Aalto University
School of Business

The Impact of the Distributed Ledger Technology on the Financial Industry

Closer Look on the Public Securities' Post-trade and the Private Equity Market

Bachelor's Thesis

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Table of Contents

List of Figures

1. Introduction

The distributed ledger technology (DLT), often misleadingly referred to as blockchain, is commonly dubbed as the next big thing in the financial industry. Though initially presented underneath an alternative cryptocurrency, Bitcoin, to be used without a central bank or any other traditional intermediary backing the system (Nakamoto, 2008), the financial industry's so-called traditional players have long since realized the disruptive potential the DLTs possess. The original blockchain recording Bitcoin's transactions and creating the trust in between the strangers has shown throughout the years its capability of reliably decentralizing operations. However, instead of just concentrating on the different cryptocurrencies and their development, the financial services organizations are now researching and investing on how the distributed ledger technology could reshape their own businesses (CBInsights, 2017).

The revolutionary feature of the original blockchain is the way it creates trust by computing. No technology had been able to transfer value in the internet without a trusted, central intermediary before Nakamoto's suggestion in 2008, as there was no feasible way to be certain of an asset's authenticity. This was solved in Bitcoin by recording the past transactions on a public ledger online and allowing every user an access to it, so that the whole community has the same view of the past and the current ownings. Furthermore, as the transactions are validated by reaching a consensus among the users, the tampering of the ledger is impossible in practice. These common technological features of the distributed ledgers are introduced in more detail later in this thesis.

1.1 Financial industry's special needs

Since 2008 and the credit crisis, the increased regulation and the lack of economic growth have resulted in a very inconvenient situation for most of the financial service providers. Consequently, the financial industry is expecting a lot from the distributed ledger technologies, as they are cited to enhance transparency, save costs and increase security while making the whole industry more efficient (IDRBT, 2017; Schneider et al., 2016). Being able to cut off manual back office labor, streamline and automate processes, reduce time and even simultaneously enhance transparency and increase security are also some of the reasons why the DLTs are topping Gartner's hype cycle for emerging technologies' peak of inflated expectations (Walker et al., 2016).

The hype around the original blockchain has buried the reality of it not being directly suitable to the financial industry's problems. As Pinna and Ruttenberg (2016) mention, there are several redundant characteristics in it for the financial industry. Firstly, Bitcoin and its technology were initially designed to be independent of the financial institutions. The lack of governance and regulation in the field of current cryptocurrencies is not suitable for other markets: vice versa, being regulated is a necessity for the distributed ledgers to succeed in the financial industry. Secondly, blockchain's absoluteness, meaning the total anonymity of its users, distribution of transactions' information to everybody and the "irreversibility of unlawful transactions" are too strict rules to be applied in the financial industry. (Pinna and Ruttenberg, 2016) These primary challenges of DLTs will be discussed in more detail later in this thesis.

1.2 Smart contracts

The smart contract refers to a programmed, predefined agreement between two entities, which is automated to execute itself independently on the distributed ledger (Mattila, 2016). For example, the smart contract can be coded to buy a certain amount of shares every day, if the price drops below a predetermined level. One can also program the smart contract to continue in a never-ending loop, or alternatively self-destruct after a certain time. After the contract has been agreed on a ledger, it functions just like any other node on a ledger: its transactions are validated by the ledger's consensus-system, and it's secured by the cryptographic elements (Pinna and Ruttenberg., 2016).

Although originally described in the 1990's, smart contracts are an essential part of the so-called "Blockchain 2.0" (Sabo, 1997; Bheemaiah, 2015). At the time of their introduction on a white paper, there was no way to exploit smart contracts due to their requirements of high computational security and the closeness to the assets being managed by the contract. Blockchain 2.0 refers to the phase after the wider usage of Bitcoin introduced people the possibilities offered by the distributed ledgers: the original Bitcoin network couldn't handle smart contracts, but the second-generation platforms such as Ethereum were meant to be extended with other applications, such as automation and intelligence (Buterin, 2014).

Pinna and Ruttenberg (2016) state that the smart contracts could be the truly value-offering part of this hyped technology for the financial service providers. These computational agreements possess the ability to genuinely cut costs, increase efficiency and simplify the industry by automating most of its now highly manual tasks. Additionally, the risks of fraud and operational mistakes would be diminished, as the smart contracts would act accurately and agreeably even without continuous monitoring. (Cant et al., 2016) This thesis will not take a stand on the legal problems the smart contracts may face in the near future when further investigated, as that does not rule out the high possibility that the combination of distributed ledgers allowing smart contracts to automate tasks could still prove to be the real game changer when it comes to the financial industry's needs.

1.3 Current research and market situation

Despite the potential significance of the distributed ledger technology, the field still lacks major scientific articles. According to Elsevier's Scopus database, the keyword "blockchain" results in only 241 documents (3.5.2017). The more current term for all distributed consensus ledgers and the one I'm preferring, the distributed ledger technology, doesn't give even ten results. Remarkably, more than three quarters of both of these articles were written in 2016 or later. Additionally, as only just over one fifth of these articles concentrates on a finance or business related theme, there is a crying need for additional research to be conducted in this field. This thesis aims to provide an overview of the financial industry's needs and potential for the purpose of future research.

The lack of research has already been stated by Yli-Huumo, Ko, Choi, Park, and Smolander in their article "Where Is Current Research on Blockchain Technology? – A Systematic Review" (2016). Although they took the freedom to exclude all the other papers than those strictly related to computer science, which is the most researched part of the field, there were still enormous gaps in the literature (Yli-Huumo et al., 2016). The findings of the aforementioned study correlate strongly with the current problems the whole technology is facing. These challenges are also the biggest reasons why DLTs haven't already been implemented in the financial industry. The fundamental, technological challenges are the ones that should be more specifically researched. Unfortunately, I'll not be able to provide anything really new on this sector, as it would require a more comprehensive study than a bachelor's thesis.

The market operators of the financial sector have not been significantly faster in recognizing the distributed ledger technologies' potentiality than the scientific community. Prior to January 2015, there were just a couple of investments in distributed ledger technologies, provided by less known players. Since then, however, the scene has changed a lot. Following the hype of Blockchain 2.0 and other than cryptocurrency innovations, every major organization is now included in the competition to be the first one to implement the distributed ledger technology into usage. As Figure 1 shows, the latter part of the year 2015 was the period when the financial industry truly realized the potential this technology possesses. Furthermore, the investments have not been held back, as the chart doesn't even include the R3 consortium of over 40 different banks.

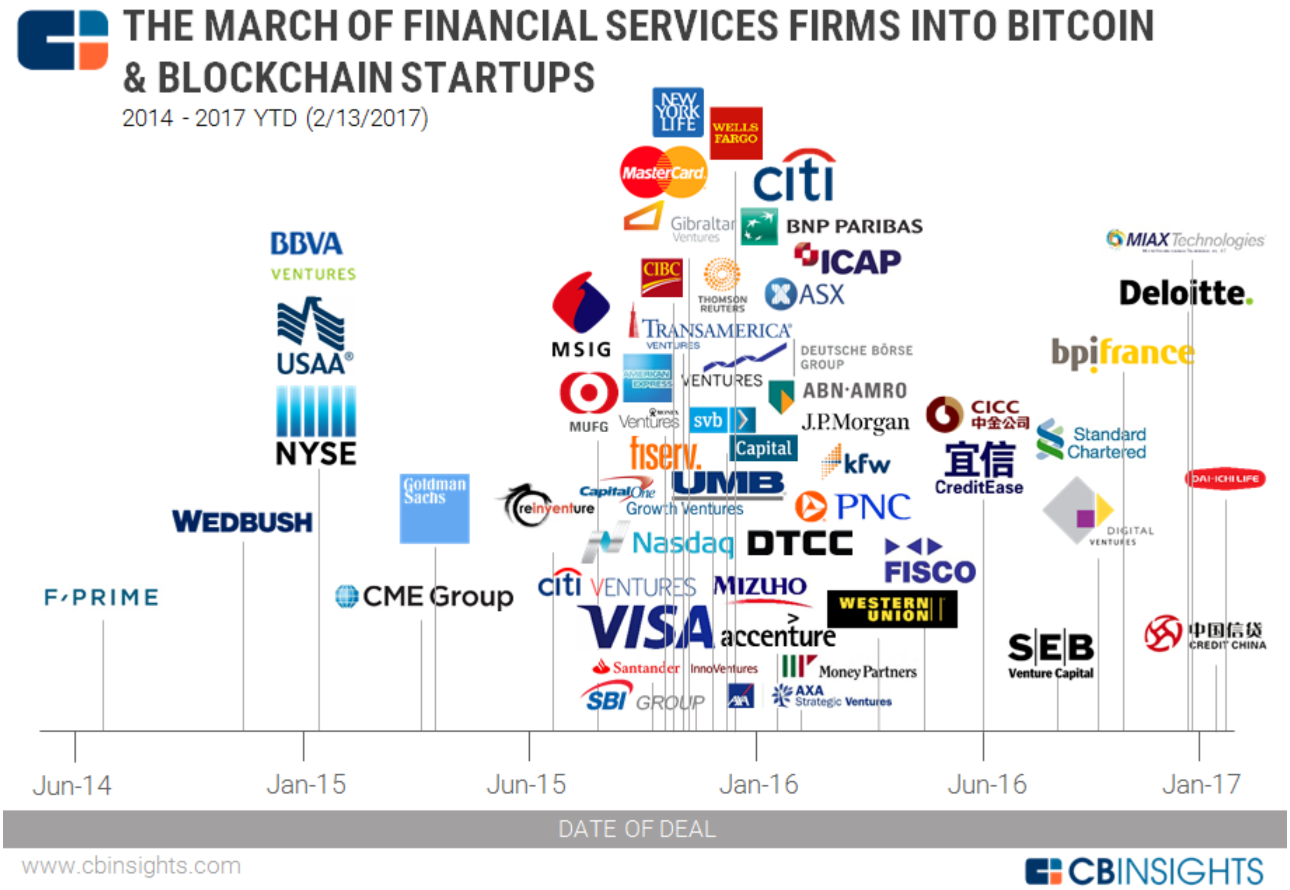

Figure 1. Timeline of investments.

There were just a couple of financial organizations that had invested in DLTs before the later part of year 2015. (CBInsights, 2017).

What is truly intriguing is the fact that the organizations depicted in the figure represent all the possible corners from the financial industry. Although all these potential markets will not be gone through in this thesis, it is worth to remark that the credit card industry, with leading brands such as the American Express, Visa and MasterCard, is investing heavily and Visa even presenting working solutions for business-to-business payments with a startup called Chain (Higgins, 2016). Furthermore, the insurance business is also dubbed as the financial sector to be disrupted (Crosby et al., 2016). As we can see from the figure, insurance companies such as

MSIG and TransAmerica have taken this emerging technology seriously, and invested prominently in it (CBInsights, 2017).

1.4 Research objectives and methodology

The objective of this research is to provide the reader an overview of the distributed ledger technology, its fundamental challenges, the current and potential future uses in the financial industry, and to suggest future fields of the topic to be researched. The first task of this thesis is trying to answer, "how will the distributed ledger technology impact the financial industry". Although the thesis will not cover exhaustively all the financial industry's needs towards the distributed ledger technology, it will give an overview of the DLTs probable usage in the industry. By reading the thesis and especially its use cases from the fields of private equity, and settlement and clearing of public securities' trading, the reader should get a more accurate answer to the secondary question "how can the public securities and private equity markets use distributed ledger technology in the near future".

This thesis will mainly be a literature review. Although it would be interesting to research the technology itself more precisely and hands on, it isn't possible with the available resources to familiarize with the programmable aspects. However, the current literature, consisting of researches, technical white papers and news, offers a sufficient amount of information to conduct a thesis of the current distributed ledger technologies. And, as the financial industry has lately learnt about the disruptive potential this technology possesses, it has started to publish its own studies on this topic too.

1.5 Structure of the thesis

The second chapter will describe the four fundamental features that construct the basis for the distributed ledger technology. The chapter mostly consists of references to the literature, but contains also some reasoning of my own. After this, a reader will be introduced the four widely identified challenges the technology must overcome in order to fulfil its potential. The fourth chapter aims to provide the reader an overlook of potential uses in the financial industry. However, the chapter doesn't cover the industry's needs exhaustively, but instead provides the reader with a slightly different view in comparison to the current literature. The thesis ends with a discussion and conclusions of the true potential the distributed ledger technology could have for the financial industry.

2. Literature review of the distributed ledger technology

As mentioned by van Oerle and Iemmens (2016), there are four fundamental features that, when put together, create the distributed ledger technologies. First, there is the distributed nature of the technology, completely independent of third party intermediaries. Secondly, the cryptographic hashing which creates the consensus of which transactions are verified. Thirdly, "the irreversibility" of the transaction history, enabled by a proofing process. And finally, the choice between permissioned or permissionless ledger, which defines much of the privacy. Although these are the major features of technology behind almost every current distributed ledger technology, a majority of these concepts were invented for different usages before the first blockchain behind Bitcoin. The truly revolutionary aspect of Nakamoto's white paper was the way it introduced these different technologies to be combined (Mattila, 2016).

2.1 Distributed nature

The first, and possibly the biggest difference the distributed ledger technologies have with other value-transferring enabling services is that they are not dependent on one, centralized and trusted intermediary (Nakamoto, 2008; Kotilainen, 2017). In fact, the first distributed ledger, the blockchain running under Bitcoin, was initially introduced as a service technology enabling peer-to-peer –transactions, which would make the trust-creating third parties redundant (Nakamoto, 2008). The reason why the distributed nature of the blockchain was and still is revolutionizing, is that it eliminates the possible disturbance of the central actor, which would affect all the transactions occurring. The single point of failures could be intentional, such as corruption or criminal actions, or unintentional, such as global economic shocks. So, although the intermediating third parties, for example banks, are designed to be trusted and function under stressful events, they are vulnerable, especially to things not related to them, and therefore not able to maintain trust in all conditions.

As the intermediaries always have numerous vulnerable features and risks that need to be covered by regulation and other intermediaries, such as supervisors, there is certainly room for some other possible way to process the transactions. The solution offered by distributed ledger technologies is that there is an unlimited amount of copies of the transaction history, distributed constantly to all "nodes", that are the different actors taking part in the ledger, so that everyone has access to the same information all the time (Fridlmaier et al., 2016). The reality of having as many copies of past and present transactions as there are nodes limits the possibility of history being changed or deleted close to zero, as there is always consensus of the real version of the transactions available (Mattila, 2016). It also strengthens the community, be it small and local, or big and global, against potential intentional or unintentional disturbance, as the data is protected by every node (Fridlmaier et al., 2016).

In the distributed ledger model the acceptance of transactions is very different compared to the intermediary-model. While the central party can accept transactions as it likes, the majority of the community holding copies of a distributed ledger must reach a consensus if the transaction can occur or not (Crosby et al., 2016). However, this is not as difficult as it might seem, as all the nodes, which have identical copies of past, are almost simultaneously offered the newest proposals to be accepted (Nakamoto, 2008). Therefore, the decision of accepting the transaction or not is already done when the transactions is occurring, as the consensus is reached simultaneously: every party knows whether the value was owned by the party which eventually tries to spend it. But how to be certain that the consensus of past is not being modified afterwards?

2.2 Cryptographic hashing

The distribution of data to all the participants does not itself create trust, but the ownership of assets and tracking of it must be secured from tampering. If the past and accepted transactions could be deleted or modified, there would be no way to know who truly has the ownership of the asset, and the trust has disappeared. So, merely distributing the data is not enough to create trust, but the distributed ledger technologies need to use cryptographic ways to ensure that the past remains unchanged (Nakamoto, 2008). This is where the hash function and the hash values are introduced.

In order to link the past data of ownership to the present transactions, distributed ledgers rely on hash functions creating hash values of certain size. A pool of transactions that have occurred recently, at roughly the same time, are gathered together, to create a block. The information carried by these transactions is then driven through an algorithm that finds the unique hash value for that certain source of data (van Oerle and Iemmens, 2016). This hash value is then "the time-stamp" of the block of transactions. The following block will again gather certain amount of transactions together, but this time also the hash value of the previous block is taken into account. This is illustrated in Figure 2: the block's hash contains also the previous block's hash. This is how the blocks create a chain, in which one block has a reference to all the previous blocks. (Nakamoto, 2008)

The trust created by this hashing is mathematical. If someone could alter the previous transactions, it would change the information included in that certain block, and neither its hash nor the following blocks' hashes would match anymore. (van Oerle and Iemmens, 2016) Hash functions create values that can be reached with only certain input: when making even a minor change to the input of a hash function, the hash value created is completely different from the former hash value. It is also impossible to reach the same hash value with two completely different inputs. These aspects make the hashing a valid way to time-stamp transactions. (HKMA, 2016) Additionally, hashes do not reveal the information underneath them (Peters and Panay, 2015; van Oerle and Iemmens., 2016). By hashing the information, the ledger simultaneously decreases the size of the blocks, and also increases privacy while not giving up of any security.

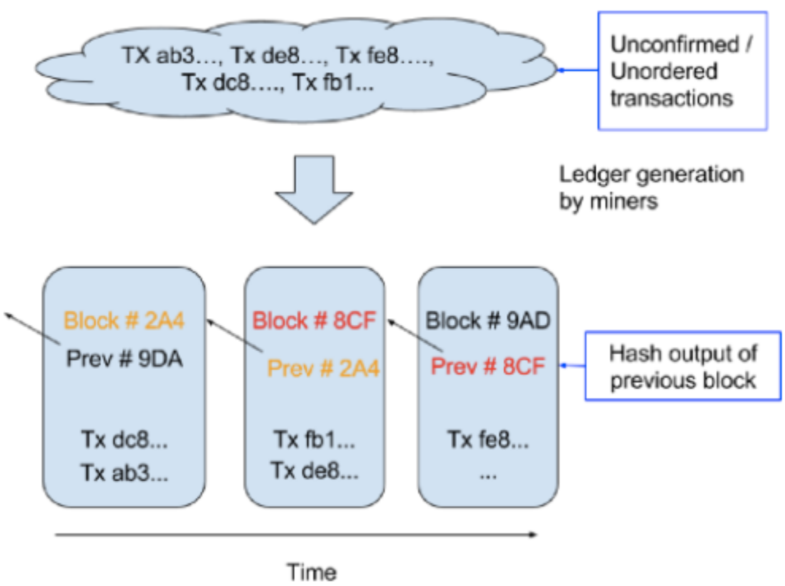

Figure 2. From transactions to verified blocks.
Hashing of the block is defined by the information it contains and the previous block's hash (Crosby et al., 2016).

2.3 Irreversibility by Proof-of-Work or Proof-of-Stake

The hashing process described in the previous chapter is still not trustworthy enough to work. What if there were hostile parties trying to get an approval for transactions that would steal assets from other peers? These parties could create blocks of invalid transactions with valid hashes at the same time with other peers, and no-one could be certain of the order of the transactions, and thus possibly validate double-spending (Crosby et al., 2016). By applying proof-of-work, or proof-of-stake, all the parties can be certain that the blocks already in the chain, and the ones that are attached to it, are the ones including only accepted transactions (Nakamoto, 2008).

In Bitcoin's solution, the verification system used is proof-of-work. It is also essential if the hashing is wanted to work "on a peer-to-peer basis". (Nakamoto, 2008) The hash function described before was made hard to solve, in a way that the hash needed for a new block could be reached only by hard, computational work and a bit of luck. If one is willing to add the next block to the already-validated chain, the user needs to compete against other users trying to do the same. The fastest peer to solve the hash for the selected transactions is rewarded, and the block is distributed to all to be validated. Once it is verified that the block includes only legit transactions, the block is attached to the longest chain, which includes only blocks having gone through similar proof-of-work –process. Then the competition to find the next hash for pending transactions will begin again using the previous block's hash to find it. (Nakamoto, 2008)

The perk of proof-of-work is the safety it creates: it is mathematically impossible that false transactions get an approval if the hostile party is not controlling more the 50% of the computational power of the ledger community (Peters and Panay, 2015; Lee, 2016). If the historical transactions were tampered by a hostile party, the same party has then to change all the following blocks' hashes for the modified history to have matching hashes (Nakamoto, 2008). All this should be done at the same time when the rest of the parties, and their computational power, are solving new hashes for new blocks, and lengthening the chain. To get the tampered blocks accepted, the hostile party should control more computational power than the rest of the peers together in order to solve hashes faster, and thus create a longer, and more proof-of-work –including chain. That is why this kind of an attack is called "the 51% attack": more than half of the computational power is needed to solve mathematical problems faster than the rest of the users. (Lee, 2016)

Although the original distributed ledger technologies were using the proof-of-work, the newest innovation that the ledgers are now introducing is the proof-of-stake as the technology with which the consensus is reached (Gupta, 2017). The proof-of-stake can refer to the stake of computational power, to the stake of assets or some combination of these, or to the respectability of the peer in the community (Pilkington, 2016; Pinna and Ruttenberg, 2016). The permission to create the next block is given to the peer having certain stake of something. The perk of proof-of-stake is that although one party would control all the computational power and ability to create hashes, it is not worth to start acting maliciously. Validating double-spending or other hostile actions would only lead to a slump of the value of the assets, as other peers could not trust the ledger any more. This leads to the monopoly-validator acting decently and only validating acceptable, unbiased transactions. (van Oerle and Iemmens, 2016)

2.4 Permissioned or Permissionless?

The final characteristic of distributed ledgers is the way users are allowed to act on the chain (van Oerle and Iemmens, 2016). Although most of the ledgers to this day have been permissionless and public, which truly enable anyone to transfer assets to any other peer on the chain, there is a huge demand for permissioned and private ledgers. When it comes to accessing the ledger, the division of distributed ledger technologies is the following: there are permissioned (or restricted) and permissionless (or unrestricted) ledgers, which can be public or private. Permissioned ledgers allow only known parties to access and act on the ledger, while permissionless ledgers are open to everyone. Publicness of a ledger refers to the privacy: whether outsiders are allowed to see the transaction history or not. (Pinna and Ruttenberg, 2016; Peters and Panayi, 2016)

The most famous permissionless, public ledger is undoubtedly the Bitcoin's blockchain (HKMA, 2016). Anyone who owns a wallet and masters its keys can transfer bitcoins (Nakamoto, 2008). The perk of this kind of a ledger is that it is truly peer-to-peer, computationally trust-creating way to transfer value in the internet to anyone. This enables new kind of markets and transactions, and certainly threatens many "third parties" acting as intermediaries, as people could be able to operate peer-to-peer (MacDonald et al., 2016). Most of these distributed ledger technologies are seen as disruptive ways to interact, transfer value and trust people. Despite their enormous potentiality, the next chapter will go through some problems this kind of open ledgers have faced.

The permissioned ledgers may not have the same, disruptive potentialities as the permissionless' ones have, but they do possess market-changing value in numerous cases in the financial industry. Actors of these ledgers somewhat know each other in the real life, which, more or less, guarantees that there are no hostile or malicious peers in the community. This creates a little trust in the first hand, compared to the starting position of no trust at all in the permissionless ledgers. (Peters and Panayi, 2016) The parties on permissioned ledgers do not necessarily need to be anonymous, and can have computationally relatively simple way to reach consensus, allowing the parties to avoid some of the largest challenges that proof-of-work and proof-of-stake bring (Mattila, 2016). This kind of ledgers are the ones that could be implemented in between some of the biggest actors in the financial industry, such as banks, exchanges and clearing houses.

Even though the blockchain is often referred to or hyped as the technology that changes everything, there are numerous, more traditional than peer-to-peer markets in the financial industry in which DLTs with permissioned usage would create tremendous value (van Oerle and Iemmens, 2016). Chapter 4 of this thesis this thesis will go through some use-cases, both permissionless and permissioned, to show that both types do have their ideal niches of exploiting. The division is roughly that with public, permissionless ledgers the creators pursue for entirely new ways of carrying out trust-requiring transactions, while the permissioned ledgers are mainly built to substantially enhance the current way of an organization's or a consortium's work.

3. Challenges and restrictions of distributed ledger technologies

The following part of this thesis will describe briefly the four widely referred challenges that are characteristic for distributed ledger technologies. Although all of the following troubles have been solved in different ways in different ledgers, we are still lacking a technology that has a viable solution to all the following issues. There are of course numerous other challenges when applying DLTs into practice in the financial industry, but these four are the challenges that need to be solved before the distributed ledger technologies can be taken into widespread usage.

3.1 Cost of computation

The cost of computation is an issue even Bitcoin is wrestling with. As described previously, proof-of-work is a great innovation when it comes to securing the past data: it only relies on computing and mathematics, and does not need a costly third party to validate and guard the data. But, the opportunity cost for this is the rising need for computing power, which itself is by no means cheap (Mattila, 2016). The energy consumed annually to keep Bitcoin's blockchain verified is estimated to be in the region of $400 million (Aste, 2016).

To answer the growing cost of computation, there has emerged big "computing pools" to run the proof-of-work –process in Bitcoin. Although the cryptocurrency was initially meant to be run by individual nodes and computers, private consumers cannot afford to compete against these large operators. (Prisco, 2015) The energy consumption and its ineffective cost-structure makes the otherwise great technology an inefficient way to compute the transactions in the financial industry. Although there are other ways of validating and securing the past data, the proof-of-work has emerged as the most reliable way, as proof-of-stake has been found to be extremely vulnerable (BitFury Group, 2015). However, for distributed ledgers to reach widespread usage, the cost of computing cannot be on this high a level.

3.2 Scalability

Global financial players, such as Visa, handle from thousands to tens of thousands of transactions per second (Croman et al., 2016). When compared to the biggest distributed ledger technologies, the numbers in the financial industry are manyfold. For example, Bitcoin's blockchain, and its proof-of-work, can handle only less than ten transactions per second (Croman et al., 2016). This difference in between existing distributed ledgers' and current financial markets' amount of transactions handled is vast. Distributed ledgers are restricted by the block's maximum size and by the interval of forming blocks (IDRBT, 2017). Increasing the size of the block or decreasing the time in between forming blocks are effective, but still insufficient ways to achieve satisfyingly scaled ledgers for the financial industry's needs (Croman et al., 2016).

Another problem faced by current, permissionless distributed ledgers is the need of spreading the data to everyone. Although also a privacy issue, if the users are private consumers, it can be demanding to store the whole history of the given ledger. (Peters and Panayi, 2016) This may become a huge restriction for public and permissionless ledgers, as the current size of Bitcoin's history has exceeded 100 GB (Blockchain.info, 2017). Although there are suggestions of decreasing the space a block's hash would take up, a more suitable solution would base on an algorithm that continuously computes the required degree of distribution to keep the space required on a hard drive and the security in balance.

3.3 Legislation and regulation

While originally developed to be able to work without regulation and under no supervision, if the distributed ledger technologies are applied to the financial industry they will be facing scrutiny and constraints from regulators (Pinna and Ruttenberg, 2016). In the world of constantly increasing and tightening regulations for banking and other financial areas, distributed ledgers will not be permitted any exceptions. According to HKMA's report (2016), regulation of DLTs is an area which lacks a lot of actions. Data privacy will be a major issue in both permissioned and permissionless ledgers: for what degree is information visible to all participants, or are certain users restricted by regulators (IDRBT, 2017)? Who will, or will anyone, oversee completely decentralized, permissionless ledgers? What if the past transactions need to be altered: is that permitted, and how is the consensus of this reached in permissionless ledgers? These are only some of the questions the DLTs will face before a global usage, that are not going to be answered in this thesis but only mentioned just to highlight the current lack of distributed ledger technologies' legislation and regulation. The critical questions of who is going to regulate, what actions are going to be regulated and how will they be regulated are still not answered anywhere (HKMA, 2016).

3.4 Security and privacy

With every new technology, there comes new threats of security breaches. This is not different with distributed ledger technologies, which rely on strong cryptography and a lot of potentially globally distributed computing power. Depending on whether the ledger is permissioned or permissionless, there are different major challenges for security of the ledger. Also, the privacy of ledgers is an issue to keep an eye on: how to simultaneously keep the personal information secured and private, but not to give money launderers and other hostile parties a possibility to evade regulation?

Some of the potential security threats have already been mentioned in this thesis. For the permissionless ledgers, the threat of the 51% attack is significant, as there may exist a couple of major computing pools. If they were to turn out to be hostile and work together, the rest of the actors on the ledger could do nothing for the majority accepting their own transactions. (Lee, 2016) A permissionless ledger could also be slowed down by a distributed denial of service (DDoS) type of an attack, which aims to make the nodes overloaded and thus prevent the ledger from recording transactions at its usual pace (HKMA, 2016). Figure 3 further illustrates such an attack.

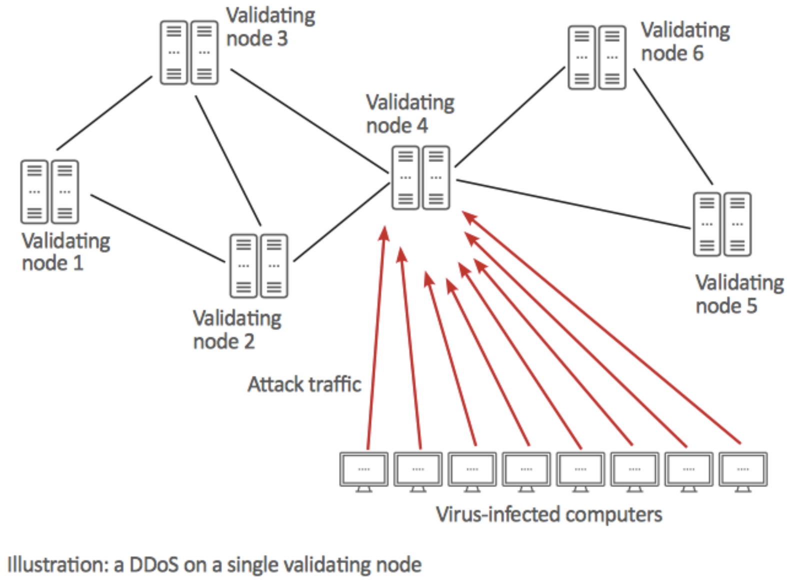

Figure 3. Distributed denial of service.
Illustration of the distributed denial of service attack on a single validating node, which prevents the nodes 5 and 6 to contact the rest of the nodes (HKMA, 2016).

When it comes to permissioned ledgers, the challenges are mainly technological. The threat of a DDoS attack is always possible, which could also lead to infecting all the ledgers' computers and thus slow down the whole system. The importance of securing systems and computers on a permitted ledger is something that should be handled even before new nodes are added. (HKMA, 2016) It should also be noted that the permissioned, private ledgers' information are visible only to those nodes that need to see them. Even though we are talking about different banks or other trusted parties in the current financial industry, it would not be necessary to distribute every bit of information to everyone. (BIS, 2017)

Privacy issues are extremely difficult on permissionless ledgers, as they need balancing the nodes' privacy and the regulator's demand to have transparency on transactions. Permissioned ledgers are obviously a better solution to this problem, as they might have a regulator-node checking the required information. (HKMA, 2016) And, although in both ledger types the nodes would like the transaction data to be visible only to those transacting, the regulator will always need an access to monitor the market. In permissioned ledgers, there can be nodes with varying roles, which would authorize also the regulator to perform individually. (IDRBT, 2017)

However, this is a major threat for the permissionless ledgers in financial industry, as the current technology does not offer any solution for this problem.

4. Introduction of use cases from the financial industry

The following part will go through potential and already established use cases of distributed ledger technologies from the financial industry. Although for example global trade financing and cross-border business-to-business and peer-to-peer payments are dubbed to be the fields that will certainly benefit from the consensus ledger technologies (World Economic Forum, 2016; McKinsey&Company, 2017; Tapscott and Tapscott, 2017), they will not be further introduced in this thesis. The reason is that these two areas, together with another huge field insurance business, have already attracted so much attention and coverage in the literature and media that it is not necessary to go through them in here again more specifically. The areas chosen for this thesis represent very different markets: the first one would benefit a lot from permissioned, private ledgers, which would decrease costs tremendously. The second one, however, is a more fragmented market: it could be even disrupted and not just enhanced by applying a fitting distributed ledger model. More significantly, there is even an opportunity to create a completely new, permissionless peer-to-peer market.

4.1 Clearing and settlement

Clearing and settlement refers to the publicly traded securities post-trade process. Although the initial transaction may occur almost simultaneously for the individual investor, it takes tremendous amount of work from multiple intermediaries to eventually trade the security and the payment securely to the different sides of the deal.

4.1.1 The current situation and its challenges

The current publicly traded securities' post-trade clearing and settlement market is a complicated world. As depicted in Figure 4, it consists of global and regional actors, including custodian banks, investors, brokers, central securities' depositories, central clearing counterparties and exchanges (World Economic Forum, 2016; Pinna and Ruttenberg, 2016). The whole process from the actual trade to its settlement takes usually from two to three days with ordinary securities, such as stocks or bonds, and with more complicated ones, such as credit default swaps or leveraged loans, even a couple of weeks (Investopedia, 2017a; Robinson and Leising, 2015). Although the investor is usually unaware of his or her trade not completed, the interim period represents a risk of the security not registered correctly. There is a little the investor can do to this risk but hope it does not materialize.

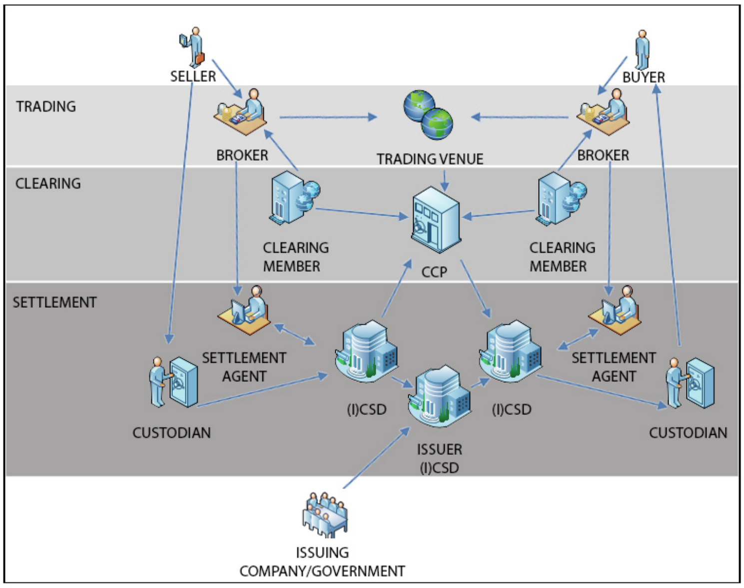

Figure 4. Securities' post-trade market.
Publicly traded securities' post-trade process requires several organizations working seamlessly together. (Pinna and Ruttenberg, 2016).

Although trading and matching sellers and buyers is highly automatized, the clearing and settlement processes require exceptional amounts of manual work from intermediaries' back-offices. During high demand for trading, it is possible that one, central partner is overloaded with transaction clearing requirements (Van de Velde et al., 2016). This leads to a counterparty risk mentioned in World Economic Forum's (2016) report: the settlement may not occur, which may even lead to a trade not occurring. This is a risk for banks and their back-offices, as they are required to wait for the confirmation of the traded asset's settlement until it can be finally registered for an investor.

Even if the central securities' depository is not overly tasked and is able to begin the clearing process of the transaction by matching the buyer and seller sides' trade details, there is a risk of inconsistent data (World Economic Forum, 2016). Being in connection with all the custodian banks who should be providing the transaction details, the possibility of some party giving false details of the trade to the central securities' depository is considerable. The current process is thus highly manual, and therefore risky. The trading details include the timing of the trade, cash involved in the trade and bank details of the trade's counterparties. According to World Economic Forum (2016), especially "frequent changes to counterparty bank details" is a weakness in the current clearing and settlement environment.

The entity carrying the credit risk of a transaction's different counterparties during the settling is the central clearing counterparty. These organizations lie in between the custodian banks of the buyer and the seller, acting as a party which simultaneously transfers equity and cash to opposite banks. However, there is an operational risk of technological and manual errors when executing these swaps. To increase efficiency, central clearing counterparties usually try to involve all the similar trades into a one "net transaction" to keep the amount of transactions lower, which also further decreases the risk of error occurring. (World Economic Forum, 2016) This still does not remove the risk of the central clearing counterparty failing to materialize the trade through a manual error.

4.1.2 Distributed ledger technologies' possible improvements

Clearing and settlement of securities is one of the biggest areas in which the distributed ledger technologies are expected to prove to be disruptive. The possibility of all the different counterparties reaching simultaneously consensus on a certain transaction, the reduction of manual work through smart contracts, and dividing the risk and pressure away from single, central counterparty reduce risk tremendously (Mills et al., 2016). This leads to decreased time and even real-time settling, and also makes matching and detail-sending back and forth done in the back-offices redundant (Van de Velde et al., 2016). According to Accenture's report (2017), exploiting distributed ledger technologies into clearing and settlement could lead to even 50% reduction of expenses. However, whether the DLTs will be used only within some single party or across the whole post-trade industry defines significantly the industry's cost-reductions.

The interim period in between the trade's actual time of occurring and the finishing of its settling can be decreased. The potential of near real-time settling is there: it is possible to manage the security side of the transaction using distributed ledger technology. The current restriction of real-time settling is the cash side of trade and its settling using distributed ledger technology, as it would require national currencies traded in digitalized form. (Pinna and Ruttenberg, 2016) Currently, the simultaneous exchange of the security and cash is reached by TARGET2-Securities in Europe, which is a central-bank backed system providing funds for trades to be settled as they happen (ECB, 2016) To bypass the current system, traditional currencies should be tradeable in distributed ledgers. Luckily for the progress there are numerous central banks all over the world researching how they can take advantage of this emerging technology (Wild, 2016). One of the most progressive nations in this field has been Poland, which already has its own, zloty-backed cryptocurrency (van Oerle and Iemmens, 2016).

The counterparty risk described in the previous section is something more challenging for the distributed ledgers. Current, blockchain-like DLTs are not especially efficient when there is a huge amount of transactions occurring (IDRBT, 2017). However, smart contracts enabled by the exploitation of distributed ledgers is a partial solution so the above-mentioned risk. The possibility to fully automatize the validation of a transaction can be achieved by strict conditions, and thus reducing the risk the custodian banks face when waiting for central securities depository to validate the transaction (Pinna and Ruttenberg, 2016). The original formation of Bitcoin's blockchain may not be efficient enough for wider exploitation and there are numerous projects and startups trying to defeat the scalability problems.

The simultaneous distribution of data through DLTs provides a solution for the risk of invalid data. (Pinna and Ruttenberg, 2016) When the requirements for the data are standardized, custodian banks can share their part of the transaction details easily to the other counterparties. Moreover, the ledger keeps all the parties updated, which further decreases the risk of data being erroneous. (Pinna and Ruttenberg, 2016) The increased transparency eases also the regulator's job, as it would be easier to monitor numerous assets and their details' correctness at a glance (van Oerle and Iemmens, 2016). As some manual work cannot be reduced just by exploiting distributed ledgers, there is of course a need for someone in the back-office to enter the details in the first place.

The central clearing counterparties' business model and the whole settling process is threatened by smart contracts of the ledger. To minimize the operational risk during this section, the settlement could be done by letting the smart contracts act programmed, and thus independently take care of trading the cash side to seller and the security to the buyer. The more the financial markets could lean on to smart contracts, the less there would be operational risks of manual errors. (World Economic Forum, 2016) There is also a possibility that the central clearing counterparties' roles in common securities settling vanishes completely. This would require a very transparent ledger, in which the counterparties are aware of the others' possessions, and therefore can settle instantly. (Van de Velde et al., 2016) However, whether the risk-decreasing benefits of “net transactions” during the settlement can be achieved without the clearing counterparties remains to be seen, as there is no consensus of this (World Economic Forum, 2016; Van de Velde et al., 2016).

To conclude, there still remains many aspects to be improved in order to the distributed ledgers become suitable to be used in clearing and settlement of trading. The current technology cannot process the vast amount of trades occurring in the securities markets throughout the world. Additionally, the lack of a trusted, central bank backed cryptocurrency which could be used in the cash leg of trading is also a big obstacle for the distributed ledgers to become globally exploited. However, as already mentioned, there is a growing need for clearing and settlement to match the more technologically progressive trading market’s efficiency (IDRBT, 2017). And as more and more central banks are researching the field of fiat cryptocurrency, the securities’ post-trade market is certainly willing to exploit distributed ledger technologies in the near future.

4.2 Private equity investing

Private equity investing refers to capital investments made directly to non-listed companies in an exchange for a stake of the firm (Investopedia, 2017b). It differs quite substantially from the public trading of securities which was introduced earlier. Typically, the market consists of small businesses seeking for a rapid growth, and institutional investors, such as venture capital firms, angle investors and pension funds (BVCA, 2010). The value of this market is enormous: in year 2016, the amount of managed assets came close to exceeding $2,5 trillion (Preqin, 2017). Nowadays, private equity companies are increasingly interested in investing to the distributed ledger technology too: venture capital investments in the technology were almost $500 million in 2016, and the cumulative investments over the years have exceeded $1,5 billion (CoinDesk, 2017).

Despite the size of the market, there are only a few parties which can operate there. To start with the investor side, an individual consumer is not able to take part in almost any private equity deal as the typical minimum deal size is north of $250.000 (Lambert, 2017). Only initial public offerings, IPOs, are partially open for the individual investors. The situation is equally challenging for small businesses not looking to grow aggressively: the private equity investors are typically looking for higher returns than they would be getting from the public equity trading

(BVCA, 2010). This leaves most of the small businesses depend on debt-financing, which has its own risks.

The private equity market is not that attractive for the private equity companies either. A huge risk is that the initial investment never even sees any profit, as the only viable ways to get return are through an IPO, merger or acquisition, or sale of the company (Lamarque, 2016). The lack of liquidation possibilities is down to the fact that there are not any marketplaces for these equity stakes of a growing company. The risk for the investor has also increased by time, as companies prefer to stay private longer than before (TrueBridge Capital, 2015) Additionally, private equity markets are lacking information. An investor is not able to gather data of the investment, as these companies are usually not required to release their financial information. (Berger and Udell, 1998) The transparency issue is still relevant even though some data may be available through researches (Berger and Udell, 1998; Lamarque, 2016)

Lastly, the initial public offering, which is the final private equity issuance before a company's shares start to trade publically, is quite an expensive way to acquire capital (Lamarque, 2016). The IPO cost for the company is usually in the region of 5% of its post-IPO valuation (Ritter, 2014). There are numerous phases which increase the cost before the stock can be issued. The whole process includes several intermediaries, including investment banks, management consultants and lawyers, who all are taking their stakes and therefore causing "friction costs" (Lamarque, 2016). Although the post-IPO trading of the stocks is quite efficiently executed in exchanges as mentioned earlier, the IPO process itself requires significant amount of development.

4.2.1 Use cases from Nasdaq and IBM

As the problems described above are widely acknowledged, there have already emerged some potential, though still quite simple solutions. Both services this thesis covers are trying to solve the illiquidity problem the private equity has, but to also enhance the market's lack of information. What is important with these use cases is that the regulators could get to monitor and investigate them much better than some theory says (Shin, 2017; IBM, 2017). Although these two would not be the eventual services for the private equity market, at least they are valuable in a pioneering way.

In December 2015, Nasdaq and a startup called Chain announced their common project called Linq (Nasdaq, 2015). Linq was the first distributed ledger –backed private equity platform for growth companies seeking to keep track of their equity shareholders transparently. The permissioned ledger instantly attracted six startups to issue their equity there. Since the platform is still just in the testing phase, it does not allow peer-to-peer transactions. However, the platform still simplifies the process of issuing shares privately, and also tracks information of the company's current valuation and owner base. (Rizzo, 2015) Remarkably, Linq can execute the whole issuance of private shares, from trades to the settlement and clearing of them. It enables businesses a much lower, and more transparent way of acquiring private equity.

The second use case this thesis is introducing is developed by IBM and Northern Trust, emphasizing the private equity fund's management. Trading the limited partners' stakes should be substantially more efficient than nowadays, as the current process is heavily reliant on manual work. (IBM, 2017; Irrera, 2017) The ledger eases the management by providing the trust that is currently created by tens of fund managers and lawyers. This not only decreases time and work spent tremendously, but simultaneously releases more funds to be invested. And, as the private equity is not traded in the same volumes as the publicly listed securities, current distributed ledger technology solutions are able to manage the task. (Del Castillo, 2017) IBM and Northern Trust's distributed ledger solves partially the illiquidity and transparency problems the private equity investors face. Next, this thesis will introduce potentially an even more disruptive way to execute private equity trading.

4.2.2 Initial coin offering

Initial coin offering, ICO, is a crypto-equity issuance, in which the company issues "tokens" that represent a piece of the company's equity, much like shares are issued in IPOs. The token is priced by the company to represent its current value, and then sold on a marketplace built on a distributed ledger platform such as Ethereum. (Kastelein, 2017) To call the token a stake of the company or equity is probably misleading: the whole initial coin offering business is legally completely on a grey area of the financial industry (Lundy et al., n.d.). The idea is still highly similar to the equity crowdfunding, executed just completely without intermediaries and using cryptocurrencies (Kastelein, 2017).

What makes initial coin offerings intriguing is not the size of its market: it represents just less than 1% of the whole crowdfunding market (Lundy et al., n.d.). However, the interesting thing is the size of these ICOs: some of the latest ones are comparable in size to “Series B financing round” (Laurent, 2017). This has alerted some more traditional private equity market actors, such as venture capital funds, to invest in them. As the traditionally high-profit-earning funds are facing decreasing returns, ICO tokens’ valuations were gaining even hundreds of percentages during 2016. Additionally, these tokens offer the venture capitalists great liquidity compared to the traditional private equity investments, as the tokens could be traded back to fiat backed currency. (Kastelein, 2017) One venture capital fund has even acquired capital to its newest fund by issuing a token, which provides the investor a piece of the funds profits (Laurent, 2017).

Although the ICO market is quite tiny compared to any other private equity market, and the tokens are under increasing scrutiny from regulators, the initial coin offering could prove to be an answer to the illiquidity problem in private equity markets (Lundy et al., n.d.). At least the model should be increasingly researched, as it could provide relatively cheap financing just from the traditional investors, but also from the individual investors for the early-stage companies (Tapscott and Tapscott, 2017). Initial coin offerings could also be linked to a distributed ledger backed exchange, where the tokens could be traded in a regulated environment, just like IPO-issued shares are traded in an exchange. Although it is not even certain whether the ICOs are here to stay, their functionalities should be considered when further designing and developing future distributed ledger applications for the financial industry.

5. Conclusions

This thesis has introduced the distributed ledger technology and the hype around its impact on the financial industry to the reader. The second chapter familiarized the reader with the four fundamental features which have so far been the corner stones for every ledger. These technological bricks are the distributed nature, cryptographic hashing, proofing process and the question about the ledger’s openness to the users (van Oerle and Iemmens, 2016). Although each feature has its challenges which need to be defeated, distributed ledgers are already in quite wide usage in the form of Bitcoin and Ethereum.

However, this thesis was not just aimed to explain the distributed ledger’s functioning. This thesis was written in order to find an answer to the two questions defined in the introduction.

The first task, and simultaneously the primary one, was to question the impact the distributed ledger technologies will have on the financial industry. Additionally, the secondary question was targeted to find out about the concrete changes the DLTs will have on both the public securities' post-trade market, and the private equity market. And, as the fourth chapter pointed out, both markets will face significant changes during the upcoming years: public securities' post-trade processes will benefit from the more secure and rapid settlement, whereas the private equity market's whole nature can become a more accessible for both the investors and the businesses seeking for financing.

The question about the distributed ledger technology's impact on the whole market is complicated. Although the easy answer would be to either live by the hype surrounding the conversation and suggest the DLTs will change everything, or on the contrary not to believe in its disruptive potential and to suggest the whole technology is just a passing fad in the age of fintech, it is hard to ignore two facts. The first fact is the ever-increasing amount of financing to the distributed ledger technology and to the teams researching its suitability to almost every current and future financial industry's problem (CBInsights, 2017; CoinDesk, 2017). Although initially the industry did not react to DLTs' potentiality, it has now turned its approach round. Every major player has now its own project, or is co-operating with other organizations to find a way to disrupt the current state of the financial industry with the DLTs.

However, the second fact is that there are no low-hanging fruits in the financial industry when it comes to the DLT. Although Bitcoin and Ethereum are quite widely recognized, their impact on the financial industry is very limited. The innovations potentially disrupting the current market are not easily reachable: there are significant restrictions for example in the technology's scalability, and regulation (IDRBT, 2017). There are no easy solutions which could completely change the nature of the current business when implemented, otherwise this thesis would have pointed them out.

The greatest impact the distributive ledger technologies will have on the financial industry is that they will make the industry's operations much more effective and secure. Although the current third-parties will not probably cease to exist, the DLTs will significantly reduce the manual work needed in the back-offices all over the different markets. The literature, and the majority of the market operators, seem to believe that the financial industry could adopt the DLTs into different global usages during the next five years. Additionally, it is expectable that during the same time frame, individual consumers will be offered practical, possibly disruptive ledger technologies with which they can manage their personal, both day-to-day and long-term-investment, financial issues without a traditional intermediary. As Bitcoin and Ethereum have shown us, the technology can be adopted in every-day life. The financial industry will almost certainly face competition from outside its traditional players.

As a suggestion for future research, the distributed ledger technology offers possibilities almost endlessly. Ignoring now all the other industries, the financial industry suffers widely from the lack of trust. The reason for this being whatever it is, the situation offers an opportunity for the future research to find out suitable computationally trustful solutions basing on the DLT. As Yli-Huumo et al. (2016) found out in their study, the lack of technical research in this field is immense. Therefore, the demand for more technical studies in the financial industry is clearly substantial. Hopefully this thesis can serve as an inspiring first step for the future research to further study and develop DLT –based solutions for the financial industry.

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