptocurrencies", etc.

In generalised and simple terms, blockchain is a kind of database - a database without any specific storage location for particular digital objects. Specifically, a blockchain can be thought of as an Excel spreadsheet that is simultaneously stored on many computers and contains certain information (Appelbaum, D., Smith, S., 2018). Such information could include, for example, information about a person's ownership of tangible objects.

The specified database stores information about all transactions of system participants in the form of a chain of blocks (ordered records). The list of ordered records in such a decentralized database is constantly growing. Each of the blocks contains a timestamp and includes a link to the previous block. New entries can only be made with the consent of the system participants. If the changes are made to the previous blocks, all the following blocks shall be incorrect, i.e there will be a need to create them once again. This peculiarity makes it impossible to change the data already existing on blockchain in a manner that will be noticeable for all other parties (Appelbaum, D., Smith, S., 2018).

The blockchain system allows to achieve the following properties of the database:

- The unified records regarding the changes to the database;

- Minimal delays in synchronization and backups;
- Ability for a group of validators to work at the same time;
- Ability to carry out a real-time audit;
- Ability to use simplified means to access the database;
- Timestamping (fixing the data in time);
- Trustless system.

The properties of the blockchain system are shown in the Table 2

Properties offered by the blockchain system	**Distributed public environment**	**Decentralized private environment**	**Centralized private environment**
Verification of the integrity of the database	+	+	+
Real-time sync	+	+	+
Consensus among validators	Available to anyone	Needs permission	For the owner only
Transparency and real-time audit	Available to anyone	Needs permission	For the owner only
Demonstrability of fraud	Possible (doesn't make sense)	Possible (makes sense)	Possible (makes sense)
Required level of trust to the system	Minimal	Trust to validators	Full trust
Using the simplified means to access the platform	Makes sense	Doesn't make much sense	Doesn't make sense
Fixing the real-time data	Makes sense (for all parties)	Makes sense (for validators)	Doesn't make much sense (for the owner)

Table 2. The properties of blockchain systems (Based on Genkin A., Mikheev A., 2017)

When the degree of decentralization of the system increases, which means, the number of validators owning a full node increases, it becomes necessary to have a mechanism for reaching consensus on a single state of the system.

The owner of a full node can make sure that the history of all transactions is correct, which makes the work in the system transparent for the auditor. If one of the users deliberately composes an incorrect transaction and sends it to the network, honest participants will immediately notice this and will not confirm it.

As for the provability of the fraud of the validators to the system, if a transaction took place on blockchain and was accepted by the blockchain (there is evidence that it was confirmed by the validators), then in the event of fraud by the validators, the user can prove the correctness. This can happen because the transaction contains the signature of the validators, which proves the fact of the decision made upon reaching a consensus. Thus, the user has the opportunity to prove that there was a fraud on the part of the validators in the blockchain, if, for example, they rewrite the history of the last few blocks (Cataline, C., Gans, J. 2016).

If we are talking about a distributed ledger, which is controlled by one organization, and for some reason, one of the blocks in the chain was rewritten, then the user has evidence in the digital wallet in the form of transactions certified by the electronic signature of the organization.

Therefore, the issue of trust between partners in an accounting system using blockchain is not so relevant. In such cases, the reliability of operation can be ensured by the rules of the protocol.

The user has the option to install a simple client application that displays the current state of the database without running the full node. Of course, this approach is applicable if the user trusts that the blockchain is working reliably.

With a fairly decentralized approach, timestamping matters, which allows validators to clearly understand in what order the transactions were formed and in what sequence they need to be confirmed.

A mechanism of Consensus as a key element of the distributed ledger system

If we delve deeper into the structure of such systems in the context of decentralization, then the most important topic that is worth discussing will be the mechanism for reaching consensus, since it is it that determines in what conditions the accounting system can operate, as well as how reliable and efficient it is.

Consensus is the state of agreement of the participants in the system about some statement or proposal.

The consensus algorithm is a set of rules and criteria by which the participants in the system reach an agreement. The consensus-building algorithm is often referred to as a mechanism, or protocol, reaching consensus (Tarek Frikha et.al. 2021).

There are many approaches to achieving consensus agreement. The most famous among them are proof-of-work (Pow) and Proof-of-stake (PoS). Educated people very rarely argue among themselves about which approach is better, because these two approaches function on totally different principles. Each blockchain is built to solve particular tasks, hence the conditions for reaching the consensus among the parties may depend on the purpose of the blockchain.

The Proof-of-Work (PoW) consensus became popular because of cryptocurrency. It is the simplest in design and at the same time the most reliable in conditions of complete decentralization and anonymity. The PoW consensus algorithm implies that in order to create a new block the miners should solve a mathematical problem. Those who are the first ones to do it create a block and get a reward. This process requires lots of computing power from miners, i.e. the more power they have the higher chances they have to get a reward after generating a new block. (Baliga, A. 2017).

Another, not the least popular consensus algorithm is called Proof-of-Stake (PoS). Unlike the PoW, the PoS is based on the principle of ownership of the tokens. In order to validate the transactions, the participants of the blockchain should stake their tokens.

In the Ethereum blockchain, for example, the users will have to stake 32Eth to be eligible for the validation process. After staking the validators are randomly selected to propose blocks to the blockchain. The more blocks the validators propose, the more rewards they can get and if the validator fails to propose new blocks to the blockchain they can get penalized and lose a part of their stake. If the participant to the blockchain provides untruthful information they lose all their stake (Zheng, Z. et.al. 2017)

This principle is much faster and much more sustainable in comparison to the PoW, as it does not require lots of electricity to be used by validators.

Another mechanism for achieving consensus is called Delegated-Proof-of-Stake (DPoS). The main idea behind DPoS is that the validation is carried out by a designated team of actors. Usually, the identities of the users who become delegates are known initially. Often these are people who have some trust, skills and experience in related issues (Smith, R., 2018).

The delegates themselves vote on conditions, that is, the outcome of the vote is decided by a simple majority of the validators. Since the number of validators is limited, their activities are easier to optimize, and as a result, this algorithm can significantly increase the throughput of the distributed ledger. DPoS development and implementation belongs to the Bitshares decentralized platform development team. EOS, Cardano, Steemit and Tezos coins are also based on the DPoS (Smith, R. 2018).

The main characteristics of the consensus methods described above can be summarized in Table 3.

Difference in consensus mechanisms	**PoW**	**PoS**	**DPoS**
Trust to validators	not required	not required	not required
Anonymity	yes	yes	no
Validation availability	permissionless	permissionless	through elections
Capacity (tps)	low	medium	high
Confirmation time	slow	medium	fast

Table 3. Overview of consensus mechanisms (Based on Baliga A. 2017)

As it can be seen, the consensus mechanism is fundamental for the reliable operation of any distributed ledger. Depending on the needs and tasks of a particular business, a blockchain system is chosen by a certain mechanism, since its properties will depend on it. In their variety, the mechanisms for reaching consensus are aimed at finding the optimal compromise in providing two properties: making the final decision in a short period of time and high throughput of the blockchain.

Analysis of some of the blockchain platforms

In addition to supporting cryptocurrency transactions, in practice, blockchain platforms can be used as a medium for smart contracts, as well as for creating other decentralised applications (DApps) that are not related to finance and allow chains of interconnected blocks of information to be used for any purpose. Blockchain platforms are divided into public and private. Public platforms are a blockchain that is open to users and developers, based on a network of Public platforms are a network of peer-to-peer nodes with all transaction data.

We will take four blockchain platforms for comparative analysis, such as Ethereum, Aeternity, Hyperledger Fabric, Cardano, which are already used to create smart contracts and decentralised applications.

A feature of the Aeternity platform is its original solution to the problem of scaling the blockchain so that the complexity of the applications and smart contracts created does not affect the network performance (Ethereum Platform official website). To support financial transactions, the system uses Lightning Network proprietary payment protocol (Poon, J. The Bitcoin Lightning Network: scalable off-chain instant payments, 2016), which operates on blocks, executing transactions between nodes. It adds a new logical layer for load balancing due to the increase in the number of transactions to solve the scalability problem. Smart contract transactions themselves take place in dedicated channels without involving the entire blockchain network. The blockchain network is used as a registry to record the financial impact of successful transactions or as an arbiter in case of differences arise.

The Hyperledger Fabric platform is also an open blockchain for universal application (Hyperledger Fabric official website). It was this feature that determined the choice of platform for the development of the IpChain system. The platform has the necessary functionality to synthesize decentralised applications and smart contracts. A feature is the possibility of multilayer configuration of the blockchain system. In order to solve the scalability problem private transaction channels with increased reliability and throughput are also implemented.

The Cardano platform is a third-generation system (Cardano Platform official website). It implements a scalable, programmable cryptocurrency value transfer technology. The main difference of the platform is the existence of a separation of computing layers. The system has a

base layer for the circulation of cryptocurrency and a layer for the synthesis and operation of smart contracts. A feature of this network is the application of a Proof-of-Stake consensus algorithm. Here, the probability of blockchain synthesis in the blockchain is proportional to the fraction that the cryptocurrency units owned by a participant, which allows owners to control the process of transactions on the network.

The Ethereum platform is implemented as a single, decentralised virtual machine on the Internet and enables transactions of any level of complexity. Smart contracts created on the platform help to register transactions of any assets in a distributed registry, protecting transactions through hash sums in the blockchain. Users implement the hash calculation in their computers. Ethereum uses the built-in Solidity programming language to develop smart contracts, which can be used to create contracts with arbitrary ownership, transaction formats and state change functions. A comparison of platforms is shown in Table 4.

Platform	**Pros**	**Cons**	**Coding languages**
Ethereum	- Widely used - Flexible - Low entry barriers	- High gas fees - High load on the network	- Solidity - Serpent - Mutan
Aeternity	- Scalability - Lower fees	- In the development stage	- Solidity - Erlang
Hyperledger Fabric	- Designed for corporate segment - Highly growing ecosystem	- Small community - High entry barriers	- Go - Java - Javascript
Cardano	- Scalability - Interoperability	- In the development stage	- Haskell

Table 4. Comparison of different blockchain platforms (Based on the information from Ethereum, Aeternity, Hyperledger, Cardano official websites).

Virtually all platforms have their advantages and disadvantages. However, to achieve the objective of the study in terms of creating smart contracts and ensuring secure and reliable interactions between the subjects of the regional innovation system, it is proposed to use the

Ethereum platform. This is due to the following considerations. The two platforms Cardano and Aeternity are still in the testing phase and require more time to learn the tools. The Hyperledger Fabric platform is more complex and is designed for building large projects in large companies. The Ethereum platform is versatile and the most common system with a low entry threshold. It is the most elaborate, which allows you to start implementing your business goals right away. Ethereum is an open platform and does not require licenses, and already created applications are freely available, which is important for budgetary educational organizations. The main limitation is the requirement to be error-free when creating smart contracts. The fact is that Ethereum postulates irreversibility and immutability of transactions, so The execution of a smart contract with errors cannot be changed or undone, which may increase transaction costs instead of reducing them. The development of smart contract algorithms on this platform requires a high level of developer attention and expertise, and multiple testing, as the cost of error is high.

Let's take a closer look at the platform. Ethereum includes a number of task-specific tools available: Solidity, Remix, Truffle, Geth, Parity, CPP-Ethereum, Ethereum protocol, MetaMask and Mist browsers, Web3.js, etc. As mentioned above, smart contracts are created in the object-oriented JavaScript-like language Solidity in the Remix cloud environment, which allows you to create and run code in a standard browser. After translation, the contracts are executed on an Ethereum virtual machine.

A disadvantage of the Ethereum platform is that Proof-of-Work is used to achieve consensus, where transactions are authenticated by the processing power of network nodes, with the probability of block creation depending on that power. Ethereum is currently migrating to the Proof-of-Stake method.

Blockchain and transaction costs

The introduction of information technology in the financial sector, the use of the Internet, and online payments make financial services much cheaper, while increasing competition in this market, as the barrier to entry is becoming very low. Financial institutions need to continuously innovate in order to continue to reduce transaction costs. Blockchain is a universal platform that makes the clearing of payments and insurance cheaper and reduces operational risks. For example, clearinghouses are involved in settlements between banks, while blockchain allows the

use of direct "business-to-business" payments, thereby reducing their costs (N. P. Ivashchenko et al. 2019).

At the same time, it should be noted that the above-mentioned positions result in reduction of costs of financial institutions in the long term, while in the medium term the costs of blockchain infrastructure development may increase. For example, as early as 2013-2014, USD 5.4 billion were invested in innovations related to the development of blockchain-based payment systems (Kiviat, 2015). According to the World Economic Forum 2016 report, investments in blockchain research in financial transactions amounted to USD 1.5 billion. McKinsey estimates that blockchain technology can:

- reduce the cost of cross-border payments from $26 to $15;
- reduce operating costs, which are currently as high as US$15 billion;
- reduce the cost of risk insurance by US$1.6 billion (Guo, Liang, 2016). FinTech estimates the benefits of blockchain adoption in the financial sector at USD 20 billion (Mori, 2016).

It should be noted that up to 80% of costs in the financial sector are attributable to the business models used in it, and only 20% to the technology itself (Mori, 2016). Therefore, blockchain implementation should not be reduced solely to technological aspects of financial institutions, as blockchain creates opportunities for the creation of new organizational forms and business processes.

Neo-institutional theory distinguishes three types of transaction costs:

- search and information costs;
- bargaining costs;
- costs of control.

Blockchain technology removes these costs, thereby bringing the economic system back to the classical type of market economy as represented in neoclassical models. A more detailed analysis of this is presented below:

The first type of transaction costs are search and information costs. First of all, blockchain information retrieval technology is characterized by the following features: the user has personal

control over the amount of information available about him; the information in the blockchain is authentic because of the mechanisms of consensus and is cryptographically protected; the information is presented chronologically and is constantly updated (Tapscott D., Tapscott, A., 2016).

Since the user regulates the amount of information about themselves on the blockchain and determines to whom it is available, the bank is freed from having to conduct a complex and costly collection of information when searching for credit information about a customer. Blockchain can be used as an inter-banking platform where complete and constantly updated information about a customer's credit history is stored. Blockchain-based information retrieval is therefore characterized by virtually zero transaction costs.

This raises an interesting aspect of the possibility for users to remain anonymous or to falsify personal information altogether. It seems that these types of opportunistic behaviour, which increase transaction costs, can be avoided by:

- Regulatory standards for the provision of personal information, where such standards are adopted either at the legislative level or at the industry and corporate level. If a customer refuses to comply with these standards, he or she will not be allowed to access credit or other banking services.
- The development of the blockchain platform itself, connecting more and by adding more financial institutions to it, which increases the amount of information available about the customer (N. P. Ivashchenko et al. 2019).

Protection of information against misuse and tampering thereof is similarly achieved in blockchain technology, as the information is stored in encrypted form and the stored blocks of information cannot be changed after the fact. This eliminates the problem of recollection of information, as a single search is sufficient due to the immutability of the blocks of information. Blockchain as a distributed database is highly resilient, as any computer connected to it has the entire database. Even if several nodes of the distributed blockchain network fail, the system will not lose stability.

In finance, one of the common transaction costs of information retrieval is KYC (know your customer) and the reconciliation of information from different sources (Moyano, Ross, 2017). A

blockchain platform ensures the consistency of information through a combination of record verification and its secure and unchanging storage. Reconciliation of borrower information can be complicated by the common phenomenon of cross-ownership, such as a shareholding, which imposes high transaction costs in determining the ultimate owner of the asset, which is necessary to properly assess credit risk, dividends, taxes, etc. But when a record of the assets is put into a blockchain, all subsequent transactions with those assets are kept intact and secure, thereby minimising the associated transaction costs.(N. P. Ivashchenko et al. 2019).

The second type of transaction cost is bargaining. There are two types of contracts related thereto:

- contracts with partners;
- contracts with consumers;

From the point of view of transaction costs on the blockchain, the transaction costs associated with partner contracting, as already noted, are determined by the level of trust achieved between the parties to the transaction. However, it is suggested here to consider the aspect of multi-party transactions, as the modern system of cross-ownership is rarely reduced to bilateral transactions and also requires the involvement of third parties holding an ownership interest or partial ownership rights. A transaction requires not only the identification of all its potential participants, but also a complex process of reconciliation of positions. Blockchain allows transaction costs to be drastically reduced by storing the entire transaction history of a given property, but it also has a built-in mechanism for reaching an agreement. It does not matter the geographical location of the parties to the transaction (Guo Y., Liang C. 2016). It is important to note that the trust factor plays a significant role here: the higher level of blockchain-based transparency ensures lower transaction costs. This is an additional argument in favour of the early introduction of blockchain into the regulatory environment and the legislative resolution of the practical application of blockchain.

The costs of concluding contracts with consumers will be reviewed on the example of the credit contracts. The transaction costs of credit contracts between financial institutions and consumers are determined by the extent to which the bank can trust the borrower, which in turn depends on the extent to which the consumer is inclined to provide complete information about himself. A

bank's customer may fear that their personal data will be used by a third party, and the bank must be sure that the customer's personal data is verified. The use of biometric data to identify users, with its placement on a blockchain platform, provides a high level of security as well as secure access to it by financial institutions. Increased trust reduces the transaction costs of this type of contract.

Nevertheless, apart from the types of contracts mentioned above, there can be also distinguished a smart contract built on blockchain. This type of contracts will be reviewed in detail in the following sections of the paper.

The third type of transaction cost is control.

Blockchain technology was originally developed to provide transparency of control by:

- the immutability of transactions recorded in the blockchain, which cannot be changed, rewritten, or tampered with;
- the strict chronological order of the records, so that any transaction can be traced from beginning to end;
- decentralised data storage (fully open to blockchain participants);
- a cryptocurrency mechanism for reconciling information;
- the ability to use smart contracts.

Let us consider these positions in relation to financial institutions.

1) A customer's purchase of an asset at a set price in a blockchain is firmly chronologically referenced. This eliminates the possibility for the seller of the asset to set a different price, which reduces the transaction costs of controlling the terms of the transaction. In addition, blockchain preserves the entire timeline of the transaction, which also minimises the cost of controlling the stages of the transaction.

2) In the case of disputes between parties to a transaction, the chronological order of the records reduces the cost of clarification and adjudication. At the same time, it allows the traceability of the payment chain, thereby identifying transactions that violate financial legislation. But it can also pose the problem of uncovering the identity of parties to an illicit transaction, again highlighting the problem of bringing blockchain out of the regulatory shadows.

3) Blockchain as a distributed database is guaranteed against corruption and loss of information blocks. This reduces the transaction costs that are spent on protecting the information bases of transactions. In addition, there are no transaction costs for gaining access to records because each blockchain participant has full access to the entire database.

4) Because blockchain is based on a cryptocurrency-based information matching mechanism, the transaction costs of control associated with limited rationality and ambiguity in the language are reduced. Each new block of information is checked for consistency with the existing database, so there is no need for additional controls.

In a system like this, parties to a transaction can make direct payments securely, removing the need for intermediaries. Financial institutions are able to develop payment systems with low costs per transaction.

Blockchain and transactional value

Blockchain does have, which positively affects the productivity and efficiency of various economic activities and macroeconomic systems in general. This is a conventional view, shared by both academia and the expert community.

But acknowledging that blockchain systemically reduces transaction costs is still not enough to admit that the technology can act as a complete substitute to the intermediaries that may potentially play an important role in transactional process. The role of middlemen is not to only reduce transaction costs but also to increase transactional value. This is quite clear when we're talking about blockchain.

Transactional value is a theory that is not that much popular in the modern economy. At the moment there are not enough researchers who would be capable of carrying out a revision of the traditional approach of transaction cost theory, which treats institutions (and institutional technology) in a one-sided manner, from the perspective of minimising the costs of transactions. This approach ignores the benefits that institutions generate (Frolov D., 2019). The transaction with the participation of the intermediaries is not only a result (for example, the sale/purchase of a commodity, or the obtaining of credit, etc.), but it is also an array of additional results/effects that characterize the quality of the transaction. The costs of a transaction or of a bunch of

transactions (total transactional costs) includes the costs of obtaining both the main and additional results. (Frolov D., 2019). "Transactional services are observable elements of transaction costs" (Wallis, North, 1986), which explains that at the current point of time the price range of the middlemen institutions differ, because most of the time, their services include not only the transaction processing part, which for sure will be cheaper in case of using blockchain, but also the side-services that allow to improve the quality of the transaction carried out. Moreover, if there is an intermediary to the transacting process, it automatically means that there is a guarantee that the transaction will be of a proper quality and there is a party which may be addressed in case when there are some issues, whereas the decentralized nature of the blockchain neither allows to make alterations nor provides a party to consult with in the course of the process of transaction.

So as it can be seen, when it comes to blockchains, the transactions are carried out automatically and there is no other party in the transaction. On one hand, this cuts the costs, but on the other hand, this means that there are no additional services offered and no additional value added.

From the perspective of transaction cost theory, blockchain's displacement of intermediaries as an "evil" of the market economy has extremely positive consequences (Frolov D. 2019). And the disappearance of intermediaries is inevitable because the costly trust in the intermediary (the trusted third party to the transaction) is replaced by free trust in the blockchain protocol. From the perspective of transactional value theory, however, the complete elimination of intermediaries is not considered to be a real case scenario, but at the same time the activities and the influence of the intermediaries in the transaction process will definitely be different. Nevertheless, even with the dominance of blockchain, "intermediaries can still add value to transactions" (Catalini, Gans, 2016), or rather to the participants of the process.

Let’s have a look at different examples. In credit card payments, the competitors to blockchain can be Visa and MasterCard. These companies though offer a vast majority of additional services: direct and deferred (cashback) discounts, savings bonuses, special privileges and offers from partners in a variety of sectors (from transportation, recruitment and business software to travelling, restaurants, museums etc) (Frolov D. 2019). All of these are considered to be an additional value for users of the payment system. Still, it is worth to mention that both of these

companies nowadays are using blockchain technology in their operations and are also heavily investing into the development of private blockchains to speed up their internal transactions.

In the case of banks, which are deemed to be among the businesses that can be eliminated by blockchain technology, the transaction cost theory approach also shows its limitations (Frolov D. 2019). If one would understand a bank only as an intermediary institution, having its main function in recording transactions, then blockchain will obviously be a threat to the banking services. Nevertheless, modern banks provide a number of additional transaction services in the area of risk management along with insurance, biometric authentication, customer support tax refunds, expense controls etc (Frolov D. 2019).

Overall, the need to apply blockchain technology to everything and a strong belief that it will outcompete the existing intermediaries is mainly caused by the fact that most middlemen provide services of a low quality, and are not even offering any other services that could be of an added value to the client. However, the services offered by the middlemen will not disappear. The intermediaries will be put in the circumstances where they will have to compete not only among themselves but also with the blockchain in terms of: setting the lowest transaction price and providing the additional services of high quality and relevance to the client. In the new reality, the costs of intermediaries will not become a cost norm, i.e. an average value of costs objectively associated with certain types of transactions, but rather as an additional cost for additional transactional services (Catalini, Gans, 2016).

Moreover, the middlemen themselves could be offering a mixed model with partial integration of blockchain to optimize the transaction costs for the client and to concentrate on the additional perks. Even now some banks are using blockchain to speed up their internal operations, thus offering a better quality of services for the clients. HSBC, for example, is using blockchain technology for better efficiency of foreign exchange transactions among its branches. JP Morgan and Deutsche Bank, apart of being active in the crypto space now, use a private blockchain to speed up the transactions among banks.

As it can be seen, the middlemen also add an additional value to the transaction process, which in most cases cannot be done by application of the distributed ledger technologies. This means that despite the fact that blockchains can cut transaction costs they will not be a substitute to the

intermediaries. Hence the hypothesis (H1): "*If blockchains can reduce the transaction costs in different sectors of the economy, they will make the transaction process more transparent and clear by eliminating the intermediaries from the process."* cannot be confirmed.

As it was discussed, the blockchain cannot fully replace the value offered by the middlemen, so its adoption will not lead to the widespread elimination of intermediaries, but it will inevitably cause institutional transformations on many different levels. In general, intermediaries under blockchain pressure will have to increase their focus on transactional value delivered to customers - value-added services that add the quality to transactions. Moreover, the distributed ledgers will put pressure on the intermediaries thus forcing them to cut down the costs of their services or in some cases maybe to offer them for free. This trend will definitely have its impact on all middlemen starting with banks and ending up with law services, controlling and auditor companies.

Smart contracts (Main Characteristics)

Apart from creating tokens and storing information on blockchain, the DLT is a technology that can support the phenomenon, also known as “Smart contracts” - systems that automatically move digital assets according to arbitrary pre-specified rules. For example, one might have a treasury contract of the form "A can withdraw up to X currency units per day, B can withdraw up to Y per day, A and B together can withdraw anything, and A can shut off B's ability to withdraw" (Buterin, 2014, P.1)

The idea of smart contracts was established by Nick Szabo, who in 1994 defined a smart contract as a computer protocol that independently conducts transactions and controls their execution using mathematical algorithms.

Smart contracts allow software to honour agreements between parties. They are computer protocols that enforce the terms in the contract and are executed on a blockchain. Smart contracts can be seen as an agent that will act exactly as instructed. Two parties enter into a smart contract by agreeing to the instructions and submitting the contract to the blockchain for execution.

Support of the automatic performance process of a smart contract requires a special environment. In fact, a smart contract exists within this environment in the form of software code that implements a given algorithm. In such a contract, all relationships between the parties have a clear mathematical formalisation and execution logic. The contract algorithm monitors the moments of achievement or violation of its clauses and makes decisions in automatic mode to reject the transaction or confirm the validity of performance

The functioning of smart contracts requires:

1) the existence of a distributed networked contract execution environment (such as Ethereum, Codius, Counterparty, etc.);
2) the existence of a distributed database for storing data on executed transactions with access for the parties to the contract;
3) use of digital electronic signature technology based on asymmetric encryption technology;
4) validation of the data source through certification centres.

The main objects of a smart contract include:

1) the subject matter of the contract describing all objects in the contract's environment of existence;
2) the parties to the transaction accepting or rejecting the terms of the contract by means of digital electronic signatures;
3) an algorithm for the fulfilment of contractual clauses in the form of a formalised mathematical description that can be translated into software code in the blockchain environment.

Smart contracts allow the shift from intermediaries to incorruptible autonomous machines. Trust services such as escrow, insurance and share trading can be in many cases substituted by smart contracts in the future.

Smart contracts are changing the way we see business processes and presenting us with new revenue models. In general terms, the many potential benefits of smart contracts can be seen in Table 5. However, it should be borne in mind that these benefits are not always applicable to every case.

Area of comparison	**Traditional Contracts**	**Smart Contracts**
Time to complete the transaction	1-3 days	Less than an hour
Transfer of Funds	Manual	Automatic
Escrow Agent	Needed	May not be needed
Costs of execution	High	Low
Presence	Needed	Not Needed
Signature	Offline	Electronic
Lawyer	Needed	May not be needed

Table 5. Comparison of traditional contracts with smart contracts (Genkin and Mavrina, 2017).

On the other hand, smart contracts have a number of limitations and do not always take into account such situations as force majeure or they also cannot be amended once completed. The Chamber of Digital Commerce outlines in its whitepaper that as of now, it is possible that the smart contracts coexist with the conventional contracts, and that there may be 2 contracts that will be concluded in relation to the same subject matter. This may help to solve potential issues the code cannot solve and on top of that, it may give the arbitration or the court an additional wider picture to the terms and conditions of the contract.

As of now, the Digital Chamber of Commerce defines two different models of the conclusion of smart contracts: internal and external model. A detailed description of these models can be found in Table 6.

External	**Internal**
There is a standard contract concluded between the two parties, and the smart contract in this case acts as an addition allowing to automate some part of the agreement.	The code of the smart contract encompasses the entire agreement and the code shall prevail over other clauses of the agreement that may be written as an appendix in words.

Table 6. Models of Smart Contracts (Chamber of Digital Commerce, 2018)

As it can be seen above, the external model stipulates that parties enter into conventional agreement and the code of the smart contract acts more like a tool that can help automate some of the parts of the code. In this case, the conventional part of the smart contract shall prevail over the code and in the case when some disputes arise, the parties should rely on the verbal version. Nevertheless, if the parties choose to follow the external model, they should make it clear in the conventional part of the agreement, otherwise, the arbitration or the courts may encounter difficulties when interpreting the smart contract.

When it comes to an internal model, it can be seen that the code plays a crucial role. There are two types of smart contracts in the internal model:

- The one which is fully based on the code and does not contain any verbal part of the agreement which could be binding to any of the parties. A bright example of this type of the contract can be DAOs (Decentralized autonomous organizations). The activities and

main functions of these organizations are based on a coded smart contract. However, these organizations also have their terms and conditions, written in a conventional language, but these have no legal power, only the code has.

- The agreements where the code is a part thereof and the verbal part is also embedded into the agreement. However, unlike the external model, this type of contract also focuses on the part with the code, and the conventional language may be used for non-operational clauses. The novelty lies in the fact that the code has a legal effect here. (Smith et.al. 2018, p. 25-26).

Next, let us focus on the attributes of a smart contract. In particular, we can define the following characteristics of a smart contract:

- the formation of a smart contract is performed exclusively in an electronic environment, in electronic form and with the mandatory use of an electronic signature;
- stating the terms of smart contracts is done by means of a programming language, and their implementation by means of a blockchain platform;
- The algorithm for a smart contract is based on the model of concluding a contract of adhesion. Thus, the terms of a smart contract, which are entered into the publicly available blockchain network, are determined by the party that creates the programming code, and the other parties join the terms of the contract;
- due to the fact that a smart contract is created by means of a programming language, it has a high degree of certainty;
- the purpose of the smart contract is to dispose of an object in electronic form;
- a party to a smart contract performs its obligations only in certain circumstances, which makes it possible to speak of the conditional nature of the smart contract;
- self-executing: The execution of a smart contract does not require the involvement of a third party, Self-execution: the execution of a smart contract does not require a third party, as the computer system itself detects when the conditions are met. self-execution: the execution of a smart contract does not require a third party because the computer system itself determines that the conditions have been met and records in a blockchain database a change in the owner of the other asset (Genkin and Mavrina, 2017).

The Blockchain technology which is the basis for smart contracts has a number of advantages that have attracted much attention from users and developers. Smart contracts can reduce transaction costs and automate the contract execution process, they can eliminate post-contract human error and exclude intermediaries from the process of execution of the contract. In addition, blockchain guarantees the reliability and security of concluded contracts in terms of their confidentiality, immutability and permanency (Bocek and Stiller, 2018, p. 171).

Despite a number of obvious benefits, the proliferation of blockchain technology and smart contracts is not a smooth and risk-free process. Let's consider three characteristics of smart contracts that are recognised as their key benefits: elimination of intermediaries and reduction of contracting costs, reduction of the human factor in contract execution, immutability of the signed agreement and its storage on the blockchain.

Reduction of costs through peer-to-peer interaction and elimination of intermediaries are probably the most attractive features of smart contracts. They are currently perceived as an innovative approach to building inter-organisational collaboration. It is this effect of smart contracts and distributed registry technology in general, that is most often discussed in the academic literature assessing the positive and negative effects of their implementation. For example, C. Catalini and J. Gans analyze the cost savings of verification (checking information about past transactions, their attributes) and networking (the ability to run and manage a network without transferring control to a centralized intermediary), which together determine savings from registry decentralisation and elimination of intermediaries (Catalini and Gans, 2016).

Moreover, it is the reduction and restructuring of transaction costs that allows blockchain to be seen as a technology that changes institutions and defines a new way of coordinating economic activity (Davidson, De Filippi and Potts, 2018, p. 641). However, to be able to save money on contracting and contract enforcement, a significant investment in the technology must be made, including the cost of hiring and training specialists, connecting to the necessary infrastructure, and negotiating with counterparties for their ability to participate in contracting in a blockchain environment. In addition, even after the initial investment, there remain significant costs of contract design, meaning that the cost structure is changing rather than clearly reducing the overall level of costs. A look at the changing cost structure by the stages of the contracting

process can be examined based on the classification of transaction costs Costs according to Wallis-North (North and Wallis, 1994):

- ex-ante - the period before a contract is concluded, when costs are associated with obtaining information about prices, product quality, the reliability of the counterparty and possible alternatives. With advanced blockchain technology, the counterparty is able to obtain the necessary information about the counterparty and its past transactions at minimal cost because all transactions are stored in the blockchain, which, however, only applies to transactions in a digital environment and does not affect the history of transactions outside the blockchain, nor is it particularly applicable at the nascent stage of technology. Moreover, a counterparty can "reveal" necessary confidential information to its counterparty, which on the one hand allows inferences to be made about the counterparty's reputation, but on the other hand allows unscrupulous actors to manipulate data by hiding individual facts and transactions (which, even if stored in the blockchain, without meaningful interpretation are not available for understanding);
- ex interim - is the contracting phase, which involves the cost of design and contracting. On the one hand, the introduction of model smart contracts may indeed reduce costs at this stage, but it would require significant costs to employ qualified programmers and lawyers to translate the legal language of the contract into algorithmic language;
- ex-post - the stage of contract execution and post-contractual relations, when the introduction of smart contracting technology should be the most effective, as the costs of contract execution are minimal compared to other forms, and peer-to-peer interaction saves on intermediary services. services of intermediaries.

Thus, as a first approximation, the main costs of smart contracts are concentrated in the design and contracting phase, and the greatest savings are achieved during the contract execution phase.

The second important characteristic of smart contracts is the reduced role of the human factor in contract performance. This is similar to the cost situation in that the human factor is actually reduced to almost zero during contract performance, but increases during design, as the damage from mistakes made at this stage can be enormous. An example is the story of The DAO Foundation. The Decentralized Autonomous Organization (DAO) project on Ethereum was an autonomous venture capital fund managed by software code based on participant voting, which

raised about $165 million in funding from interested participants. A month after the launch of the project, one of the participants took advantage of the poor terms of the smart contract and withdrew more than $60 million from the project. The problem was solved and the money was returned to users by a global rollback of the system by the developers, which violated the basic principle of blockchain's immutability. In this case, the vulnerability of the original smart contract terms cost a real loss, and solving the problem through hard fork had a serious impact on the reputation of the entire Ethereum network. Also unresolved is the allocation of responsibility for programming errors or the transformation of legal contract language into software code (Giancaspro, 2017, p. 829).

The automation of the contract execution process is not immune to the risks of non-performance of the part of the contract pertaining to assets in the real, non-digital world. At the first sight it seems that non-digital assets can be monitored by integrating blockchain with the Internet of Things, which is now being implemented through specialised software - oracles - programmes that supply smart contracts with necessary information from the external Internet (registries, quotes, etc.) and from the real world via data from various sensors and devices (Internet of Things technologies). However, the oracles are not always adequately secured, and thus may be vulnerable to potential misrepresentation of information critical to the execution of a smart contract. Moreover, this information can be compromised even before it enters the programme at the collection stage: wrong data from scanners, etc. (Wüst and Gervais, 2018, p. 49), which creates additional risks for the execution of smart contracts.

Another characteristic of smart contracts, presented as an advantage, is the immutability of records of agreements already made, a fact determined by the technology itself (Buterin, 2014; Baliga, 2017).

On one hand, this protects the contract from unauthorised changes and tampering with the content of an already signed agreement, but on the other hand, it makes it inflexible to changes in the external environment and force majeure circumstances for which the algorithm has not been programmed at the inception of the agreement. Thus, the smart contract has a 'zero-tolerance' policy (Wright and De Filippi, 2015, p. 25-26), where the parties cannot 'soften' the terms in the course of the contract, for example by extending payment terms, which at the same time is optimal when there is no trust between the counterparties. Probably, in the future, with a

sufficient level of development of technology and institutional provision, the introduction of processes of automatic adjustment of the terms of the agreement as a manifestation of collective adaptation in the digital sphere, based on the involvement of artificial intelligence technologies, is possible. In such a situation, it is important to understand the limits of the introduction of artificial intelligence, i.e. to determine which aspects of the agreement can be adjusted without or with minimal involvement of the counterparties. The difference between Artificial Intelligence and a simple smart contract algorithm is, among other things, that Artificial Intelligence is able not only to enforce a given sequence of actions, but on the basis of analysis of available information to propose (implement) various solutions to problems unforeseen at the design stage (completing an incomplete contract).

While smart contracts have significant advantages and potential to transform the contracting procedure in general, there are a number of institutional barriers to their diffusion, the main ones being their uncertain legal status and lack of legislative regulation, which will be dealt with separately, from the perspective of the new institutional economic theory.

Smart contracts and incomplete contract theory

The advent of DLT technologies has led to the emergence of smart contracts, a new form of contracts that may require significant changes in the regulatory environment as well as in the existing mechanisms to enforce the agreements. Analysis of smart contracts can be carried out both on the micro-level, in relation to specific transactions, and on the meso-level - with respect to the emerging rules of the new form of networking (Kirdina-Chandler, 2018, p. 8).

Apart from exploring the matter of institutional neutrality of blockchain-based contracts, it will be interesting to interpret smart contracts within the framework of the economic theory of contracts. The contract approach is currently being developed along many lines, including the approach of neoclassical economic theory, the theory of incomplete contracts within the new institutional economic theory, the study of asymmetries of information in behavioural management and other approaches.

Modern studies consider the mechanisms of contract enforcement. For example, K. Mike and J. Kiss conducted an empirical study on the question of the combination of formal and informal mechanisms of contract enforcement (Mike and Kiss, 2019). The authors also note that

considerable debate about transactional governance structures relate to the matter, whether different enforcement mechanisms are substitutable or complementary. Furthermore, the combination of formal contracts and behavioural approaches to managing inter-organizational interaction is discussed, for example, in an article devoted to a meta-analysis of research papers in this field (Cao and Lumineau, 2015).

The issue of trust in contract formation and performance, as well as repetitive interactions between parties, has also been the matter of interest to researchers (MsSappon, Asaad and Wilson, 2018). Trust, selectivity towards counterparties and repetitive transactions are closely related to the study of framework relational contracts and incomplete contracts, both theoretically and empirically (Mouzas and Blois, 2013).

Another aspect is related to the analysis of contract disputes caused by the limited rationality of the counterparties and incomplete information at the time of contracting - the problem of the completion of incomplete contracts. Grant, S. et al. in a number of studies (Grant, Kline and Quiggin, 2012; 2018) have attempted to identify the causes of ambiguous interpretation of contract terms and include an uncertainty component in the modelling of decision-making. This issue is also important for understanding the prospect of transforming contracts into a "smart" format, which is characterized by algorithmic processes and clear criteria for distinguishing contractual events.

In this paper, we focus on the interpretation of smart contracts from the perspective of new institutional economic theory approaches, accepting bounded rationality of economic agents as a basic premise.

The first question we will address is related to determining which kind of contracts - complete or incomplete - have more opportunities for formalization in the form of a smart contract.

If we follow one of the grounds in the classification of contracts by E. G. Furubotna and R. Richter, the completeness of a contract is defined according to the degree of detail of prohibitions and opportunities to choose alternatives for the parties (Furubotn and Richter, 2005, c. 311). If we think in terms of this approach, the form of smart contracts is more applicable to full contracts because from the moment it is signed it offers the parties no alternatives other than

those stated in terms and conditions. In other words, a smart contract imposes strict limits on the possible strategies of the parties.

On the other hand, according to the transactional approach to modelling incomplete contracts, counterparties are under structural uncertainty, i.e. incomplete information, when due to their own limited rationality they cannot ex ante formulate contract terms so as to account for all possible future states of affairs by prescribing the required course of action for each case (Shastitko, 2018, p. 181). The emergence of smart contract technologies allows for automatic contract enforcement procedures, but does not affect the predictive abilities of the parties, which limits the ability to form a complete contract that takes into account all future interaction scenarios. From this point of view, the scope of application of smart contracts should not be explicitly limited to the category of full contracts because situations may arise which have not been included in the original terms, although the technical impossibility to change the existing smart contract limits the parties' ability to amend terms and conditions without entering into a new smart contract that may be an additional mechanism that adjusts the effects of the original algorithms in order to reflect the new arrangements between the parties to the contract.

As a result, agreements in the form of a smart contract can rather be categorized as full contracts, as they involve the fullest possible consideration of contract terms at the design stage and their formalization in the form of programming code without subsequent adjustments. However, this does not preclude the use of smart contracts to formalize incomplete agreements, provided that the parties accept the high risks associated with the uncertainty of the external environment.

The second issue of interpreting smart contracts within the contractual approach is related to the concept of enforcement mechanisms, which has received considerable attention in the works of economists like Douglas North and Claude Menard (North, 1997; Menard, 2000) and many others.

Contract enforcement activities involve obtaining information about a violation and threatening or actually imposing sanctions for the violation identified (Shastitko, 2010, p. 192). The aspect related to sanctions is important in three ways, which we will consider in relation to the specifics of smart contracts.

First, depending on who performs the enforcement actions and how, two basic alternatives stand out:

- Self-enforcement mechanisms;
- Mechanisms for enforcing agreements with the involvement of third parties.

Based on the very idea of smart contracts, we can conclude that they are self-executing because they are implemented based on automatic algorithms without the involvement of a third party. This is consistent with C. Menard's interpretation of self-executability, according to which "self-executing contracts are built-in mechanisms with specific characteristics: they include automatic procedures for their execution" (Menard, 2000, p. 242). This is the main advantage of smart contracts, which allows to make cuts in the transaction costs associated with intermediary services. It turns out that smart contracts are self-executing rules, but it is important to note that the existence of an automated contract execution process does not mean unconditional performance by the parties in the real non-digital world, which still has to be controlled by fine-tuning the parties' incentives to comply with contractual terms. In addition, conflicting issues may require the involvement of a third party, which is not always possible, especially when the legal status of smart contracts is uncertain.

Smart contracts also fall into the category of self-executing agreements as understood by E. G. Furubotn and R. Richter, who define self-executing agreements as 'contracts that cannot be enforced through the courts because only the parties to the agreement can determine whether the terms have been violated, and only they, through the threat of termination, can enforce the contract (Furubotn and Richter, 2005, p. 240). The situation with smart contracts in current institutional regulation and technical execution is very much in line with this description, as there is no universally recognised third party, capable of analyzing an agreement coded in a blockchain network and relating the results of performance thereof to the real world.

In self-executing agreements, information is assumed to be perfect except that the parties do not know whether the counterparty is a trustworthy (honest) partner. In this regard, the possibility of entering into such contracts is often based on the concept of reputation of the counterparties and the value of an intangible asset such as a firm's brand (Furubotn and Richter, 2005, p. 301). There is always the issue of ensuring trust between the parties, especially if they interact for the

first time. This issue is planned to be solved by the use of blockchain technology, which creates a mechanism to ensure trust between initially mistrustful actors. However, this solution extends to interactions strictly in blockchain space, but if any of the objects of the agreement are located in the real world, blockchain cannot guarantee the fulfilment of obligations related thereto, even if it is integrated with the internet of things.

Thus, in terms of evaluating the enforcement processes of the agreement, the smart contract is a new form of self-executing agreements, but it is imperfect in terms of overcoming the incentives of the parties to engage in opportunistic behaviour and fail to comply with the terms of the contract.

Let us return to the aspects related to the parties' performance in enforcing the terms of the contract.

The second point is the assumption that the threat of sanctions and their actual application are indistinguishable with respect to the outcome in case when all other conditions are equal. However, looking at the contracting process as a whole reveals significant differences caused by the relationship between the costs of preventing violations and those of avoiding them. In the context of smart contracts, the costs of prevention relate to the inclusion of possible penalties in the event of default in the contract code. It is also possible to include insurance mechanisms, e.g. when funds intended to be transferred to the seller in payment for goods and services under the contract are placed in a certain account where they are "frozen" and not available for use by either party to the contract until certain events (receipt of goods, rejection of goods by the buyer, etc.) occur. This is essentially analogous to escrow accounts or letters of credit in real estate transactions only without the involvement of banks or other third parties. The issue of enforcement of the smart contract and reducing the parties' incentives for opportunistic behaviour is discussed in more detail in J. Gans (2019, p. 11-14), where the conditions for limiting the parties' incentives to breach obligations are considered through a comparison of the value of goods to the seller and the buyer.

Thirdly, the form of sanctions matters. The variation in the form of penalties for non-compliance with the contract is also determined at the design stage of the smart contract, as all sanctions are automatically applied. An example of a light form of sanction would be ‘sending an automatic

warning’ to the supplier in case of delivery of the goods by a specified number of days overdue. It could then provide for a penalty charge for each day of delay, starting from the day n, etc. In such circumstances, it is important to exclude the buyer's interest in hiding the fact of receipt of the goods.. Therefore the function of proof of receipt may be entrusted to the port of entry, where the marking of the cargo would be scanned and the information would be automatically sent to the blockchain environment. The exclusion of such an agent can also happen later with greater levels of adoption of the Internet of Things. An example of this can be the smart car rental contract, in accordance with which access to the vehicle shall be restricted when no payment under the contract is received.

The automatic sanctioning mechanism built into smart contracts may not always be justified. On the one hand, in circumstances where there has been no interaction between the counterparties, they may use such a mechanism as a hedge against default (fits with the type of classic contracts). On the other hand, in the context of repeated interactions, the parties may attach more value to the relationship with a partner than to the funds received from the fines in a particular transaction. Then the parties are prepared to make certain concessions in the performance of a separate contract for the sake of preserving the relationship, which is characteristic of relational and partially neoclassical contracts. However, it is not clear how to make such concessions if they have not been envisaged in the design of the smart contract.

Another point related to the institutional characteristics of smart contracts as enforcement mechanisms for mutual obligations of the parties is the allocation of not only the costs of entering into the contract but also the responsibility for its correct operation afterwards. The smart contract is a computer algorithm (a programmer must be responsible for the correctness of the protocol itself) that reflects the legal categories defining the rights and obligations of the parties (responsibility of the lawyer), but who is responsible for correctly translating the legal terms into mathematical algorithms has not been defined. The question is what would be the mechanism of liability for incorrect design of a smart contract resulting in real losses for the parties to it: the contract participants themselves, the developers, the lawyers, the blockchain system operator? The answer to this question is not certain, as long as it depends on a case-by-case basis, but in general, there should be formed practice and a certain category of

specialists will be vested with responsibility for the correct depiction of the original agreements of the parties to the smart contract.

Taking into account all of the above, the processes that do not have any uncertain circumstances can be formalized by the companies into smart contracts and the transaction costs related to the enforcement and preparing the contracts can be cut. However, the blockchain and smart contracts do not allow cutting the bargaining because this is usually done offline by the parties. Hence the hypothesis (H2): "*If the contracts of the company are complete, the applications of blockchain are likely to reduce costs of writing and enforcing contracts, whereas the costs of bargaining and renegotiation are unlikely to be affected."* can be confirmed.

In this section, smart contracts were analyzed in the context of the contractual approach in the new institutional economic theory, determining that they can be classified as self-executing rules and are more suitable for formalizing complete contracts.

Smart Contracts and Legal Contracts

The three-part classification of legal contracts was proposed by Macneil in 1974. Macneil's 1974 tripartite classification of legal concepts of contract (Macneil, R. 1974) has been economically interpreted and developed in the works of O. Williamson. Contracts were divided into three types according to the underlying varieties of contract law - classical, neoclassical and relational (Williamson, 1996, p. 128).

In the classical contract law, the efficiency of economic exchange is reached by means of the increase of discreteness and representativeness of contracts. Transactions in a perfectly competitive market correspond to these conditions.

The discreteness of a transaction means that the transaction occurs at the time of the conclusion of a particular agreement and ends with its complete fulfilment (Macneil, IR. 1974). Contractual obligations are thus definitively established at the start of the transaction and the parties have no reciprocal obligations either before the transaction begins or after it ends.

Presentation of the contract means that the contract defines in detail the essence of the agreement and provides for all possible scenarios of future events with a probabilistic assessment of their

occurrence and the corresponding distribution of costs and benefits in the implementation of these scenarios.

Under classic contract law, independent individuals enter into standard formal contracts under which homogeneous goods are sold at the same price without restriction to all comers within an organized market. A classic contract does not involve investment in specific assets, because it is impossible to ensure the efficient performance of a contract with specific assets within the framework of a classic contract.

For a classic contract, it is not important for the parties to the transaction to be consistent with each other; the formal terms of the contract prevail over the informal terms. The involvement of a third party to settle disputes is not foreseen in a classic contract because all possible future events are determined before the agreement is signed (at the ex-ante stage). The effectiveness of classical contracts is enforced by a court, which forces the parties to fulfil the obligations stipulated in the formal contract.

The neoclassical contract, or tripartite management, provides for a long-term relationship between independent economic agents and takes into account the need for the parties to adapt to contingencies arising at the ex-post stage of contract implementation. The duration of the agreement under the limited rationality of economic agents leads to the impossibility of concluding a complete, or presentational, contract.

According to C. Llewellyn, the contract never precisely defines the real economic relations, but only establishes an approximate framework and guidelines for the ordering and development of these relations. The parties in the process of implementation of the contract are forced to adapt to emerging circumstances and adjust the terms of the exchange when the implementation of the original contract proves impossible due to new circumstances.

The relationship in a neoclassical contract is long-lasting, so the goodwill and informal agreements between the parties complement the formal provisions of the contract. In order to effectively implement the neoclassical contract and to ensure flexible adaptation to changing circumstances, the parties rely on a dispute resolution mechanism involving the assistance of a neutral third party, the arbitral tribunal.

The arbitral tribunal interprets and corrects the provisions of the formal contracts when disputes arise between the parties. The starting point for effective adaptation to emerging circumstances is the original formal agreement.

Permanent arbitral tribunals shall be established by chambers of commerce, trade organizers, public associations of entrepreneurs and consumers and other legal entities and their associations. The decision to establish an arbitral tribunal to resolve a particular dispute shall be made by agreement of the parties.

Arbitral proceedings are possible if there is an arbitration agreement concluded between the parties. An arbitration agreement is an agreement of the parties to submit a dispute to an arbitral tribunal for settlement. The parties who have entered into an arbitration agreement voluntarily surrender the right to resolve the dispute to the arbitral tribunal and undertake to abide by the arbitral tribunal's decision. The arbitral tribunal renders a decision in accordance with the terms of the contract and with due regard to the custom of business.

Under the attitudinal theory of contract law developed by Macneil, contractual rights and obligations are analyzed in the context of a long-term relationship between the parties. Relational contracts involve formal and informal promises of repeat business in the future. As a consequence, the expected benefit from repeated orders exceeds the benefit from maximizing opportunistic behaviour leading to a relationship breakdown. Therefore, in such contracts, the economic agents adhere to the community of interests and the economic exchange becomes more cooperative.

The terms of a relational contract are interpreted and adjusted by the parties to the contract themselves. A guarantee for the effective fulfilment of relational contracts is the motivation of the parties themselves, not the threat of litigation (Macneil, 1974)

In the course of long-term contractual relations, certain norms of behaviour emerge. The requirement to observe these norms becomes a part of the parties' obligations and is incorporated into the system of their mutual expectations in the process of contractual interaction.

The recognized need to cooperate makes the parties to a contract behave in a mutually beneficial way, i.e. they react more flexibly to external changes, try to maintain the relationship, jointly

resolve problems and disclose all the information regarding the subject and circumstances of the transaction. In relational contracts, informal norms complement formal contractual norms.

Let us move on to the comparison of their characteristics and evaluation of prospects for formalizing each type in the form of a smart contract. To do so, we turn to Table 7, which presents the key characteristics of contracts and highlighted in colour the extent to which they correspond to the specifics of the design and application of smart contracts.

Contract properties	**Classical contracts**	**Neoclassical contracts**	**Relational contracts**
Degree of asset specificity	No specificity	Low specificity	High specificity
Frequency of transactions	Single, regular	Single, sporadic	Continuous
Validity of contract	Short-term,	Mid- and long-term	Long-term
Degree of selectivity and importance of personification of the parties	No selectivity, personal relations do not matter	Identity of the parties and personal relationships counterparties are of non-zero significance	High degree of selectivity, partner replacement is almost impossible
Completeness	Complete	Incomplete	Incomplete
Mechanism of collective adaptation	Not foreseen	A mechanism for collective adaptation to contingencies is foreseen	The collective adaptation mechanism plays an important role in preserving relations
Mechanism of compliance with the terms and conditions of the agreement	Self-fulfilling, passive role of judicial system	It is possible to enforce the contract with the help of a third party - specialised court, arbitrator etc.	Self-executing. Internalization of the mechanism of enforcement of transactions. A third party does not have complete information

Value of future relations	Not important	Slightly important	Very important. Relations are of a higher value than the transaction itself
Priority of formal/informal relations	Formal provisions of the contract prevail. No informal relations are present.	Formal provisions of the contract prevail. Informal relations are also taken into account and may have an impact on formal	Informal relations are of a higher value than formal
Degree of formalization and standardization	Formal standard form	Formal not standard form	Maybe formalized as a framework agreement, however, informal agreements prevail.

Table 7. The correspondence of relational, classical, and neo-classical contracts to the characteristics of smart contracts. (Based on Williamson, 1996; Tambovtsev, 2004; Richter, 2005).

According to the results presented in Table 7, smart contracts are best suited to classic contracts. The only problem remains the lack of a regulatory framework for contracts executed with the use of code. An example of the relevant area is the financial market and securities trading, direct car sharing between the owner of the car and the lenders and smart contracts in the field of insurance. The second priority is the neoclassical contract, which is slightly more difficult to be implemented as a smart contract because of its incompleteness and the need for adaptation mechanism in the event of certain circumstances, which cannot be foreseen in advance and included in the contract. An example of this area would be a service with rental accommodation. The most difficult to design in the smart contract format is the relational contract, which doesn't require any formalisation per se because the most important part of such a contract is the possibility to review the conditions for the sake of preserving good relations between the parties. However, the smart contracts do not provide for this option.

At the same time, there are characteristics that are not relevant when designing a smart contract: the frequency of transactions, the personalisation of the parties, the importance of personal

relations, which means that a smart contract can be entered into without regards to all those factors. Thus, the hypothesis (H3): *"Smart contracts as a new form of contracting are similarly applicable to all types of contracts within the context of the traditional transaction cost typology: classical, neoclassical, behavioural"*, cannot be confirmed.

When it comes to possible areas for the proliferation of smart contracts, two main approaches should be identified. The first approach implies that self-executing contracts may be of greatest value in areas with stable, predictable demand, unchanging rules game, recurring transactions, where a once-developed and tested smart contracts can be implemented in similar situations at progressively lower costs (as compared to the initial costs of designing the first similar contract). This correlates with C. Menard's view that automatism in compliance with the contract in some cases reflects its completeness, which is possible in a stable environment, high transaction frequency or in the use of general-purpose resources (Menard, 2000. (Menard, 2000, p. 243). Thus smart contracts can be applied in transactions with clear terms that will not be renegotiated within the period of validity of the contract. This may be applicable, for example to a lease agreement with periodic payments, a loan agreement with a lined up payment system, a loan agreement with a fixed payment schedule, or a loan agreement with a fixed payment schedule.

Another point of view is held by J. Ganz, who argues that blockchain-based smart contracts will only be of value if they create the conditions for building trust in situations where existing social and institutional mechanisms fail or are insufficiently effective (Gans, 2019, p. 9). An example of such an area is the financial market, where current contractual mechanisms can be replaced by more effective ones.

In general, both approaches can be combined, as smart contracts can be designed for different purposes, both in industries with a stable environment where they can pay for themselves in a shorter time through mass application and allow significant cost savings, and in areas where traditional contracting practices are insufficient and a new tool is required. However, it should be remembered that smart contracts are not applicable in all areas and their introduction where they do not reduce transaction costs or simplify the contracting process without increasing the risks of non-compliance. An example of such contracts are relational contracts and framework agreements, which preserve well-established informal relations rather than act as a mechanism to monitor the fulfilment of obligations by the parties.

Smart Contracts and Institutions

Due to the fact that the subject of the contract is preserved regardless of whether the contract is on paper or on a blockchain, it can be said that a smart contract is not a stand-alone type of contract (both under civil law and in the blockchain), but a form of agreement or a way of enforcing an obligation implemented on the blockchain. The Smart Contract, as a "self-executing private law agreement represented in code, meets the definition of a contract and can be embedded in standard contract classifications" (Lukoyanov, 2018, p. 60). The parties to a smart contract also do not differ from the parties to a classical contractual agreement, only the contract design process presents a difference. Let us move on to consideration of smart contracts in the context of the current legal system.

At the moment, smart contracts have no enshrined legal status, which means that there is no legal relevance of concluded smart contracts, neither are they supported by an agreement on paper or in an established electronic document format. Apart from that, their conclusion and implementation is only secured by the will of the parties. Possible reasons for the lack of legal status of smart contracts shall be considered below.

First of all, one of the reasons is the traditional inertia of formal institutions in relation to significant changes in the form and principles of contractual relations. As R. M. Jankowski points out, a situation arises where "market participants exist in a new paradigm, but the state is unable to accept it and tries to regulate it by traditional (legal) means, which destructively affects the legal culture as a whole" (Jankowski, 2018, p. 65). Such issues related to changes in formal rules, the relationship between formal and informal rules, their complementarity and contradiction, occupy a significant place in institutional research.

Second, the acquisition of legal status by smart contracts may be hindered by their association with cryptocurrency, which in most cases is one of the key assets in exchanges governed by smart contracts and also acts as a fee to keep transactions on the public blockchain. In this environment, all the risks associated with the proliferation of cryptocurrencies and mistrust on the part of public institutions extend to smart contracts. Thus, I. V. Sudets, considering the development of legislative support for new technologies, identified three approaches of the state to the legal regulation of blockchain and cryptocurrencies - prohibition, a wait-and-see attitude,

an attempt to create a legal framework that stimulates the development of technology and innovation (Sudets, 2018, p. 94). The prospects for the development of smart contracts in a particular country largely depend on the choice of approach, and the choice itself is largely determined by the history and practice of institutional development of a particular country (Nureyev, 2009).

Thirdly, there is no uniform approach to understanding the processes of integrating smart contracts into the current system of civil law relations. For example, M. Yurasov and D. Pozdniakov distinguish two main models of smart contracts integration:

- a stand-alone model in which traditional contracts will be supplemented by computer algorithms and the code will be only a technical means to ensure automatic performance of the obligation
- a hybrid model in which most of the legal contract will remain in the traditional form and part will be written in one of the programming languages (Yurasov and Pozdniakov, 2017).

One option for the initial implementation of smart contracts would be precisely hybrid forms, where in addition to code reflecting the contract terms in an algorithm format, there is a paper backup created in case of contract violations or lawsuits (Genkin and Mavrina, 2017). That said, there are few supporters of the idea that smart contracts may soon be integrated into business circulation in a fully automated form without the creation of additional documents.

In general, these barriers will be overcome over time and smart contracts may be integrated into the civil law system, which will be modified or expanded by the addition of new rules and regulations governing the application of smart contracts. But does this limit the impact of smart contracts on the legal system itself? No, because there are several trends reflecting upcoming changes in the institutional framework for contractual relations. In particular, smart contracts create an environment where software code becomes an element of law and that gradually leads to the "codification" of law - the translation of complex legal constructions to simple ones, simplifying the texts of contractual relations for clear execution on the platform. Smart contracts have a high degree of certainty because the terms and conditions of a contract are written in the form of a code that is not ambiguous, but also do not allow for the coding of such evaluation

categories as reasonable time, fairness and good faith. The terms and conditions of a smart contract containing such categories can be classified as non-operational (Clack, Bakshi and Braine, 2016), i.e. those that the parties are unwilling or unable or cannot technically automate. The existence of such conditions also speaks in favour of a hybrid form of smart contracts, and also imposes restrictions on the scope of distribution of smart contracts.

Another legal controversy stems from the fact that some smart contracts have the ability to introduce counterparties into subsequent, secondary contracts created pursuant to the first contract (Giancaspro, 2017). The parties may not even be aware of the secondary contract, and so several questions arise: can the intent to create a legal relationship be established in this case, and can a smart contract or another program autonomously introduce parties into legally enforceable agreements? How would these situations be handled, and how would such automated agreements be governed by the law? How might the legal system be modified when artificial intelligence technologies are integrated into the execution of smart contracts? These questions call for further research in an interdisciplinary field.

The institutional implications of the proliferation of smart contracts also relate to the transformation of dispute resolution procedures - whether the parties will choose the traditional method of dispute resolution or an alternative mechanism will emerge. In the case of traditional methods (court procedure, mediation, etc.), there is the difficulty of whether the judge will be able to understand and interpret the will of the parties as expressed in software code, and who will conduct the technical expertise and bear the costs of providing it. Alternative mechanisms have not yet been developed, as smart contracts themselves have no legal status, but it is conceivable that new institutions could be formed in the form of, for example, an online platform of arbitration companies, which would produce a decision that would be accepted without appeal by all parties to the contract and automatically enforced after its publication (Yurasov and Pozdnyakov, 2017). Furthermore, blockchain and smart contracts may lead not just to new legal rules, but also to the emergence of 'Lex Informatica' (Reidenberg, 1998) as an effective alternative to the existing legal system in which self-enforcing and individualised rules, of which smart contracts are an example (Millard, 2018, p. 846), and to 'Lex Cryptographia' - a set of rules and regulations that are implemented through smart contracts and decentralized(potentially autonomous) organizations (Wright and De Filippi, 2015).

To draw a conclusion to the above, not only do smart contracts need to fit into the existing legal system, but the system itself needs to change under the influence of new technologies, including new institutions and mechanisms that may emerge. The introduction of smart contracts is not an institutionalized approach, smart contracts are not institutionally neutral, which means that the hypothesis (H4): "*The application of smart contracts in economic practice is institutionally neutral, as it only changes the form of conclusion and execution of the contract"* cannot be confirmed.

Framework for Blockchain Applications

Taking into account the current trend of the application of blockchain technologies by many companies, the purpose of this framework (See Fig. 4,5) is to provide theoretical guidance to the managers when they make a decision whether they need to implement blockchain and smart contracts inside their companies or whether it would be a useless thing to do.

The framework for blockchain applications (Fig 4,5) is divided into two main parts with suggestions for companies providing goods and services for their customers. The scheme also demonstrates what kind of solution is more suitable for the company and under which circumstances it makes sense to resort to the technology.

As it was studied and mentioned above blockchain technology is applicable in case when it is needed to store a database with some information about the company or about the goods and services. The purpose to have such a database on blockchain may be the need to check whether the product is original or not or alternatively the need to track the process of fulfilment of the service. In the latter case, there is a need for a fast and scalable blockchain, which will allow to cut down the transaction costs.

When it comes to smart contracts, it was previously argued that they are applicable in the following cases:

- Stable environment, meaning that there is no unforeseen circumstances may arise in course of carrying out the conditions of the contract by the parties
- Fully standardized services, which assumes that the process of contract execution is the same for all clients and the type of the work done is not changed during the execution process.
- Information can be easily retrieved from the databases and is recorded online.

If all of the requirements described above are met, then the use of smart contracts will indeed cut the costs of writing and executing contracts, apart from that, it will make the workflow faster and more efficient for both parties.

If we take a look at the framework for services described below (Fig. 4), it should be mentioned that they were divided into internal and partially external services. The internal ones are those, which the company provides by using only its internal forces, hence all the information about the work progress can be retrieved from internal databases. The services, which are partially external are those that require the sub-contractor or the third party to handle a part of the process while providing a service to client. Such a division was used in order to emphasize the need to be able to track the flow. Hence the first thing to consider when making a decision whether to implement blockchain and smart contracts, is the possibility

to quantitatively measure and record the result and, if it is doable, there is a need to sync the data, especially 3rd party data.

When it comes to services, and if they are standardized for all parties and are performed in a stable environment without any unforeseen circumstances, it will make sense for the company to shift to smart contracts. The bright example of the kind of services suitable for this type of contracts are online services. For example digital advertising: the user usually signs a full contract where they specify what kind of countries and what audiences he/she wants to show their ads to. The advertising company can use a smart contract in this case. The data received from the ad campaign is usually stored internally and even if there is a subcontractor performing a part of the contract, the data can be easily synced via API. The smart contract in this case may automate the payment process between the executor and the advertiser as well as guarantee the performance of the contract, by ensuring the client that the payment will be released as soon as the services are performed.

Smart contract for financial services can be another example. Moreover, this type of contracts is quite widely used today by various financial organizations. Smart contracts in the field of finance help to automate many processes (like peer to peer payments, or sync between correspondent banks) and save time and money on preparation of different documents. At the same time, these contracts allow regulators to intervene in the contracts automatically in case if some of the conditions of the contracts were violated.

Storing the information about services on blockchain, however, is not that widespread at the moment. The use of blockchain in this case is needed only to create some open registrars or to make a database of the information which cannot be changed. This is applicable to the services for verification, or for the institutions that provide credit scores of individuals or companies.

Moving forward to the part of the framework discussing the need of implementation of blockchain technology for the companies selling goods (Fig.5), it is important to separate tangible and intangible products. Tangible products are not the ones where the use of smart contracts can really have a positive effect on cutting transaction costs for the companies. Nevertheless, the use of blockchain as a database for some of such products can be quite useful. As of today, companies like Louis Vuitton, that are selling products in the luxury segment are already using blockchain to protect their customers from counterfeits. Another use case for such blockchains are pharmaceuticals. In the latter case, the fact that the product is real can play a crucial role in saving someone's life. By adding the QR code to the product, the company allows the client to check whether the product is original or not. The record about the product may contain any kind of information like the information about the steps in production and shipment data. This kind of

databases allow companies to save costs on elaborating new watermarks and symbols that guarantee that the product is original, and they solve the issue of client's trust on the other hand.

Intangible products can be sold by means of implementing a smart contract. In this case, the contract can be a substitute to the escrow, enabling the process of exchange automatically when the conditions of the contract are fulfilled by both parties. Over the last year, the smart contracts for intangible goods have become quite popular and the monthly volumes of purchase of these products via blockchain are more than 2bln USD, according to the data from Coinmarketcap. These intangible goods are called NFTs, or non-fungible tokens, which are digital images, or pieces of art, or music and videos, sold with the use of smart contracts. In this case, the contract also proves the ownership of the product.

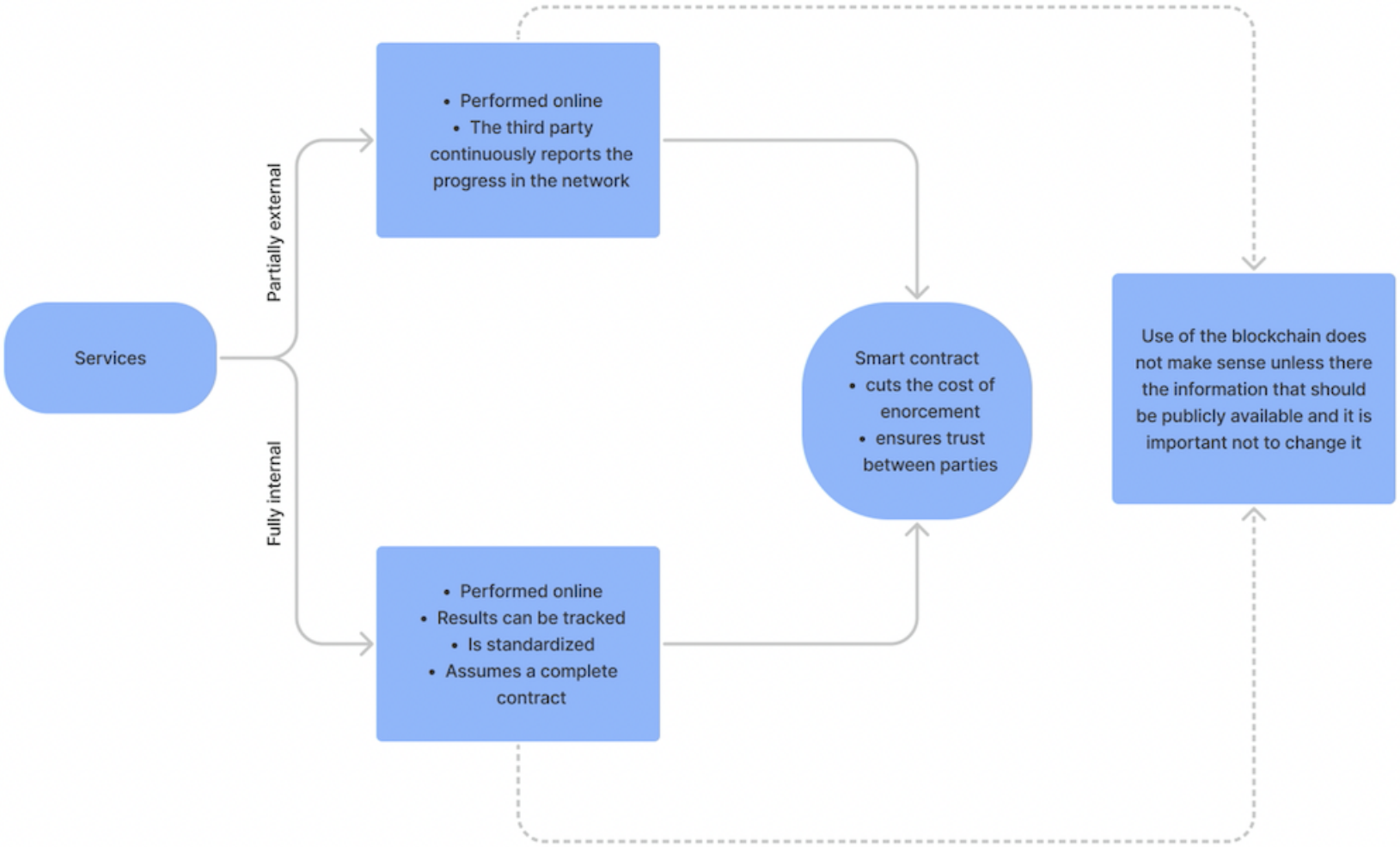

Figure 4. Framework for Applications of Blockchain Technology for Services

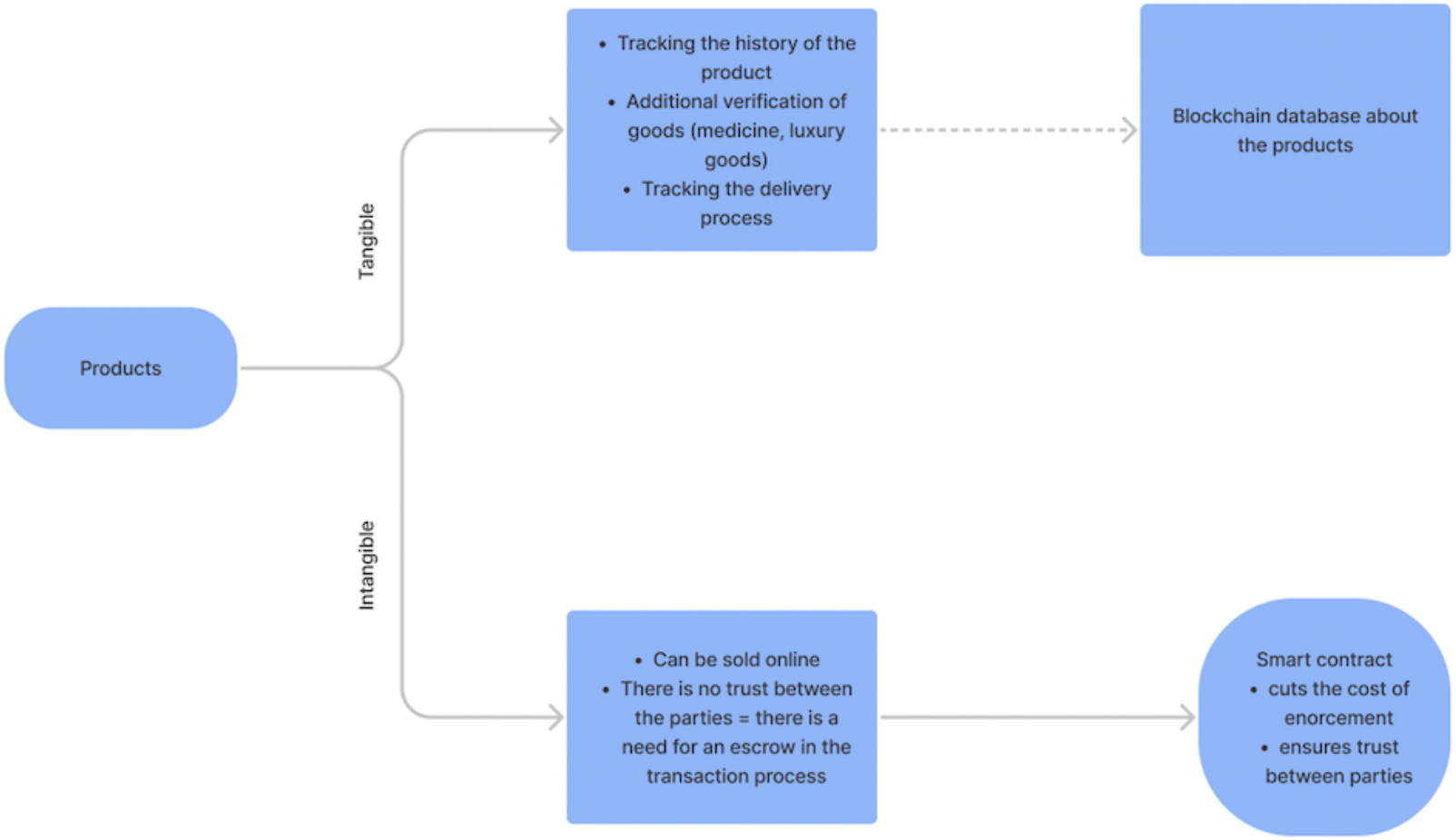

Figure 5. Framework for Applications of Blockchain Technology for Goods

Conclusion

This paper sought to explore the possible applications of the blockchain technology and smart contracts from the perspective of lowering the transaction costs and making the contracting process more transparent with the use of these technologies. This paper demonstrates how the technology can be utilized by the firms in order to speed up the processes of enforcement of smart contracts and to lower the firms' transaction costs.

Blockchain is a complex digital technology that is the basis for fundamentally new ways of coordinating transactions. Blockchain can be rightly considered as an institutional technology, which may lay a foundation for the innovations in the current system of economic institutions of capitalism. At the moment the technology has managed to capture the attention of the majority of the researchers as well as firms that already are beginning to integrate it into some of their operations.

This research was aiming to provide a systematic review of the scholarly literature devoted to the topics of blockchain and smart contracts. At the same time, the research was trying to cover the research gap which is connected with the studies of the blockchain technologies being considered from the perspective of the institutional theories.

At the beginning of the research, the main assumptions were quite idealistic, - that blockchain technology and smart contracts can completely eliminate opportunism and intermediaries as well as significantly cut down the costs of transactions by reducing the information and enforcement costs. However, in the course of the research it appeared that this point of view was rather limited.

In order to answer the central research question, it is worth saying that blockchain technology and smart contracts are indeed applicable for the firms and can improve transparency as well as to cut some of the costs associated with retrieving the information and enforcing the contracts. However, they are applicable only in cases when there is a complete certainty about the processes and no further conditions will be subject to a change in the future. As for the intermediaries, the distributed ledgers can indeed reduce the role of the intermediaries by offering much cheaper institutional solutions, however, the technology cannot offer additional

transactional value, which is very possible in the case with the intermediaries. The good thing is that the technology forces the middlemen to adjust to the new conditions on the market and to set more attractive costs for the clients.

After all, it can be seen that the technology has indeed a huge potential, however, neither the current institutions are yet fully ready for the adoption thereof, nor does it fit into existing legal systems.

Despite the fact that the main goal of the research was fulfilled, the study still has a number of limitations.

First of all the study is theoretical and the main materials of the study were scholarly reviews. This is first of all caused by the fact that the technology is new and there is a lack of practical applications thereof in the traditional institutions. This can be also noticed from the analyzed literature: the approaches in the articles were mainly conceptual. Hardly any articles contained empirical studies. Because of the novelty of blockchain, the case studies and empirical papers in the field are just starting to emerge. Secondly, the research was mainly concentrated on a systematic literature review, which means that a limited number of articles were selected and the paper may constitute a bias. Another limitation of the research is that despite the fact that the current research offers a quite broad overview of the literature, there is much more new research and studies to be released, which is caused by a large amount of attention to the technology nowadays, especially starting from the Corona pandemic.

As for the suggestions for future research - first of all, this would be the more empirical approach to the study and analysis of the real case scenarios adopted by the companies by using both quantitative and qualitative methods. Another suggestion is to continue examining the changes in the blockchain industry and provide additional research based on the new updates in the field. The technology is rapidly evolving and what is popular today may not be so widely used in the future. New blockchains, new ways of creating smart contracts and new mechanisms of consensus are appearing every day so further research on the changes to the technology will be definitely needed. One more suggestion would be to analyze the blockchains from the perspective of transaction costs theories in more digitized companies and see whether the technology will have broader advantages there. In particular, it will be interesting to see the

performance of the smart contracts in the firms where most of the operations are handled online and where there is a more standardized approach of concluding contracts with the clients. After the COVID-19 pandemic, the number of such companies has increased and more operations have been digitized and automated.

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Appendix 1

Thematic map