Exploring Supply Chain Blockchain Potential in the Pharmaceutical Industry

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Abstract

This study analyses blockchain technology with respect to its advantages and limitations as well as its application in the context of pharmaceutical supply chains. A qualitative analysis was conducted among employees of a pharmaceutical company belonging to the Big Pharma. The analysis was performed using semi-constructed interviews aiming to draw conclusions about possible applications of the blockchain technology in the pharmaceutical supply chain, the solutions that it could provide and the readiness of the industry to adapt this technology. The results showed that the current supply chain technologies and systems, despite their usefulness, have some significant disadvantages that can be addressed by blockchain technology. Furthermore, it was noted that blockchain is a well-known technology to the central management team of the company that pinpointed as main advantages privacy, security, traceability, and anti-counterfeiting of medicine. The innovative technology is expected to change the industry and could be applied effectively in the pharmaceutical supply chain operations due to the great advantages that it can provide to the stakeholders involved. Finally, the readiness of the pharmaceutical industry to embrace blockchain technology was found to depend on each company's willingness to invest money on contemporary supply chain technologies.

Keywords
Supply Chain, Blockchain, Pharmaceutical Sector, Innovation, Case Study.

1. Introduction

In the past years, the attempt of the advanced digitalization of production systems led to a new shift in the industry and a fourth Industrial revolution, also named Industry 4.0 (Lasi et al., 2014). Researchers and practitioners have realized its undeniable benefits, such as provision of companies with successful business models, higher quality and efficiency and better working environment (Bai et al., 2020; Mangina et al., 2020). The concept of Industry 4.0 includes several interconnected technology tools for the improvement of the supply chains and the implementation of a digital solutions, which could gradually replace some of the traditional approaches. LeMay et al. (2017) suggested the following definition for supply chain management (SCM): *"Supply chain management is the design and coordination of a network through which organizations and individuals get, use, deliver, and dispose of material goods; acquire and distribute services; and make their offerings available to markets, customers, and clients."*. Nowadays, the constant rising of competition requires innovative technologies and processes in order for a firm to develop and sustain its competitive advantage to remain profitable. The advantages of the coordination in a SC include the avoidance of the bullwhip effect, the decrease of inventories along the SC, the increase of the efficiency of the activities in the SC, the achievement of a certain level of quality along the SC and building trust among SC partners (Vlachos and Bourlakis, 2006; Zaridis et al., 2021; Singh, 2015).

Blockchain technology is an innovative technology which was introduced through the cryptocurrency "Bitcoin", which is a peer-to-peer electronic payment system (Nakamoto, 2008). A blockchain consists of cryptographically interconnected data, called blocks which are combined and form a chain. Blockchain technology includes a shared database of public or private ledgers of all the transactions/activities that have been carried out and shared between the blockchain members (Saberi et al., 2019; Hughes et al., 2019). The application of blockchain technology in SCs has already been tried in some industries and is a very promising technology because of its undeniable advantages such as traceability, security, privacy, and transparency. Especially in the pharmaceutical industry the technology could contribute to the prevention of anti-counterfeiting of drugs which is an increasing phenomenon.
In this paper, the potential of the application of blockchain technology in the pharmaceutical SC is examined by employing the case-study methodology in the case of a company of to the Big Pharma. The research aims to investigate the possible applications, the problems that could be solved in a SC context and the degree of readiness of the pharmaceutical companies to apply blockchain technology. It is investigated whether and how these applications can be used in the future to detect and prevent existing obstacles and challenges in SCs, as well as promote sustainability through advantages such as modularity and immutability that blockchain technologies offer. This study also examines how blockchain technology could give solutions to the main problems that the pharmaceutical SC faces, such as lack of transparency and traceability, infiltration of falsified medicine etc.

2. Blockchain technology features and main applications in SCM

The term of blockchain technology was first introduced in 2008 by a person or people with the nickname Satoshi Nakamoto, who created the cryptocurrency Bitcoin (Nakamoto, 2008). A blockchain consists of cryptographically interconnected data, called blocks which are combined and form a chain. Blockchain technology includes a shared database of public or private ledgers of all the transactions/activities that have been carried out and shared between the blockchain members (Casino et al., 2019; Saberi et al., 2019; Hughes et al., 2019). There are two main categories for a blockchain, permisionless – public blockchains (e.g. Bitcoin) and permissioned – private blockchains. Public blockchains are free and open for anyone to participate via the Internet, while private blockchains are not accessible to anyone, requiring an invitation and validation according to the pre-agreed rules (Cole et al., 2019). The basic idea is that when a new transaction is added in the database, it is transmitted to the network of the blockchain in order to be verified and checked by a consensus mechanism. When approved by the majority of the nodes of the blockchain, according to pre-agreed protocols and rules, the transaction can be added in the blockchain, forming a new block and the new data are visible and accessible by all authorized parties of the blockchain (Bakaman et al., 2020; Xiao et al., 2020). Furthermore, another key feature of the function of the blockchain technology is that once the new data elements enter the blockchain they cannot be changed or processed as they are distributed to all the nodes of the chain. All transactions are filed by chronological order and the data stored in the blockchain are permanent and available to all authorized parties. This feature differentiates the technology from the conventional technologies that allow the changing or re-ordering of the data. Finally, the blockchain technology is based on computational logic and does not include a central node, so the transactions are completed automatically through an algorithm in a decentralized manner, without the presence of a central authority (Puthal et al., 2018). According to the above, some of blockchain

technology's main characteristics that make it innovative and different are decentralization, immutability, transparency, security and automation. These really important characteristics pave the way for its application in a wide variety of fields, such as SCM, smart contracts, online payments and accounting (Beck and Müller-Bloch, 2017; Chen and Chen 2019; Hughes et al., 2019; Vlachos, 2021). The application of blockchain technology from organizations and firms can make them reevaluate their strategies and capabilities. Because of the immutability of the database of the blockchain, the transactions that are made are traceable and proven without the need of authentication. Furthermore, the decentralization of the technology and the subsequent absence of a central authority provide more efficient transactions and reduced costs (Gurtu and Johny, 2019).

2.1 Smart contracts

The idea of smart contracts was introduced by Szabo (1994) and the term was used because of the similarity of these contracts with legal ones but with the ability of automated implementation. Smart contracts were presented as an extension of the protocol of digital-money and were defined as a set of agreements in a digital form which include protocols used by the system's parties. In the terms of blockchain, smart contracts are digital tools that promote, verify and enforce the contracts that are made among the parties of blockchain. The smart contracts used by blockchain have some significant characteristics (Gurtu and Johny, 2019; Wang et al., 2019):

- they are tamper-resistant because the program code of a smart contract is being monitored and verified on blockchain
- the smart contracts enforcement is made among anonymous nodes of the chain with decentralized control
- they have their own cryptocurrencies which can be transferred when the specific conditions are triggered.

Furthermore, smart contracts increase contractibility and promote exchanging money, shares, service, or other valuable things with an algorithmically automatic and conflict free process. The decentralized consensus of blockchain technology can significantly reduce no contractible contingencies (Cong and He, 2019).

When applied to blockchain systems, smart contracts function as computer programs across the network of the chain, expressing triggers, requirements and business logic enabling programmable transactions. Smart contracts have two main characteristics, state and value. The triggering conditions and the subsequent actions included in the terms of the contract are predefined by using statements such as "If-Then". The contracts are agreed and signed by all parties of the blockchain and are then submitted to the blockchain's transactions, which are distributed to the network, verified and stored in specific blocks. The new block is chained in the blockchain when all parties reach a consensus (Wang et al., 2019). A smart contract can be used as part of a blockchain system in different fields in order to eliminate the third-party transactions and make the system automated.

2.2 SCM concerns

Blockchain technology can be applied in SCM to verify sustainability and identify the parties that take every action in the chain, while facilitating the validity and effectiveness of the outcomes of all the relevant procedures. Once the data enter the blockchain they cannot be altered and other suppliers that are part of the chain can track down other shipments, transactions, and deliveries, enhancing transparency and trust among all the suppliers of the chain. By the elimination of intermediate parties, there is a decrease of costs and an improvement of the efficiency of auditing. Blockchain also can be used to assess the quality of products being transported. Furthermore because of the numerous documents, transactions and contracts involved in shipping, through the blockchain technology information exchange can be facilitated. In general, SCs are characterized by specific features such as cost, quality, sustainability and flexibility and global SCs deal with several uncertainties because of their complexity. As a result, blockchain technology can contribute to meet the key objectives of SC and to overcome the obstacles (Gurtu and Johny, 2019).
The features of the blockchain providing integration and organizing among the parties of the SC are transparency, validation, automation, and tokenization. Transparency refers to the distributed and shared information that is added from various parties of the blockchain, while validation of data is verified by the immutable character of the records and the consensus-based verification of information. Automation refers to the application of smart contracts in the blockchain, which are based on verified information. Tokenization includes the ability to create tokens that represent specific claims on valuable features and their exchange by the parties of the chain. These four features of blockchain technology enhance the following core objectives in SCM (Blossey et al., 2019):

- *Visibility* – Lack of end-to-end transparency in SCs is one of the reasons that cause inefficiencies and sometimes lead to bullwhip effect. Blockchain technology provides to all the members of the chain information about the

location and status of an object in real-time. When used in combination with sensor technologies and the Internet of Things, measurable conditions can be easily tracked, improving the accuracy of the data and facilitating the collaborative planning of the SC and the application of risk management measures.

- *Integrity* – Due to the immutable and transparent storage of the shared records, blockchain technology provides the opportunity to track down the origin of an asset. This could promote responsible sourcing as well as monitoring and detecting malicious actions such as product counterfeit. The applications could include the detection of the owner of an asset after its sale for guarantee purposes.
- *Orchestration* – The combination of transparency with validity and automation through smart contracts, could lead to SCs that function automatically based on pre-defined rules. As a result, speed is increased and coordination is easier because information, decisions and measures are spread throughout the SC.
- *Virtualization* – This dimension is known for increasing the utilization and flexibility of IT assets, by constructing a representation of physical hardware in software. The tokenization of some physical assets of the SC such as technical equipment could lead to better capacity utilization of the SC assets and increased contract flexibility.

SCM is confronted with some major challenges which are of particular importance in global economy. These challenges are relevant in most sectors and may jeopardize the ability of SCs to respond to stakeholders' expectations. In this paper we focus on three such challenges which may be addressed with the support of blockchain technology:

- *Track and trace* –Blockchain technology is a very promising technology in this area because of its decentralized character. The information and the transactions of the SC are stored in chronological order in blocks and all the members of the blockchain can execute, track down or verify any transaction being made in the SC. Relevant blockchain solutions have been mainly applied already in agri-food and pharmaceutical SCs. In the latter SC track and trace solutions are important for the physical movement of medicines and monitoring their authenticity and quality. Blockchain solutions in the SC can be used in notifying the SC members about the expiration date of medicine and about the demand and supplies of medicine in emergency cases (Hastig and Sodhi, 2020; Sunny et al., 2020).
- *Anti-counterfeiting* – Counterfeit and pirate products have increased exponentially in the last years and the pharmaceutical sector is vulnerable to such practices (Yiu, 2021; Hastig and Sodhi, 2020). Blockchain technology could be a very promising anti-counterfeiting solution. Block-SC is a decentralized system that uses the nodes of the blockchain to authenticate products, while it can track and trace products without the existence of a centralized system and it can detect the three counterfeiting attacks providing transparency of the SC (Alzahrani and Bulusu, 2020). The application of blockchain technology in anti-counterfeiting products relies on the characteristics of the technology such as immutability, consensus mechanism and traceability (Zhu et al., 2020). In addition, smart contracts include the terms and conditions of the transactions that have been agreed and signed by all parties of the blockchain (Haq and Esuka, 2018). As a result, the blockchain technology can prevent malicious use and actions by suppliers or other members of the SC, such as counterfeiting of products, assuring their compliance to the regulations of the SC's function (Min, 2019).
- *Compliance* –Blockchain technology is applied in SC because of its specific way of functioning that can monitor and track down the exact moves of the suppliers and general parts of the SC and therefore monitor their compliance. The most important feature of blockchain technology that contributes to the control of compliance of its members is the use of smart contracts. Another advantage of applying blockchain technology for SC compliance is its immutable and transparent character. Generally, blockchain can be used in the SC to ensure compliance of the parties, providing transparent transactions between the members and total tracking of shipments (Anjum et al., 2017).

The above challenges constitute determinants of SC resilience, which is one of the contemporary concerns surrounding SCs' design and operation. When a SC is resilient, it can resist, adapt, and recover from disruptions in order to satisfy consumer demand and maintain performance (Hosseini et al., 2019; Lin and Vlachos, 2018).

Today's ongoing rise in business competency necessitates the development of novel technologies and procedures in order for a company to sustain its competitive advantage. SCM is a crucial area for the advancement of new technology and blockchain technology is regarded one of the most promising solutions of our times.

3. Methods

In order to investigate the applications of blockchain technology in the pharmaceutical SC, as well as the advantages and the problems that could be solved in the current way that the SC works, a qualitative research was carried out. Qualitative analysis is based on social sciences to investigate specific phenomena. Researchers, interview people in person, observe their interactions, carry out case studies and report and analyze their observations, as well as the

existing documentation. The goal of qualitative method is to answer at questions of "why" and "how" and to collect the qualitative characteristics of the studied phenomenon by the group of people that is used for observation. The number of people that take part in a qualitative analysis is small and the researcher has a more personal perspective (Steckler et al., 1992).

In qualitative research the data is usually expressed in text or pictures, rather than numbers. The methods used for applying qualitative research were created by educational researchers and other social scientists, to investigate the complex reasoning of human beings, such as their motivation and communication. Qualitative analysis has some big advantages, such as providing the ability to the researcher to deeply investigate the complexity of a phenomenon, which leads to more informative and comprehensive results. Furthermore, it gives the opportunity to answer to inquiries that contain variables that cannot be quantified, like perception or experience of human beings (Seaman, 2008). There are several methods of collecting the necessary data, by using particular tools and techniques. One way is interviewing, which is used by the researcher to collect information from several people by asking specific questions. Another way of data collection is focus groups. The researcher interviews a group of persons, and the data arise from the interaction of the people having a conversation led by the researcher, who asks questions related to the topic. Another approach is conducting a case study, in which the researcher chooses to study a particular case (phenomenon) to examine a specific theory or concept. Finally, data collection could be done by the method of fieldwork, which refers to observing, recording, and taking part in the activities of a group by the researcher. The method of interviewing is usually used in combination with focus groups, case study research etc. (Jackson et al., 2007).

Case study is a way of conducting qualitative research, by examining a specific case in depth, acquiring a holistic view of the topic being studied, such as a procedure or a person. Among several definitions of the method, case study research is a way of detailed investigating, with data collected in a certain period of time, in order to analyze a phenomenon within its context in real life. Thus, it contributes to understanding, explaining, and describing the phenomenon. The method is used for answering questions of "how" and "why" and it is usually preferred when the phenomenon and the context are not clearly distinguished (Nije and Asimiran., 2014).

4. Data Collection

In this study, a qualitative analysis was conducted at a pharmaceutical company which belongs to the Big Pharma, using the method of case study research. The topic of the study was the application of blockchain technology in the pharmaceutical SC and the examination of its possible applications and advantages, as well as the company's readiness for the application of this technology. The collection of data was conducted by interviewing four employees of the pharmaceutical company that are related to the SC of the company. Specifically, the employees interviewed were the Supply Chain IT Manager, the Quality Assurance Program Manager, the Global Security Manager and the Manager of Logistics Europe. The type of interview was semi-structured; after the interviewing, the collected data were classified and analyzed depending on the similarities/ differences of the answers of the participants using the Constant Comparative Method.

4.1 Research questions

The review of the literature about the function and applications of blockchain technology generates significant research questions that we aim to answer by conducting a qualitative analysis. In particular, we focus on the following issues:

- Which are the possible applications of blockchain technology in the pharmaceutical SC?
- Can blockchain technology detect and prevent existing problems in the SC, especially the problems that exist in the healthcare SC? How could this happen?
- Are the pharmaceutical industries well prepared for the application of blockchain technology?

4.2 Interview questions

The case study was conducted through qualitative analysis with the method of semi-structured interviews. Apart from the predefined questions, the semi-structured character of the interview also gave the opportunity to the researchers to ask more questions based on the answers of the interviewees in order to get more information, as well as make comments or explain the question's meaning. The predefined questions of the interviews asked to the employees of the pharmaceutical SC, are listed below.

- Which technologies are you aware of, that are used so far at the SC of the company that you work?
- Are there any problems/disadvantages that you detect in the SCM by the technologies that are used so far? (e.g. lack of traceability of medicine, lack of transparency, lots of documents and intermediate parties involved)

- Are you familiar with the term of blockchain technology? If yes, what do you know about it?
- Are you aware of blockchain's applications in the SC?
- Which do you think are the advantages of blockchain technology?
- Do you believe that blockchain technology could be applied effectively in the pharmaceutical SC? Which problems would be solved?
- To what extent do you believe that this technology will influence or change the ways of working in your company?
- Which characteristics of blockchain technology make it an innovative technology? In which type of innovation would you categorize blockchain technology?
- Is blockchain technology going to provide a comparative advantage to the company that you work for, compared to other pharmaceutical industries? Which characteristics of the technology will make the difference?
- Do you think that pharmaceutical industries are well prepared and informed to apply blockchain technology? If not, what do you think they should take into consideration?
- How do you think the future in SCs will be like?

5. Results and Discussion

In this section, the interviews of the four employees in the SC of a big pharmaceutical company are analyzed and discussed to draw conclusions related to the objectives of the paper.

5.1 Supply Chain IT Manager

When asked about the technologies that are applied to the SC of the examined pharmaceutical company, the referred systems were ERP system and some downstream systems for complaint distribution and stabilization and recording quality issues. Data exchange is executed between third parties and software solutions via EDI technology. Furthermore, the Manager referred to demand-planning systems the company uses. When asked about the disadvantages of the already used technologies, the interviewee pinpointed the difficulty of using the ERP system. He pointed out the difficulty and the complexity of its use, especially when a record needs to be changed, while its cost is very high. The company depends on this system since it is the most popular, marginally a monopoly, in the market but the Manager would prefer if it could be replaced with another one.

As far as blockchain technology is concerned, the interviewee was aware of its function and its relationship with cryptography. The distributed character and privacy of blockchain technology was mentioned as its biggest advantage because of the ability it can offer to companies to collaborate and transact with each other. Furthermore, those two characteristics allow collaboration with patients as well as keeping their data anonymous, while providing continuously updated critical information like leaflet data, anti-counterfeiting information and drug interaction information. Security and anonymity were also pointed as extremely important advantages of the technology. As for blockchain's applications in the SC, the interviewee talked about its use for tracking and tracing products and their origin and also tracking and tracing the patient. The importance of e-leaflet was highlighted as a way of anti-counterfeiting and assuring the authenticity of a product leading to a big benefit of planning the market based on the consumer's demand. The interviewee commented blockchain technology as very innovative and capable to change the industry and the way it works, mentioning that people sometimes are suspicious and try to find problems in new technologies. Moreover, he pinpointed that blockchain technology has so many advantages, like the protection of data, that it could be integrated well in the SC system. The application of blockchain in the pharmaceutical SC was commented to be effective because it provides "trust in collaboration over a SC between different pharmaceutical companies". The combination of data of many different companies and the privacy that blockchain technology offers for these data, can lead to finding ways of improving the SC processes and find potential mistakes while adding trust because, as he commented, "PharmaLedger is a consortium of all the parties (of the blockchain)" and "blockchain actually makes it possible and easy to work together". As for the competitive advantage that a company could gain by using blockchain, the interviewee commented that not only it could provide their company with a competitive advantage, it could also lead smaller companies to join the chain. In the meanwhile, the Manager was asked to explain more about ledgers in the pharmaceutical industry and the systems that are going to be used and their possible combination with blockchain technology. As he explained, until now there is not a system available, but a proof of concept, so there is a need for a system production for operational environments. This system will not have an owner and it will have a cost, which will probably be shared between the parties to be maintained, while there will be a governing board for decision-making. The cost is not expected to be too high, especially for smaller companies, because the idea is "to improve the world and not just the top ten". The already existing systems are not for free, so the purpose is not to make it more expensive. When asked about industry's readiness, the answer was that it depends

on the company and its mindset, and that in several large companies there are people that always want to innovate and invest money to new, promising technologies, so the industry is almost ready. As far as the advantages for the patients when applying ledgers and blockchain, he pinpointed that the biggest advantage is more and better information for the patients and ensuring the authenticity of drugs, making it an anti-counterfeiting solution. Furthermore, patients can easily find a clinical trial by having their data uploaded to a distributed system, while the companies will cut down on costs related to searching patients for clinical trial recruitment. Finally, in the interviewee's opinion, the future of the SC is going to be more efficient and based on the companies' collaboration, so that shipments and transportations and problem-solving becomes easier "without giving away any secret or confidential information".

5.2 Quality Assurance Program Manager

When asked about the programs used in the SC of the specific company for assuring the quality of the products, the interviewee referred to: EU falsified medicines directive program (EU FMD), which ensures the implementation of the safety features to all the products of the EU including serialiazation; and a traceability platform built in-house that connects the company to the EU hub and allows sharing product data and batch data with the end users and pharmacies of other European countries that are also connected to the EU hub. Furthermore, the company tries to integrate data with another company which has a trace link too, so there will be finally three different databases for reporting into the EU hub. The Manager highlighted that with those systems in place, counterfeited products can be prevented from entering the legal SC of Europe, providing control and safety. As for the disadvantages of the systems used so far, although the systems and especially the EU hub platform are interoperable connecting stakeholders and other parties, there is a big gap in the connection and accessibility of the patients in the database. According to the interviewee, there are patients still not able to connect and through the pandemic, there was no authority with the role to check and solve this problem. The main concern and biggest challenge is to allow to all patients to connect while securing all their personal information, providing them safety. When asked about the complexity of the systems involved to upload data for tracing and transferring, the answer was that the procedure involves many systems and is really complex. The procedure includes the ERP system which includes all the data of the products, as well as the system used for the serialization of products and provides serial numbers to the manufacturing sites and third-party manufacturers, reporting back the serial numbers that have been applied on each batch, so that all these data and the data from the ERP system come into place. The data from all these databases and the data coming from the third-party manufacturers lead to a lot of systems interactions, making the process very complex. There is also a system which is used when a rework takes place or decommissioning at a warehouse level.

When asked about blockchain technology, the Manager was familiar with the term and blockchain's functions, pinpointing that it is an innovative solution that provides secure data sharing among SC stakeholders, which makes document exchange much easier when used for shipping products to a customer or to a regional or local warehouse. According to the interviewee's opinion, the biggest advantage of blockchain technology is the existence of e-leaflet, which replaces all the booklets that are included inside medicines about the instructions, storage requirements and risks, saving paper consumption and making it more consumer-friendly. The interviewer commented on the situation with the medicine leaflets expiration in Greece and the possible solution of scanning medicine's barcodes, which is important for the patient that will be able to scan the medicine and get important information about it. Even elder people that do not use mobile technologies or smart devices can get information from pharmacies if needed, but surely blockchain could contribute to secure data sharing. As for the type of innovation that blockchain technology represents, the interviewee stated that blockchain is a "rather transformational" innovation, because of the conservative character of pharmaceutical companies and the difficulty and fear of working together and collaborate with other companies. Therefore, blockchain can make the industry to collaborate with external parties under a trusted and secure environment, protecting the data being shared.

When asked about the industry's readiness the answer was that the pharmaceutical industry is not ready to apply blockchain technology compared to other industries, because the pharmaceutical industry emphasizes more on the production and commercialization of the product and because the value of the products is already high, and the cost of the SC function is limited. Another reason of lack of readiness is that the management of the data cannot yet successfully be performed because there is not an authority behind blockchain technology and as a result there is lack of trust of the data being shared, an issue that could be discussed for decades before being resolved. As the Manager stated, "A lot of discussions but no changes". The data of a pharmaceutical product is directly related to the quality of the product, so if something is wrong with the data, the shipment of the product to the patient should be terminated, and therefore it's very critical to reassure quality of information being shared with external partners. However, the application of blockchain technology was considered to be effective in the pharmaceutical SC, because it can provide

tracking and tracing of products, as well as patients' safety through high security standards. The ability to scan the barcode of the medicine and check whether it is the right one for the patient, guarantees the safety of the patient. The interviewee predicted that in the future aggregation of data will be a standard and the ability to connect patients through mobile phones will be quickly possible. In addition, according to him, it would be very useful if there were data that could inform the system about medicine demand and also if there was the ability to scan whether a product's distribution has been done under specific regulatory standards, assuring its quality.

5.3 Global Security Manager

When asked about the technologies used in the SC of the company, the technologies referred were mostly about the protection of the SC. Some technologies are more focused on physical asset protection and are based on tracking products being transferred through the SC by using GPS or cellular triangulation. There are other technologies used for authenticating products such as scanning them with a mobile phone, looking for certain physical features and characteristics that ensure that the product is legitimate, that it was manufactured in the specific facility or that the product is suspicious because it does not include the key markers or security features needed. These systems of tracking and tracing need to meet regulatory requirements which differ among countries. The biggest disadvantage of the SC systems according to the interviewee is the inability of the patients to authenticate the products so far. Most companies are providing authentication via mobile phone but there are a lot of obstacles and a "tremendous amount of education" that must be implemented, as there are regulations preventing direct communication with end customers in some countries, and there are also technological complications. Not all patients own a mobile phone and especially a smartphone, so it is impossible for them to use this anti-counterfeiting technology. Also, the privacy concerns that increase these days do not allow collecting location data with GPS. The education of the stakeholders and end users/ patients of SC was referred as the most important part for a legitimate SC and authenticated products.

As far as blockchain technology is concerned, the Manager was well aware of the technology, pinpointing that it is a secure solution that has the ability to be controlled and not manipulated. The main concern has always been who puts the information and who is authorized to place that information in the database, so blockchain technology provides that security and "it is focused on the legitimate SC", ensuring the legitimate origin of the product. The interviewee highlighted though the possibility of counterfeiters to hack or mimic blockchain technology, which has already happened in the past, by changing the numbers of counterfeited products to be the same as the genuine ones. However, he considers blockchain technology safer than EU FMD which is applied now as a SC system. As for the effectiveness of the application of blockchain in the pharmaceutical SC, it is considered to be effective, but it is going to take time in order to be involved and merged into all the parts of the chain. The blockchain technology according to the interviewee is going to be an innovative technology that will improve the detection of a malicious action or a suspicious, counterfeit product that is trying to enter the legitimate SC; however, this ability cannot be completely applied to the illegitimate SC that is active mainly through internet.

Regarding the readiness of pharmaceutical industry to adopt the blockchain technology, the answer was that the technology is already in the spotlight and that some big players have already adopted it, so there will be more followers in the future especially when its benefits are proven. If Big Pharma adopts it there will be more pharmaceuticals following the same path and maybe its cost will decrease as well. Finally, regarding the future of the SCs and their security the interviewee commented "when it comes to security there will continue to be a race between companies trying to protect their product and bad actors", who try to change and attack to the SC from the counterfeiting perspective.

5.4 Manager of Logistics Europe

At first, he was asked about the technologies that are used so far in the SC of the specific pharmaceutical company. The technologies that were referred were the ERP system, which is used to manage all the inventories, send information to 3PL providers and monitor orders, a platform used to perform or monitor the performance of the orders, specifically the arriving time or a problem of a product being shipped, a platform which monitors the performance of 3PL providers and a complaint system in which complaints are submitted and analyzed. There are a lot of portals so that the performance of the company is evaluated regarding SCM. As for the disadvantages of the programs already being used, the interviewee distinguished the complexity of the systems because of the several portals and platforms and the fact that the whole information about a product is not located in one specific platform, leading to misunderstandings and lack of awareness of certain problems in the SC. Moreover, another disadvantage referred was

problems in tracking and tracing products and partial lack of visibility of the market, such as the tracking of an order, which is a consumer demand from several countries and is a big challenge for the company.

As far as blockchain technology is concerned, the Manager was not aware of the technology, so it was necessary to explain it to him. After a detailed explanation of the function of the technology and its potential applications in the SC, the interviewee commented on the blockchain, pinpointing its advantages that could change the SC's function. The interviewee commented that blockchain is similar with EU FMD but has some better features, highlighting the advantage of security, because it provides the SC with secure information, it can track and trace batches of products and ensure that there is no counterfeiting of falsified products neither in the end nor during the SC. Furthermore, the ability of having all the information distributed on a common system for all parties was considered to be much easier to manage the SC for suppliers and the company itself. The immutability of the data uploaded in the database of blockchain was commented for the security and transparency of the blockchain system, but it was also considered strict because mistakes, like a wrong expiration date in a batch of products, are not allowed when the data that are uploaded cannot be altered. Although this feature is an anti-counterfeiting solution, there should be a way of correcting these mistakes or a platform where probably the data are not submitted yet and can be muted. Furthermore, in terms of traceability, the interviewee commented that a tool for patients and users to scan the products would be really useful for tracking down the product and its origin.

When asked for the industry's readiness to apply blockchain technology, the answer was that pharmaceutical industries are prone to investing money in innovative technologies but mostly in those which are related to product development, so maybe it would not be something that would easily happen. Maybe if pharmaceutical companies overcome this habit, they could invest in the SC technologies as well. Supply chains are trying to improve the interaction of the companies and the final customer, so in the future they are expected to reduce time and facilitate the end customer by adopting system that provide data faster, as well as reduce the inventory level, making the SC more efficient and sustainable. Blockchain could be one of these systems that speed up the process of data exchange and distribution to all parties and suppliers of SC.

6. Conclusion

The qualitative research in the form of a case study was conducted in this paper so that certain research questions could be answered about the applications of blockchain technology in the SC of pharmaceutical industry, its contribution to solving the problems caused by already applied systems in the SC, as well as the readiness of the industry for the application of blockchain technology. The interviews with the employees of a pharmaceutical company that are related to the SCM, lead us to draw very interesting conclusions.

The employees that were interviewed referred to many systems applied in the SC so far, which differ depending on the area of concern of each employee. The most important system that was mentioned was the ERP system, while other systems deal with specific issues such as quality, traceability, and security.

The biggest and most mentioned disadvantage of the already used systems was the complexity of their use, especially because of the existence of several portals and databases interacting with each other or depending to each other for the upload or exchange of information. This complexity leads to misunderstandings and lack of awareness of existing problems throughout the SC. Two out of four people that were interviewed also referred to the inability, or difficulty, of the patients to access or connect to the database. There is a big gap in the connection of the end user with the system and a lack of security and privacy of personal data that needs to be controlled. Moreover, there is an inability of patients to authenticate products so far, which is caused by technological complications. Other disadvantages mentioned, were the lack of traceability and visibility of the route of the products, as well as the high cost of the systems. Therefore, it can be concluded that the technologies used so far may be useful but have some serious disadvantages that negatively affect the SCs, as well as the patients as the last part of them.

Blockchain technology was known to three interviewees, while the fourth was not aware of it. The Supply Chain IT Manager was aware of the function of the technology and its relationship with cryptography, while he stated that its biggest assets are privacy, distributed character, security and anonymity of the information. He also acknowledged blockchain technology as an anti-counterfeiting solution. A big asset of the technology was the ability of companies to work together and exchange data while tracking and tracing of products and the use of e-leaflet were the main applications of blockchain technology that were mentioned. The Quality Assurance Manager was also aware of the technology and its function, commenting it as an innovative technology, which provides security and facilitates the

data exchange in the SC. E-leaflet was again stated as a most important advantage and application of blockchain in the pharmaceutical SC, being an anti-counterfeiting and consumer friendly solution. The Security Manager was well aware of blockchain technology, pinpointing the security of the system and the difficulty to manipulate it, although he mentioned that the technology can be hacked or mimicked by counterfeiters by changing the numbers of fake products. The Logistics Manager did not know about blockchain technology, so the term was explained in detail. After the understanding of the concept, the interviewee commented that blockchain has lots of advantages that could improve SC's function, such as security of data, traceability, as it tracks and traces products throughout the chain, and the anti-counterfeiting and distributed character. The immutability of the data uploaded was considered as a safety feature, but it was commented as a very strict characteristic, which allows no mistakes.

Given the above discussions, we can conclude that blockchain is an emerging and promising technology that has lots of advantages, like data privacy and security, distribution and sharing of information, traceability of products through the whole SC, anti-counterfeiting character, immutability of data and anonymity. However, counterfeiters can sometimes jeopardize security, so there should be more security perspectives to ensure the system's safety, while some advantages like immutability of the data can be demanding when a mistake occurs. The most promising and important applications of the blockchain technology in the SC, as it is concluded from the above, are e-leaflet and tracking and tracing of products.

In the future, according to the interviewees, SCs are going to be more efficient and based on the collaboration of the companies, while protecting the patient's personal information. There may also exist the ability to connect patients through mobile phones and scan the demand of medicines or the distribution of a product. When it comes to security of supply chains, there will still be a race between companies trying to protect their product and counterfeiters. Finally, the SCs are going to improve the interaction between the pharmaceutical companies and the final customer by reducing the time of information exchanging.

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