POLITECNICO DI TORINO

Department of Management and Production Engineering

Master's degree programme in Engineering and Management

Master's Thesis

Analysis of innovation in Blockchain and its areas of application: a patent data study

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A.A. 2018/2019

ABSTRACT

The first reference to Blockchain technology dates back from 2008 when an anonymous paper published online set forth the Bitcoin cryptocurrency. However, innovation in the field did not pick up until 2014, when the first patent related to Blockchain was filed in the United States. This technology has become attractive to many businesses and society because of the many benefits it can offer in terms of data decentralization and auditability. Regardless of it being popularly related to the Payments sector, Blockchain has more to offer in other fields. It promises to reshape the business landscape with disruptive technology paradigms such as Artificial Intelligence, Big Data, Internet of Things, and Cybersecurity. Furthermore, the study of patent data in Blockchain can provide statistics that offer insights into current trends within this technological field. Under this context, this study aims to obtain a general picture of the Blockchain innovation landscape by employing data found in patent fields. A search strategy was designed to query and extract patent data from a patent database. Consequently, several data analytics reports were generated via statistical tools in MS Excel. This study is focused on evaluating general trends in the field to then provide more detailed analytics in terms of a break-down by main players and most utilized patent categories for patent filing. Results reveal that while there has been significant progress with Blockchain technology since 2014, opportunity remains for advancement across multiple sectors. Ongoing research is fueling global competition, particularly between China and the United States.

Keywords: blockchain, bitcoin, innovation, intellectual property, patent landscape

Acknowledgments

Throughout the writing of this thesis, I have received a great deal of support and assistance. I would first like to thank my supervisor, Prof. Federico Caviggioli, whose knowledge was vital in the formulation of the study and the methodology to follow. I am particularly glad to have been given the opportunity to write a thesis in Innovation, which I find is a fascinating area of study.

I am grateful to all of those with whom I have had the pleasure to work during this and other projects along during my Bachelor and Master studies. Especially, to the professors in the Engineering and Management department at Politecnico di Torino and the Mechanical Engineering department at Universidad Tecnológica de Bolívar, to whom I will always be deeply thankful for having shared their expertise in their courses.

Nobody has been more important to me in the pursuit of this project than the members of my family. I would like to thank my mother, aunts, and uncles, whose love and support are with me in all my endeavors. They together have raised me to the professional I become today. Most importantly, I wish to thank my loving and supportive partner, Jeff, who has been there with me since the beginning of this adventure, providing endless inspiration along the way.

Finally, there are my friends, to whom I would like to express gratitude. Especially to my Colombian, Venezuelan, Brazilian, Mexican and Italian friends, who were my greatest support through good and bad times. Thank you for your sympathy and to always bring a smile upon my face when things seemed difficult.

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Introduction

Innovation has been strongly tied to human history since the beginning of our species. However, it was not only after the Industrial Revolution that we started talking about innovation in science and products. During the 18th century, governments began to introduce patent law as a source of protection and creation of economic advantage to new disruptive inventions. Blockchain technology is a disruptive technology that has been around since the year 2008. When the technological features of a decentralized transaction ledger under the name of 'Bitcoin' were described within an anonymous publication. It was not only the start of Bitcoin but the building blocks of an entirely new paradigm of decentralized trusted networks that would revolutionize the world. Ever since 2008, Blockchain technology has received a lot of attention from business and society in general. Companies have rushed to become essential players in this brand-new technological field. Many have done this by developing Blockchain-based inventions and applying for patents to protect their innovative efforts.

Under this context, the objective of this thesis is to analyze current trends in Blockchain technology innovation by the collection of patent data. To provide a holistic background summary to this study, it will first comprehend an initial description of the technology: its technical features and societal impact are discussed in Chapter *11. Blockchain*. Next, a brief introduction to intellectual property and a thorough step-by-step explanation of the methodology employed to analyze patent data is discussed in Chapter *12. Methodology*. Then, taking into account the considerations and constraints presented in the previous chapter, a detailed discussion of results is presented in Chapter *13. Analyses Discussion*. These analyses were developed by elaborating reports from raw data collected from a trusted patent database. Finally, the main takeaways and considerations drawn from the patent data study are mentioned in Chapter *14. Conclusion*.

Chapter 1

1 Blockchain

In this chapter, the focus falls on analyzing the technical bases that define Blockchain technology and how it is disrupting modern society. In particular, Section *1.1. Technical Aspects* contains a general explanation of blockchain technology whose aim is that of providing a technological basis to the patent data study that will be further developed in this thesis. Primarily, in this section, a definition of the technology is presented, and thus its essential elements are explained individually. Conversely, Section *0. Blockchain Roadmap* includes an assessment of advantages and challenges in Blockchain, an analysis of the blockchain market worldwide, a summary of its areas of application, and finally a review on the future directions that the research in this matter is headed.

Furthermore, this chapter was mainly built based on blockchain reviews found in different databases such as the IEEE-Xplore Library, Springer Link, Statista, books, and original publications. The start of Blockchain technology appears to be S. Nakamoto's whitepaper on Bitcoin, as it is the first depiction of the technology's architecture. Most of the information found was not completely homogeneous. That is, different sources used different terms to name the same things. This happens because Blockchain is under development and many definitions are still being reviewed and created. As a result, many of the Blockchain elements mentioned in this chapter are named after the most frequent denominations in research documents.

1.1. Technical Aspects

1.1.1. Blockchain: technology definition

Blockchain is a technology-based on a decentralized general ledger that contains information about transactions executed by all users in the network. Its purpose is to validate and safeguard transactional data and maintain historical records. This technology leverages a *peer-to-peer* network (P2P), in which nodes (i.e., users) are connected to others via the Internet, and each one serves as a file server for the entire blockchain network. Its participants handle a copy of the ledger's transaction history, facilitating the validation and retrieval of past events or transactions along the chain [1].

Currently, assets are generally exchanged in a transactional system that requires a third party to validate each party's capability to effectuate a requested transaction. Blockchain technology defies this paradigm and instead proposes a system that is changing the way how transactions are currently handled and tracked. In particular, blockchain and distributed ledger technologies purpose:

- **A decentralized database**, through a decentralized general ledger of transactions shared by a pool of users in a distributed network.
- **Inalterability of data**, enabled by data encryption techniques embedded in the blockchain framework.
- **No third-party participation**, since no intermediary is needed for data validation as participating users in the network can verify the bonafide of a transaction.

Despite the term *blockchain* being generally linked to *cryptocurrency*, there is more at stake than that. Blockchain is a broader technological sphere that comprises various business applications within different industries. Reviews in the matter show that there exist essential blockchain applications in sectors like finance, internet of things, healthcare, logistics and supply chain management [2] [3].

In 1991, S. Haber and W. S. Stornetta were the first in conceptualizing the theory behind blockchain [4]. A functional concept was brought to life in 2008 when Satoshi Nakamoto first published a white paper setting forth the *Bitcoin*, which would later become the cornerstone for *cryptocurrencies* [1].

Nakamoto described the technology as a decentralized data structure whose security relies on leveraging scalability from a large pool of users. Up to this day, Blockchain technology has proven it has the potential to be an instrument of value that can disrupt mature industries providing them with an innovative set of industrial applications.

During the 2018 IEEE Global Blockchain Summit, C. Lima proposed a thorough framework to describe the concepts behind Blockchain technology, as shown in **Figure 1**. Upon this model, blockchain anatomical elements are described, which contributes to the creation of a more standardized and structured concept for divulgation purposes [5].

The anatomy of Blockchain comprehends three major domains for data structure definition, data processing, and network linkage. Namely, a *Data Domain*, a *Process Domain*, and a *Network Domain*.

- The **Data Domain** relates to the essential elements of a blockchain, like a *block*, incorporating the underlying data structures and encryption algorithms that define the nature of a blockchain.
- The **Network Domain** allows the update and distribution of the blockchain among users thanks to decentralization and P2P networks.
- The **Process Domain** displays scenarios where a blockchain operates with several protocols for different applications. Each protocol defines the logic used by a network to validate transactions in a blockchain's general ledger.

By the degree of freedom to participate, blockchains can be conceived as **permissionless** or **permissioned**.

i. In a **permissionless** blockchain —also called *public* blockchain—, any individual can join the chain (e.g., Bitcoin) and can agree about its current state with the rest of the network by spending some computing power [1].

ii. Whereas in a **permissioned** blockchain —also called *private* blockchain—, it is only designated individuals (e.g., legal users) and not anonymous entities who make part of the authentication process. Therefore, for a node to be part of the network it must be granted access by an authority. This is the foundation for enterprise-like use cases of Blockchain technology.

By type of transaction, a given blockchain can be made up of **on-chain transactions**, and **off-chain transactions**. It is important to realize that on-chain and off-chain transactions may be present in any blockchain. That is, a blockchain can contain both types of transactions as it splits while trying to reach *consensus*. This topic is covered further in *Section 1.1.2, Anatomy of a Blockchain*. Namely, two kinds of transactions are defined as follows:

i. **On-chain transactions** are public events registered on the general ledger in the blockchain, and every user in the network can retrieve it.
ii. **Off-chain transactions** are private events happening exclusively between two or more parties in a network, and only they can validate such events. These transactions branch-out from the principal chain.

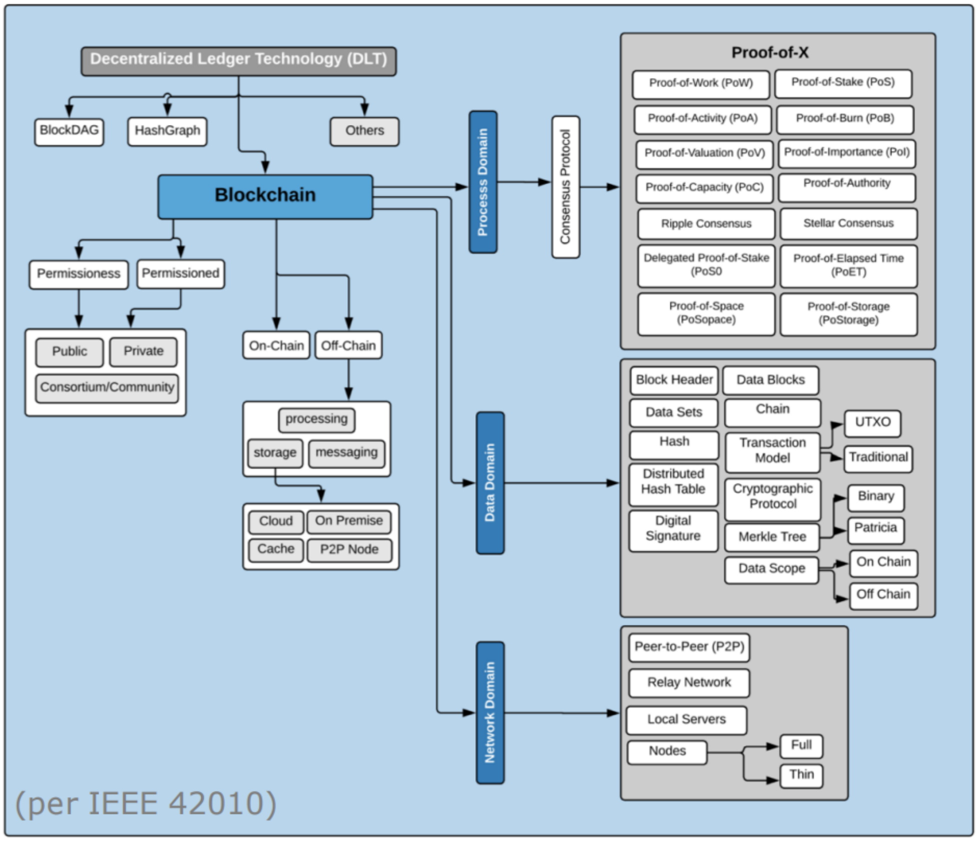


FIGURE 1. BLOCKCHAIN FRAMEWORK OF INTEREST [5]

1.1.2. Anatomy of a Blockchain

For clarity in describing Blockchain technology in this thesis, the sole technical elements that make part of the broad concept of blockchain will be described. It is essential to highlight that these are fundamental elements constituting blockchains in general and not a specific type of blockchain. Hence, the following concepts are crucial elements that may apply to every single blockchain that there exists.

Block

A *block* contains all the relevant information in the blockchain at a certain point in time. It includes a *hashed* string of data relative to the blockchain's state at a given point in time. Such that may have been previously added to the blockchain, and this process is shown in

Figure 2. Hence, the reason why the term 'blockchain' was used to name a series of chained data blocks.

Within a block, there is also a unique data structure named *Merkle tree* containing encoded transactional data and a *nonce* number used by users to "compete" in reaching the network's *hash value target*, an encrypted target value set by default by the system.

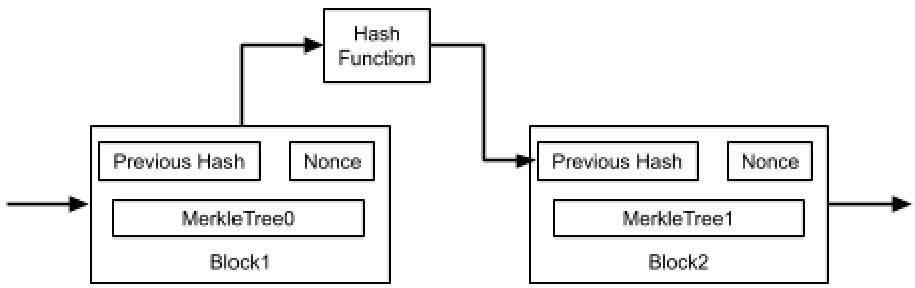


FIGURE 2. STRUCTURE OF A BLOCKCHAIN

Transactions

A transaction is a particular event stored in a data block. These events are data records that are encrypted and concatenated along with the blockchain. Participants in a blockchain's network employ digital signatures to authenticate the ownership of their transactions. Some examples of transactions include financial exchanges between users or the result of data inputs to the chain.

For instance, a transaction in the case of the Bitcoin blockchain can be when a user is selling an asset (i.e., an X amount of Bitcoin) to another user. Nonetheless, thanks to the decentralized nature of blockchains, these transactions can happen without a trusted third party to act as a referee. Instead, it is the blockchain itself executing its own rules seamlessly as transactions occur.

Digital signatures

In a blockchain network, users can sign and verify the authenticity of a transaction. The participants along the chain can either trigger these events or prove they happened at a particular time point of time, by retrieving the necessary information from many nodes in the network [6].

A blockchain requires that the issuer of a transaction signs a *hash* containing the previous transaction and the receiver's public key, using her private key. In this way, the receiver can verify the authenticity of a transaction by tracing back the chain of ownership using the issuer's public key. Even though signers transfer ownership of a transaction, their signature will prevail forever in the chain. The digital signing process is shown in **Figure 3**.

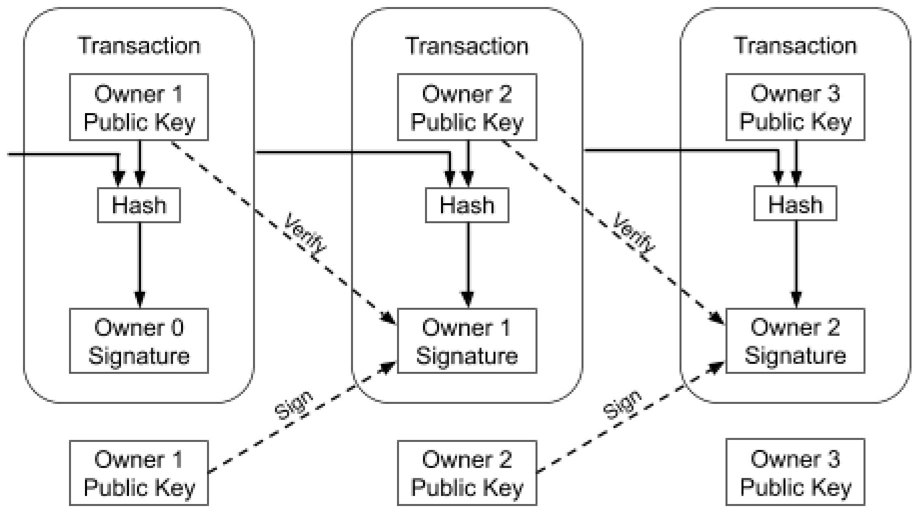


FIGURE 3. DIGITAL SIGNATURE IN A TRANSACTION, ADAPTED FROM [1]

Merkle trees

A *Merkle tree* is a data structure that supports the blockchain in the transaction authentication process. It is one of the main components of a block and can be *binary* or *MPT* (Merkle-Patricia Trie) [5]. The basis for Merkle trees was first proposed by R. Merkle with the aim of authenticating numerous public keys within a single value [7]. Merkle trees facilitate the validation of different data appended in a blockchain, thus allowing to keep proof of events that happened in the past since the beginning of the time. **Figure 4 is** a graphical representation of a binary Merkle tree.

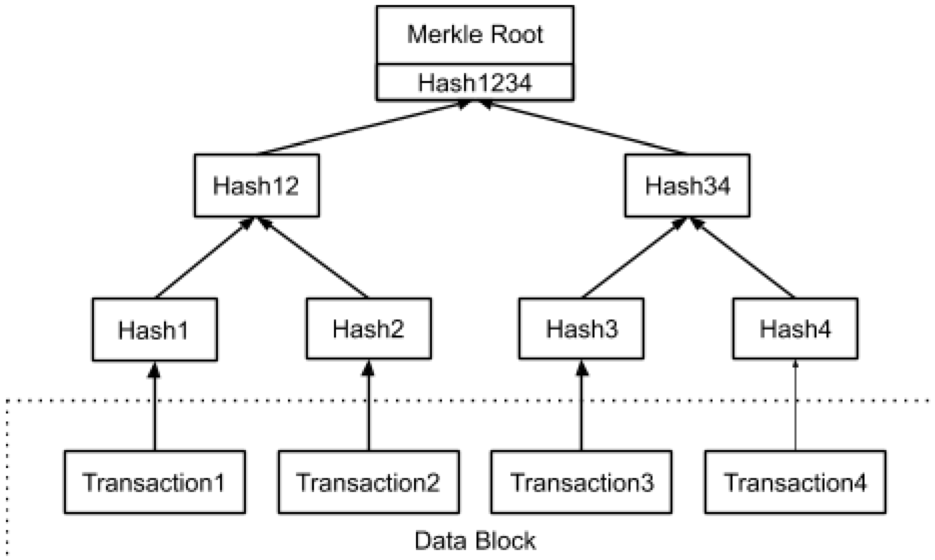


FIGURE 4. A BINARY MERKLE TREE, ADAPTED FROM [8]

The Merkle root is a core element for the transaction validation process. It is found at the uppermost part of the hierarchy in a Merkle tree and holds the result from hashing all the transactional data in a block consecutively. This particular data structure provides the advantage of certifying data through the whole chain without having to download the entire ledger. Changes in a single transaction downstream reflect changes in the topmost part of the Merkle tree (i.e.The trustworthiness changing the Merkle root), enabling data transparency, security, and coherence across the chain.

Timestamp

A *timestamp* is used to keep a record of time on data. In order to ensure traceability, a timestamp server provides proof that data existed at a given point in time, and it can be verified back within the blockchain [1]**,** as shown in **Figure 5**. Given that the latest block contains a hash of all the previous timestamps, such block has an exact copy of the earlier stages of the blockchain [4].

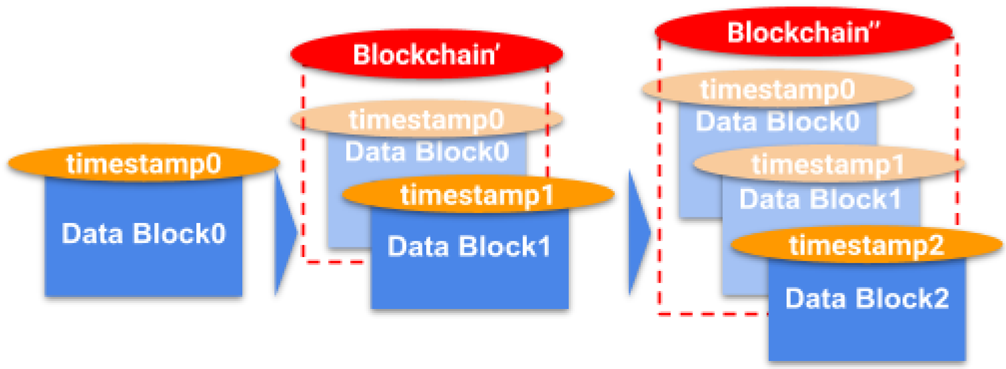


FIGURE 5. TIMESTAMPING WITHIN A BLOCKCHAIN

Hashing

The *hashing* process is the substance of the theory supporting the operating scheme of blockchain technology. It ensures data is trustworthy, stored securely, and inalterable within the blockchain. The product of this process is called *hash*, and it is a data element created through a hash function. Namely, a hash function is a mathematical algorithm that encrypts a given data into a fixed-length string called *hash* [9].

Hash functions are used in computer science for many applications, especially encryption, compression, and indexation of data. There are many types of hashing functions available [10]. For instance, in the case of Bitcoin, the hash function implemented is SHA-256 [1]. Although this process requires a gross understanding of the most technical aspects of blockchain, once understood completely, it provides a thorough overview of this technology's incredible advantages, and the value-added that could contribute to society in general.

Nonce

In cryptography, a *nonce* is a random number that can be only used once for a given user and is used as an input to the hash function [11]. It plays a fundamental role in the network's authentication process. In fact, users in the Bitcoin blockchain employ it as a trial-and-error value to reach the network's hash value target. After this condition is met, the *consensus protocol* (i.e., Proof-of-Work) is satisfied, validating the candidate block and appending it to the chain.

The hash that meets such criteria must start with a certain number of zero bits. As a consequence, this condition will allow the block to be added to the blockchain. The user that completes the mathematical puzzle receives a reward in the form of cryptocurrency (or a token) [1]. Say, the network is playing a game, and the nonce is a sort of dice—the user that gets a nonce that yields a higher hash value earns a reward and the chance to add his/her block to the chain.

Smart contracts

Smart contracts are self-executing protocols stored in a blockchain and the concept behind DApps [12]. The concept of *smart contract* was introduced by Nick Szabo in 1994. These scripts are responsible for the authentication process of certain conditions when transactions happen in a blockchain. Smart contracts provide a different outlook on the regular written/oral contract since they are introducing the automation of verification procedures.

Thus, automating the verification procedure that determines whether a participant party is legally compliant to its binding obligations in a transaction. In other words, smart contracts allow the automation of enforcing the rules that there would be in a regular contract.

In the case of a blockchain, smart contracts are the set of protocols agreed upon by all the participant nodes within the chain and define how transactions are done. Smart contracts are now enabling blockchain applications in financial and non-financial fields that would have not otherwise been able to thrive separately. A blockchain leverages smart contracts to define its transactional-contractual rules.

Consensus protocols

The *consensus* is an agreement between nodes in a blockchain network. Specific criteria are taken into account when participants of a network attempt to agree on the legitimacy of a given data block. A *consensus protocol* is a logic defining how an agreement is reached. It specifies the criteria and rules participants in the network need to follow in order to reach consensus.

But how do consensus protocols contribute to making Blockchain technology reliable and trustless? Since anybody could load data to the Blockchain, it is necessary for the network to take verification provisions. Data validation is required to help identify valid and invalid transactions in a candidate block. Once the data in a candidate block is validated, it is annexed to the chain.

There are different paths for which a network agrees who gets to review, and ultimately add the last block to the chain. Examples of consensus protocols are Proof-of-Work and Proof-of-Stake, among many others [5] [6] [13].

Proof-of-Work (PoW)

In a PoW setting, users must prove the network that a certain computing effort was spent to verify the validity of the transactions in a Blockchain [1] [14]. This protocol is the basis for Bitcoin and the rest of consensus protocols in the Blockchain technology framework. In a PoW-based Blockchain, there are two types of users: miners and signers [6].

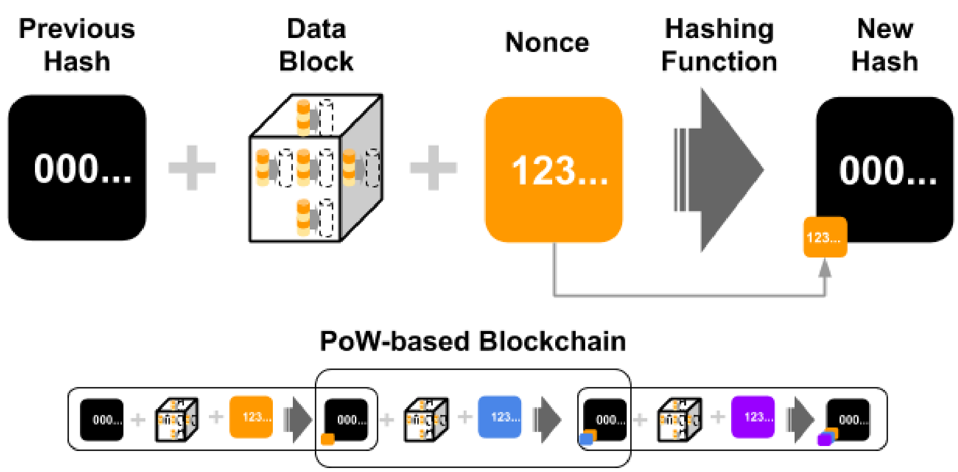


FIGURE 6. PROOF-OF-WORK BASED BLOCKCHAIN, ADAPTED FROM [6]

Miner users verify that transactions made by signers are valid and, in order to do so, they are required to retrieve all transactions done in the entire blockchain. They do so by obtaining a hash of the previous block plus a nonce, and such hash must start with a certain amount of zero bits in order to be validated and accepted within the chain. This process is shown in **Figure 6**.

On the other hand, signers are users triggering transactions in the network (i.e., making a payment). Miners are incentivized to validate data because each time they solve the data puzzle, a reward is provided in the form of a token or cryptocurrency. The miner that solves the puzzle first gets to add the last block to the chain. This miner is called *leader* and is most likely to be a node with high computing power [15].

Proof-of-Stake (PoS)

For a PoS setting, the probability of appending a block to the chain depends on the number of assets a participant owns in the network and the time he or she has owned it. It was first developed in 2011 by S. King & S. Nadal as an energy-efficient alternative to PoW (nodes consume energy to function as PoW requires computing power) and is the base for Peercoin [16], a cryptocurrency.

In the Peercoin, blockchain is exemplified in **Figure 7**. In this process, a data block is appended to the chain taking into account a hash obtained from a data set including the *coin age*, which is a number including a given user's number of coins and the time he/she has owned them.

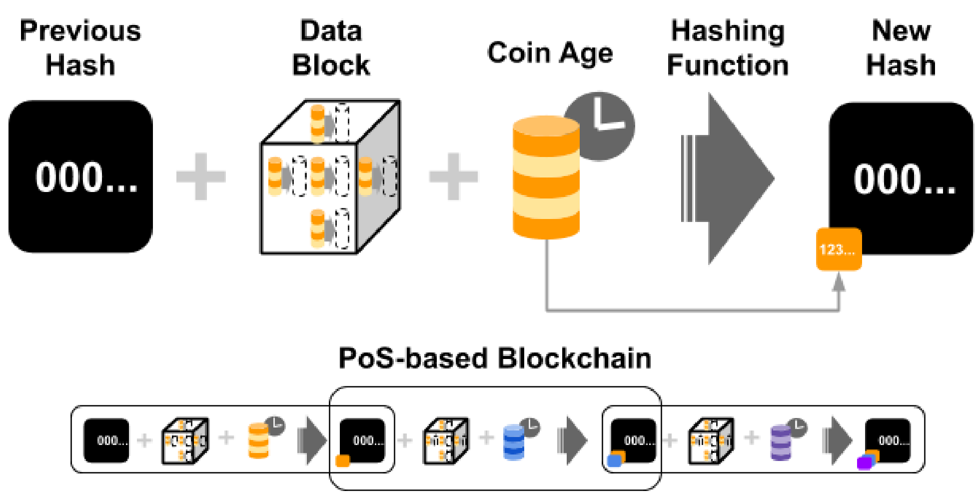


FIGURE 7. PROOF-OF-STAKE BASED BLOCKCHAIN, ADAPTED FROM [6]

To sum up, a PoS protocol is a trial-and-error iteration in which the user attempts to obtain a new hash with a different timestamp the next time. The more assets a user has, the more likely he/she is to find a hash value higher than the network's target value (i.e., to add a block to the chain) [6]. Like in PoW, the leader in PoS is rewarded with a token or cryptocurrency.

Other consensus protocols

PoW set forth the development of new consensus protocols. Each one aiming to cover their predecessors' flaws such as energy requirements, security issues (e.g., chain attacks) and degree of anonymity (e.g. permissioned and permissionless blockchains). Among the many existing protocols, some remarkable examples are *Proof-of-Burn (PoB)*, *Proof-of-Space (PoSpace)*, *Proof-of-Elapsed-Time (PoET)* and *Practical Byzantine Fault Tolerance (PBFT)* [13] [17].

1.2. Blockchain Roadmap

1.2.1. Advantages

Blockchain offers the potential to contribute to different sectors of society. So far, it has been explained what Blockchain is and its many technical components, but what can be argued about its contribution to social welfare? Which positives aspects can blockchain technology bring for businesses and society? User trust, transaction cost reduction, and enhanced privacy are among the most important contributions from Blockchain.

Different researchers in blockchain attempted to list such benefits in an easy-to-understand manner. In their study, Z. Zheng et al. dug into deeper analysis and described four specific benefits that blockchain technology is contributing to businesses and society [18]. Namely:

- **Decentralization:** no third-party authentication leveraged by P2P networks is key to reduce operating costs and processing bottlenecks.
- **Persistence:** users in the network are constantly validating and processing transactions, making it difficult for malicious entities to tamper with the chain.
- **Anonymity:** each transaction is encrypted in a way that the sender and receiver identities can only be retrieved by the parties involved in the exchange.
- **Auditability:** timestamped transactions allow each participant to keep track and have visibility of the history of all transactions that have happened since the creation of the network.

1.2.2. Challenges

Now after having described some of the advantages brought by blockchain, it is imperative to also highlight some of its hurdles. Every technology has its pros and cons, and this technology does not escape this reality. It is true though that its potential advantages exceed the challenges it may pose when implementing it in various scenarios. Particularly, the biggest difficulties of adopting Blockchain arise from legal regulations, change management, scaling, security, and wasted resources [19].

- **Legal regulation** initiatives from the Government may pull the technology towards a more compliant framework, yet these would require important investments from incumbent firms to accommodate. Such investments might be addressed largely to security and identity authentication issues. Ultimately, blockchain still has a few security flaws like *user anonymity* and the *51% attack*, being the latter a situation in which an individual could take over the entire network and modify it at the expense of its users, especially in small blockchain networks.
- Significant **change management** is required for firms and users that will eventually move from the traditional third-party paradigm to a decentralized private structure. Such a shift involves incurring in migration costs to transfer offline and online data to the new Blockchain models. The assumption is that societal and economic gains from adopting BT will be higher than the efforts required to set it forth.
- **Scaling**, on the other hand, might be a concern in Blockchain when it comes to data storage and execution time. For instance, if new users want to make their first transaction, they should first download and validate the entire network ledger to finally make the transaction. A process that might spend a considerable amount of time.
- **Cybersecurity;** security on the blockchain is still an on-going discussion as regulation is at an early stage of development and no industry standards have yet defined clear definitions on main risks posed by Blockchain.
- **Wasted resources;** refer to waste in energy needed to sustain a PoW-based blockchain like Bitcoin. Bitcoin mining is estimated to be consuming around 20 gigawatt-h of electricity each year [20]. This is an important concern since sustainability is considered as a driver for innovation in the upcoming years.

However, standards for blockchain technology are under development. The normalizing entities are taking the necessary provisions to elaborate proper industry standards since the information available is highly technical and heterogeneous. The creation of Blockchain guidelines will ease the work into improving some of its flaws.

Consequently, the International Organization for Standardization (ISO) has set a goal to prepare a set of guidelines for blockchain and decentralized ledger technologies by 2021 [21].

1.2.3. Current market situation

Blockchain has had a significant impact on modern society. Since it was first developed as Bitcoin in the wake of the 2008 financial crisis, it has challenged the way organizations will provide the services of the future. Picturing a bank service without an actual bank regulating what happens sounds pretty distressing, but this is in part for what this technology could point towards in the future.

Moreover, the financial sector remains an important field in Blockchain technology since it concentrates almost 60% of its market value, as reported in **Figure 8**. Important areas such as Manufacturing and Distribution accounted for almost a third of the Blockchain market size. Other relevant areas include the Public sector and Infrastructure services, which account for <10% of the total market value.

Financial services are amongst the most relevant sectors for blockchain and distributed ledger technologies. Alone it accounts for more than half of the market size in the world, which makes one infer that the biggest profits from entering the Blockchain market come from financial applications.

Even if the latter were true, this technology could offer more than just that. As a matter of fact, in sectors like Manufacturing and Healthcare —Financial services included—, the convergence of different key technologies like Big Data, IoT and Artificial Intelligence (AI) is revolutionizing the way data is generated and used.

In the face of the Industry 4.0 (often so-called “fourth industrial revolution”), it has paved the way for advanced cybersecurity studies, for example. To date, a lot of research and investment is being put forth to develop Blockchain technology. Such numbers keep rising thanks to the outstanding range of advantages and applications it provides to businesses and society [22].

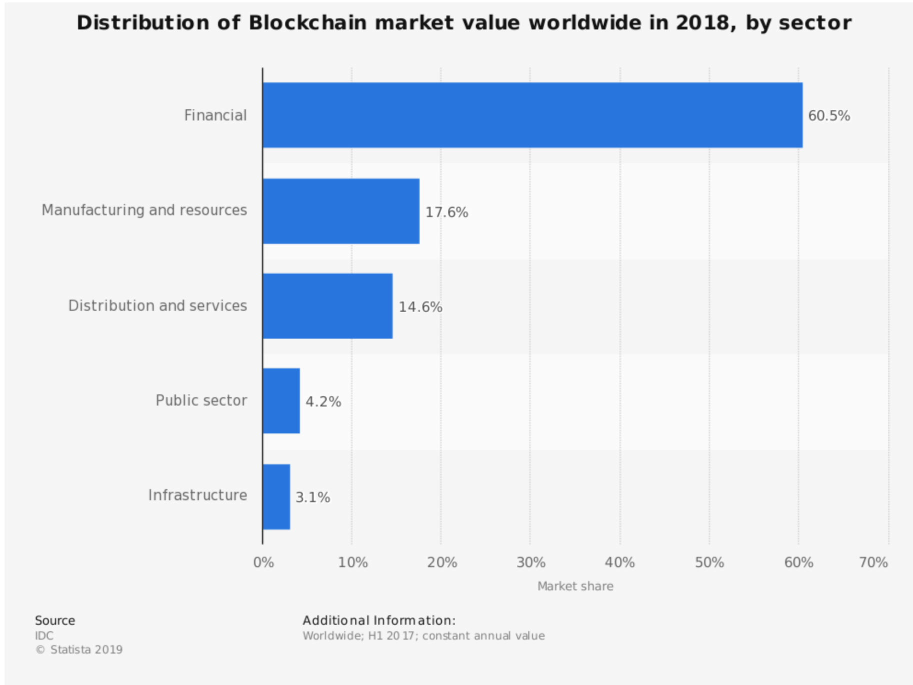


FIGURE 8. DISTRIBUTION OF BLOCKCHAIN MARKET VALUE WORLDWIDE IN 2018, BY SECTOR [23]

Additionally, the International Data Center (IDC) expects worldwide spending on Blockchain-based solutions to keep growing through 2022, as reported in **Figure 9**.

Statistics indicate that spending is slightly above USD 2.5bn. In fact, the entry of China and the MEA (the Middle East and Africa) in the blockchain market lead by the 2017 Bitcoin boom, for sure had a great impact on the incentive to foster innovation.

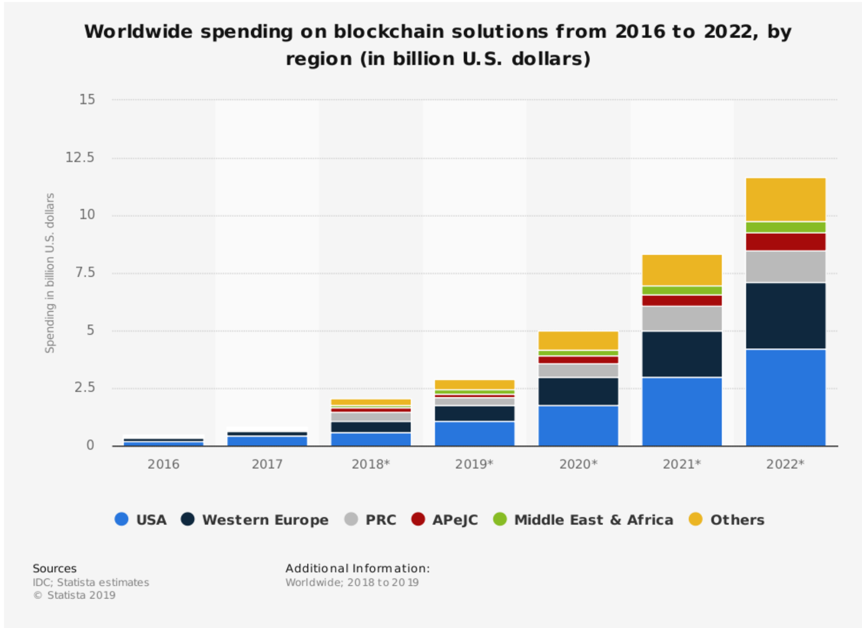


FIGURE 9. WORLDWIDE SPENDING ON BLOCKCHAIN SOLUTIONS FROM 2017 TO 2022, BY REGION (IN BN USD) [24]

In the face of different system constraints, start-ups have it easy to develop solutions that can leverage blockchain technology. In fact, the innovative attention could be focused on startups as they can provide a high number of possibilities to improve different spheres of business.

Smaller companies like startups could improve businesses at a faster pace due to the minimum change management inertia that bigger companies face when it comes to a technological shift. **Figure 10** shows the external barriers that companies could face when implementing Blockchain in their operations.

Startups can escalate and build knowledge faster than established companies as they do not have to deal with interoperability and are flexible to quickly adapt to the Blockchain changing paradigm, given that it is still a work in process worldwide.

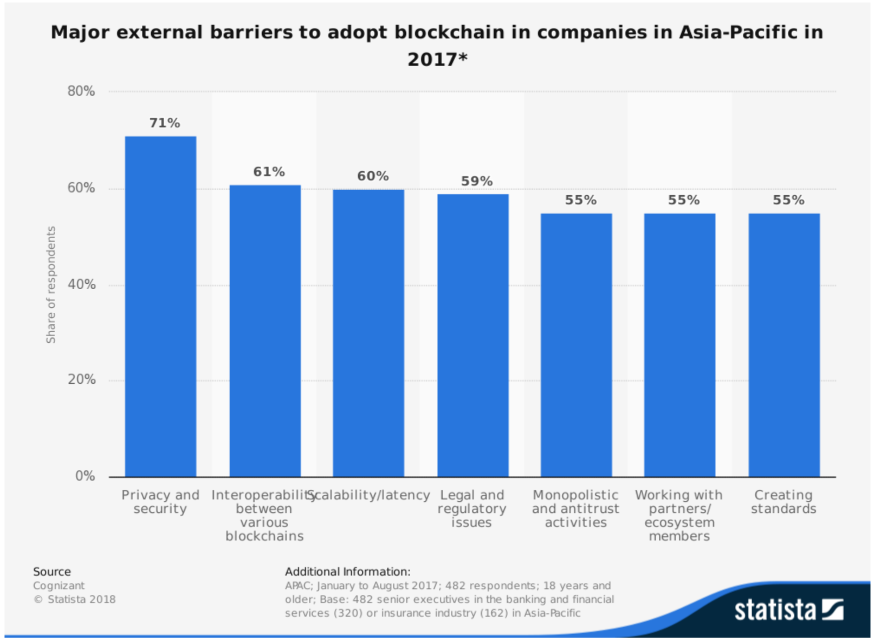


FIGURE 10. MAJOR EXTERNAL BARRIERS TO ADOPTING BLOCKCHAIN IN COMPANIES IN ASIA-PACIFIC IN 2017 [25]

1.2.4. Areas of application

Blockchain was first developed to deliver a new transactional alternative in the face of extremely trusted financial services and high transaction costs. These requirements have grown over time and, consequently, interfaces between blockchain and other technological landscapes have appeared. Research began from a financial root and has since spread to many different areas.

Cyber Payments and Cybersecurity

Is it cryptocurrency the most popular financial application of Blockchain technology? Maybe. Although it started as the base for cryptocurrencies, so far it has proven to provide a new financial paradigm in terms of payments and accountability. This technology's offerings bring into place a sophisticated way to optimize payment clearing and credit information systems [26] in banks and disrupt current competences in the global financial markets by leveraging the decentralization and automation embedded within Blockchain [27].

Payment infrastructure takes a big toll on the many business use cases for Blockchain. Banks, FinTech companies (financial technology companies) and financial institutions look towards using Blockchain to improve mainly their payment infrastructure, trade finance, and digital identity management capabilities. In the future, other applications such as insurance, loans, and securities might find its betterment thanks to the upheaval of further research and development from banking institutions and FinTech companies.

However, the introduction of Blockchain technology in financial schemes poses a new challenge to cybersecurity. Among the many issues, data privacy and assets are at stake. Developing cybersecurity procedures and standards remain a priority in this area.

Cryptocurrencies

Cryptocurrencies are currencies based on blockchain technology and the cryptographic logic behind it. Up to this date, the most widely known and expensive cryptocurrency ever created is the Bitcoin [28]. Leveraging blockchain technology, any transaction made on cryptocurrency can be audited, reviewed, and visualized by the beneficiary network.

Additionally, each cryptocurrency uses a different payment structure that can be defined at the basic block level or the consensus protocol employed or a mix of these. Like Bitcoin, there are other cryptocurrencies currently available such as Ethereum, Ripple, Tether, Litecoin among many others.

Internet of Things

The Internet of Things (IoT) is the concept of different physical objects connected that can share data between them. Blockchain and distributed ledger technologies can track, organize, carry out transactions and store information from a large number of devices, enabling the creation of applications that require no centralized cloud [29]. The main challenges to developing IoT include extensive capital requirements, maintenance of scaling volume of smart devices, data privacy and reduced trust of closed-source software [30].

IoT can be complemented with blockchain technology capabilities to overcome the issues mentioned above. However, certain aspects of blockchain must be adapted in order to create blockchain-based IoT (BIoT) applications since it was not particularly designed for IoT. With the scope of creating seamless BIoT apps, researchers are currently focusing their work on how consensus algorithms could be optimized [31] [32].

Supply Chain and Logistics

A supply chain is the conglomerate of resources, activities, and information involved in the end-to-end transport of goods from supplier to end-user. Blockchain technology is the key to a new panorama inside supply chain management systems. Thanks to its can seamlessly fit, it could incorporate all of its advantages to existing and future systems with information chain schemes.

It is important for a supply chain management system to ensure that information streams are reliable and visible to ensure transparency. Much business attention has been focused on how blockchain can improve the quality and safety of goods that are processed through different layers of stakeholders. Especially in the food industry, where many researchers have proposed traceability systems that can leverage blockchain capabilities [33] [34].

The Industry 4.0 paradigm fosters the interest of developing business and Blockchain-based manufacturing developments [35] [36]. The concept of Industry 4.0 means the interoperability and flexibility of diverse manufacturing systems that can communicate between them [37]. Blockchain plays an important role to decentralize and enable the self-regulation of vast manufacturing data management systems.

Supply chain management became an important application scenario for blockchain technology development. Such a liaison can be complemented with IoT, cloud computing solutions, and many other integrative technologies.

Furthermore, this technology can provide improvements to overall performance measurement and a competitive chain infrastructure. Yet —aside from researchers—, organizations remain ignorant and are mainly trying to figure out what blockchain is and how it can be applied to fulfill their needs. As reported in **Figure 11**, manufacturing and logistics organizations are directing Blockchain-related expenses, mainly on creating a Blockchain knowledge base.

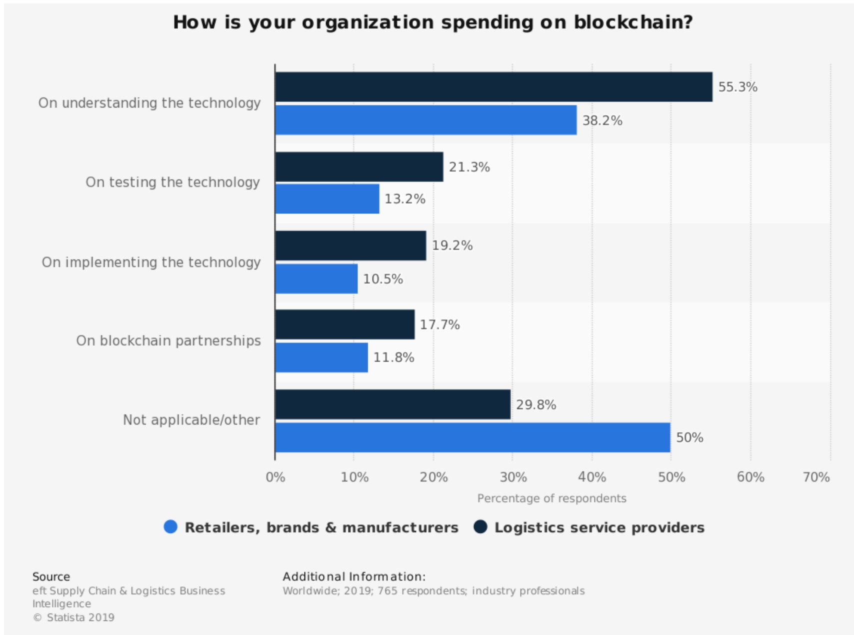


FIGURE 11. TOP SPENDING ON BLOCKCHAIN IN THE SUPPLY CHAIN INDUSTRY 2019 [38]

Healthcare

Blockchain technology is expected to rediscover ways in which healthcare data can be enhanced for the patient's benefit [39]. The main objective is to decentralize health information registries (HIR) and provide a new model that enables efficient, decentralized, and secure electronic medical records.

Also, Blockchain-related improvements in security, privacy, and robustness of healthcare data can facilitate the collection of dissimilar sources of patient data in a cost-effective manner.

The better the quality of the data shared in HIR, the better the quality of healthcare service provided by many physicians looking at data of the same patient. Blockchain can act as a system integrator that aids in standardizing information flows in the medical sector.

Public Sector

Land registry and voting systems are among the most common applications of Blockchain in the public sector [18]. The trustworthiness of real estate historical records and electronic ballot systems can be enhanced by leveraging Blockchain to create recordkeeping systems [40]. Accurate, reliable, and authentic land records can be generated, stored and tracked in a blockchain-based land registry system.

Under this context, land records and votes would be more difficult to tamper with, and land fraud could be avoided. For example, by eliminating a third-party that stores sensitive data about citizens' assets (i.e. a national land registry office). Thus, making savings in lawyers and government taxation on transactions or ensuring that elections are 100% democratic.

Inevitably, society demands more transparency from governments as public services evolve into the digital era. Blockchain can serve as a catalyst for this objective. Actually, national services can leverage its capabilities to create robust databases that citizens can use without compromising their data but at the same time ensuring total trust from a central government.

1.2.5. Future directions for Blockchain and distributed ledger technologies

Mainly, research is focused on applying blockchain to technological disciplines such as IoT, artificial intelligence, big data, and a combination of them [26]. Comprehensive research in technological capabilities can create new opportunities for growing applications in financial and non-financial fields.

An important concern for researchers remains how to ensure that blockchain' security and privacy is as superb as it is expected to be. Blockchain is still a recent and likely-to-change technology. Thus much research needs to be done in this matter.

Nevertheless, Blockchain technology standards are yet a work in progress. ISO, IEEE, and many other standardization groups are working on guidelines to define clear guidelines for Blockchain [5] [21]. The opportunities to develop this technology are vast, but further research is needed to understand whether it can cover up the security flaws of existing or recently developed applications successfully.

Surprisingly, businesses remain confident about employing Blockchain in their quest to be one step further among competitors; as it is the case of Carrefour Italy in which they are currently using Blockchain to ensure transparent traceability of agricultural-sourced goods. In this respect, it can be considered a smart move from the company to ensure the reliability of its supply chain.

A list of important future developments in the Blockchain research field is provided, as follows:

- Smart healthcare applications [41]
- Smart cities and sustainability [42]
- Smart government [43]
- Big data analytics [44]
- Blockchain and AI-based applications [45]
- Insurance policy enforcement [46]

Chapter 2

2 Methodology

In this chapter, the aim was to describe the methodology employed to develop the present study. Particularly, Section *2.1. Intellectual Property (IP)* presents a general introduction to patents by defining the basis of intellectual property and patent particularities. Here, the basis to understand patent documents and databases are introduced with a top-down approach.

Consequently, the search tool utilized for data extraction is as well introduced along with a brief explanation of its features and method of use. Lastly, Section *2.2. Search Strategy* provides a methodical explanation of the search structure used in this study. Also, the data extraction process is explained in chronological order, along with the criteria considered for such a task. Complementarily, assumptions considered are presented at the end of this section.

Moreover, this chapter was mainly built based on recommendations provided by the *WIPO Guidelines for Preparing Patent Landscapes Reports* [47]. In this chapter, the sample for the study was defined, yielding a total of 6.623 patent records. The sample is divided into six different clusters (i.e., areas) that enclose patent records for a single area of application. The total number of clustered patent records amount to circa 6.579 records. Hence there is a small remaining amount of 'other' data fields that did not fit within any classification.

2.1. Intellectual Property (IP)

2.1.1. IP & regulatory bodies

What is IP?

Intellectual property in innovation law is defined by the World Intellectual Property Organization (WIPO) as all inventions product of creativity, literary documents, artistic works, designs, symbols, names and images used in commerce [48]. Intellectual property rights protect creative works by law and grant its beneficiaries with legal vests that can later be used against those who infringe on using registered IP deliberately (or not).

IP rights enable individuals to earn acknowledgment and economic benefit from their inventions. There are different types of intellectual property rights, namely: patents, utility models, copyrights, trademarks, registered designs, and trade secrets. The IP systems keep the balance between the societal interest in innovation and innovators by safeguarding inventions. Under such conditions, creativity and innovation can thrive in an environment where people are rewarded for novelty.

Many products may be protected by different kinds of intellectual property rights. For instance, a phone manufactured by Samsung has different hardware components and software applications that may be entrusted to hundreds of IP rights. The visual design is registered and thus protected, the processor could have both a registered design and a patent, the camera, battery, screen and operative system (among many other components) can have a complex combination of trade secrets, copyrights, trademarks, patents, and designs. This is just proof of how complex the development of a product can be and why it is important to companies and individuals to keep close attention to IP rights law and enforcement.

In this thesis, the scope is that of studying blockchain-related patent data. For that, the focus on this section is the description of the intellectual property right granted by a patent. The next paragraphs focus on identifying the bodies that are responsible for enforcing and providing IP rights internationally and regionally in Europe.

IP regulatory bodies

The World Intellectual Property Organization (WIPO) is the global agency part of the United Nations (UN) in charge of serving as a forum for intellectual property, policy, and cooperation [48]. It is based in Geneva, Switzerland and is composed of 192 member states. The WIPO aims to regulate intellectual property worldwide and foster creativity and innovation for the benefit of society.

Without the WIPO, there would not be an organism that provided worldwide[1] protection to creativity. This branch of the UN ensures that IP rights are applied worldwide to cope with geographical barriers that can make it difficult to keep inventions protected outside. Through the Patent Cooperation Treaty (PCT), the WIPO guarantees IP protection in about 152 contracting states. By filing an international patent application, applicants look after their inventions in the countries part of the PCT.

As for Europe, there are two bodies in charge of ensuring IP is protected: the European Patent Office (EPO) and the European Union Intellectual Property Office (EUIPO) [49]. The EPO is exclusively in charge of patent applications, and the EUIPO pertains to the registration of trademarks and designs. EPO is the European intergovernmental organization accountable for innovation, competitiveness and economic growth[2] of its member states. Patent applications for EPO can be filled out in German, English or French and it is currently one of the largest public service organizations in Europe.

EPO was established on October 7th, 1997 based on the articles covered in the 1973 European Patent Convention (EPC). Its headquarters are located in Munich, Germany [50]. Initially, EPO's geographic scope began with 16 member states. However, over time it grew into a total of 38 countries comprising 28 EU states and ten additional states outside the EU, being them: Albany, Croatia, Iceland, Liechtenstein, North Macedonia, Norway,

[1] Protection not exclusive to a specific economical area such as the Euro Zone in Europe, or Mercosur in South America.
[2] Related to innovation

Switzerland, San Marino, Serbia, and Turkey. Additionally, **Figure 12** reports EPO's extension across Europe and beyond.

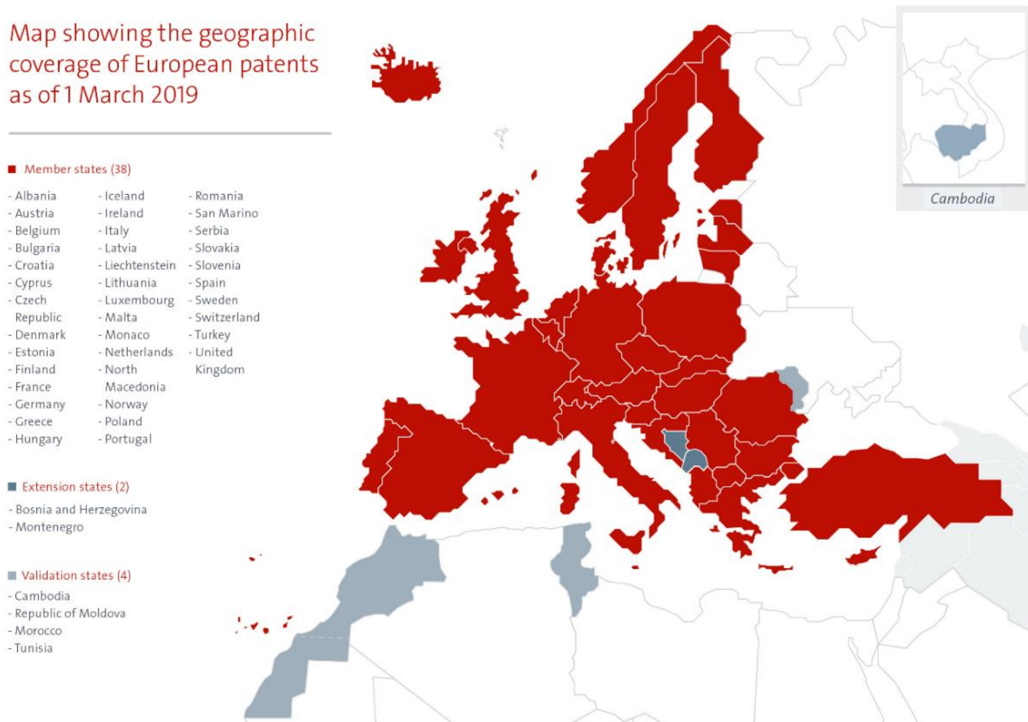


FIGURE 12. EPO'S GEOGRAPHIC SCOPE

2.1.2. Patents

The WIPO defines patents as a type of intellectual property right with the aim of protecting inventions in the specific territory that it is granted, for at most 20 years. Inventions must be explained and illustrated for the patent to be issued [47].

In other words, a patent is a fixed-term contract between a patent applicant and the society in which the applicant agrees to disclose the technical information regarding her invention in exchange for the right to exclude others in the making, use and commercial exploitation of the invention.

Furthermore, patents encourage innovation and have business value as applicants are vested in claiming for damages when others infringe their patents. Lost profit damages are an important legal feature, provided that inventors and businesses would like to enjoy exclusiveness when it comes to economic benefits from their research and development.

Patents grant a kind of limited monopoly to applicants, thereby crowding-out any competitors willing to enter the market. Hence, any incumbent can be penalized over the unauthorized use of the applicant's invention.

On the other hand, society gets benefits from this legal vest as well. New products go to the market, and new technologies are disclosed to the public because there are economic incentives for innovation (e.g. high profits from a new product based on new technology).

Individuals or groups of associated individuals (e.g., a company) could apply for a patent if their invention is considered a novelty. That is, the invention to which an applicant is pursuing a patent must not be included in the technological state-of-the-art by the time of submission.

A patentable invention is rather something different from what is already patented. Else, the patent application is rejected, and thus no exclusive rights are granted. Particularly, Article 52 of the EPC provides that patentable inventions must involve:

- **Novelty**; as mentioned before, the invention must be totally new and not related to any pre-existing creations.
- **An inventive step**; the invention must not be obvious to a person skilled in the related art.
- **A subject of industrial application**; the invention must be replicable. Namely, it is possible to manufacture it.

Not everything can be patented. As mentioned before, inventions must be considered a technological novelty for an application to be submitted. Nevertheless, these requirements may change from one country to the other. The EPO does not provide a precise explanation of the word *invention* but does state **what is not considered an invention**. Namely, are not considered the subject matter of patents:

- Computer software

- Methods for treatment and diagnosis
- Plants and animals
- Inventions contrary to morality

Components of patent documents

Patent analysis reports are performed, taking into account different data attributes contained in patents. Regardless of the governmental body that issues a patent, the structure follows basically similar information layers. The following description of patent documents metadata is based on the information found in the Guidelines for Preparing Landscape Reports, by WIPO [47].

In particular, patent documents are composed of a front-page which contains three major sections: the bibliographic data, a description of the invention and claims. Each of these sections is then composed by subsections that offer specific information about the document, and for each specific data, a field is assigned.

Bibliographic data

This section defines the basic data regarding the technical content of the document or the entry in the official database. Bibliographic data can be found on the front page of a patent document, as shown in **¡Error! No se encuentra el origen de la referencia.**.

In general, statistical analyses (e.g., patent landscape reports) are focused on studying bibliographic data. Herein, the document identification data, data about the domestic filing of the application, priority data, publication data, classification data, and other data relevant to the invention can be found. Additionally, a patent could also include drawings on the front page to better interpret the invention.

i. **(71) Applicant/Assignee**; represents the entity or person who files a patent application. A patent assignee is a person to whom patent rights are discussed.

ii. **(72) Inventor**; represents the person or group of individuals who are the authors of an invention. Generally, it does not change during the patent lifecycle.

iii. **(22) Filing date**; is determined by the patent authority that receives the patent application.

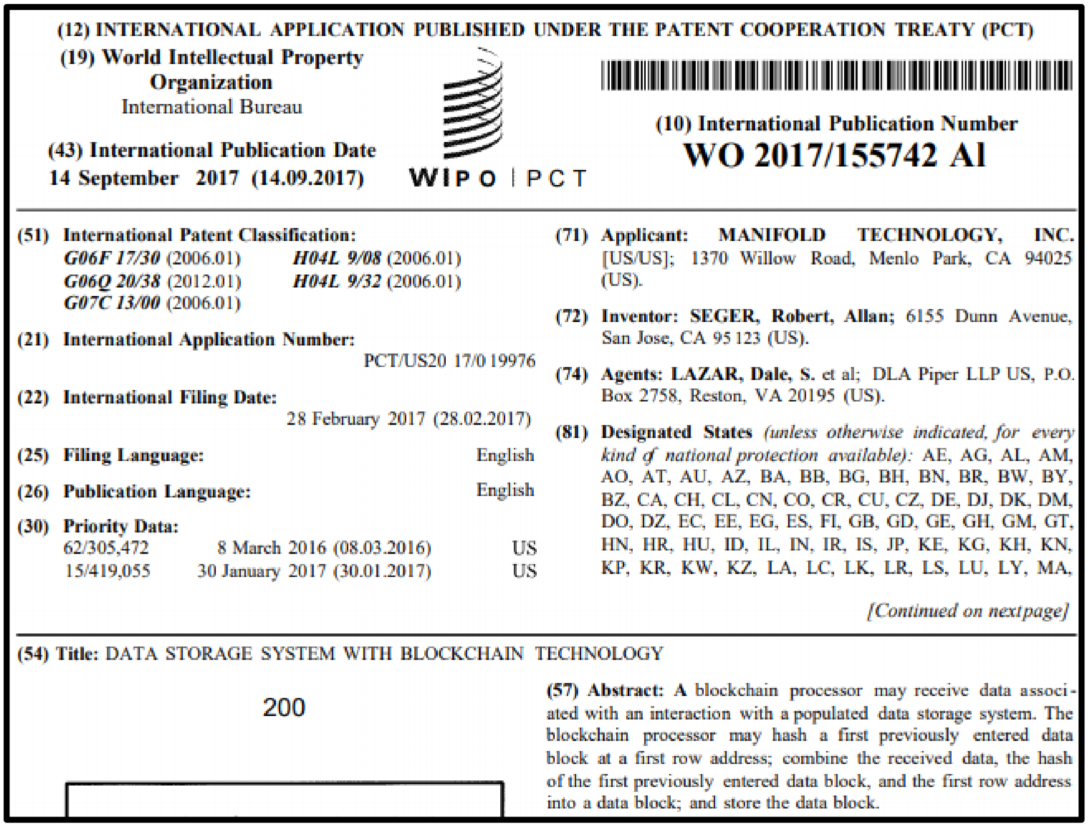
iv. **Priority date**; corresponds to the absolute date on which an applicant files a patent application related to an earlier patent published. In particular, the date in which the applicant refers to the priority of that earlier application. In **Figure 13**, the priority date field cannot be found since it matches the filing date as there is no prior related art published.

v. **(43) Publication date**; corresponds to the date in which a patent document is published. This happens approx. Eighteen months after the filing of the application, or 18 months after the earliest priority date (in different jurisdictions).

vi. **(30) Priority data;** is composed of the ***application number***, the ***filing date,*** and the ***identification of the country/organization*** where the respective earlier application of the patent was filed.

vii. **(51) Classifications**; with the aim of organizing the different inventions published, technological areas are divided into distinctive and more specialized units. In 1968, WIPO established the International Patent Classification Codes or IPC codes in an attempt to standardize patent classification systems. More information regarding IPC codes is presented in Section *2.1.3. IPC Codes.*

viii. **Citations**; it regards all prior-art related to the novelty, obviousness, or an inventive step, associated with a given invention. Citations can provide hints of a potential relationship between two inventions. Studying them provides a means for identifying documents that may have had a high impact on the development of technology.



(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 September 2017 (14.09.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/155742 Al

(51) International Patent Classification:
G06F 17/30 (2006.01) *H04L 9/08* (2006.01)
G06Q 20/38 (2012.01) *H04L 9/32* (2006.01)
G07C 13/00 (2006.01)

(21) International Application Number: PCT/US20 17/0 19976

(22) International Filing Date: 28 February 2017 (28.02.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/305,472 8 March 2016 (08.03.2016) US
15/419,055 30 January 2017 (30.01.2017) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA,

[Continued on nextpage]

(54) Title: DATA STORAGE SYSTEM WITH BLOCKCHAIN TECHNOLOGY

200

(57) Abstract: A blockchain processor may receive data associated with an interaction with a populated data storage system. The blockchain processor may hash a first previously entered data block at a first row address; combine the received data, the hash of the first previously entered data block, and the first row address into a data block; and store the data block.

FIGURE 13. SECTION OF A BLOCKCHAIN-RELATED PATENT DOCUMENT [51]

Description

The description is one core section of patent documents. It identifies the technical field regarding the invention. In general, it provides a summary of the technical background of the invention and describes important features, generally supported by technical drawings. Descriptions provide an overall glimpse of the invention to the reader.

Claims

On the WIPO Handbook claims are defined as "*the part of a patent document which defines the matter for which protection is sought or granted*" [52]. Claims determine what an applicant is claiming as an invention. The first claim declared is called the *main claim*, and it includes all technical features that help solve the technical problem for which the invention was conceived. Patent applications are required to have at least one claim. This section is written by attorneys in non-conversational English, difficulting the understanding of regular people. Due to its legal and technical nature, the claims section is difficult to read and interpret.

2.1.3. IPC Codes

Since 1968, patents are classified under the IPC codes. Before this date, many countries used their unique classification systems to sort patents issued by the domestic government. In this respective, WIPO created the IPC system in order to standardize patent classification systems across nations in one unique language.

IPC codes relate to the technical nature of the disclosed invention. That is, the IPC system serves as a way to represent predefined concepts for describing the technical characteristics associated with an invention [47].

A single IPC code defines a hierarchical structure that ranges from a general high-level to a specific low-level classification symbol. For exemplification purposes, the different IPC symbol hierarchies are reported in **¡Error! No se encuentra el origen de la referencia.**. Taking into account, the classification code **G06F 17/30** from the patent document in **Figure 13**, a dissection of the component symbols is presented as follows:

i. **Section (G)**; defines the broadest technological field in which a patent can be allotted [53]. The IPC system defines eight major sections[3] and represents the highest level of the classification hierarchy. Additionally, sections range from letter A (i.e. HUMAN NECESSITIES) to H (i.e. ELECTRICITY). In the presented example, section **G** is the 1st level of the classification and corresponds to the section title "PHYSICS."
ii. **Class (G06)**; sections are divided into classes, making them the 2nd technological level of the classification hierarchy [53]. In this particular example, the class symbol is **G06**. There is also a class title that indicates the content of such class. The class title for G06 is "COMPUTING;

[3] IPC system list can be retrieved from the official WIPO site: https://www.wipo.int/classifications/ipc/ipcpub/

CALCULATING; COUNTING.” Sometimes a class index is available in order to provide additional information about the class.

iii. **Subclass (G06F)**; describes the 3rd level in the technological classification hierarchy. Single classes comprise one or more subclasses. The subclass symbol is the class symbol plus a capital letter. In the example, the subclass symbol is **G06F**. Corresponding to the title of “ELECTRIC DIGITAL DATA PROCESSING.”

iv. **Group (G06F 17/30)**; subclasses are broken down into groups. They can be *main groups* —hence being the 4th level in the hierarchy— or *subgroups*, thus being in a lower hierarchical position subject to the main group. Both have a symbol and a corresponding title. The main group for **G06F 17/30** is **G06F 17/00**, and its title is “Digital computing or data processing equipment or methods, specially adapted for specific functions.” The subgroup is **G06F 17/30**. Depending on the amount of dots preceding the subgroup title, its level of indentation from the main group is specified.

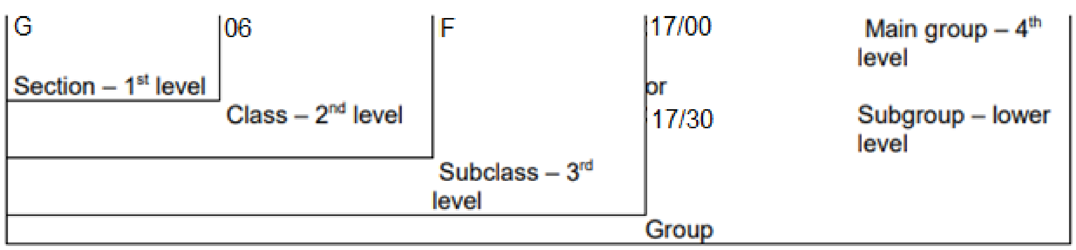

FIGURE 14. COMPLETE IPC SYSTEM CLASSIFICATION SYMBOLS, ADAPTED FROM [53]

2.1.4. Patent Databases

What is a patent database?

Patent databases store relevant data fields reported on patent documents. Almost all of the information reported on patents is also reported in patent databases. Many of them are available to the public in online repositories. Innovation researchers can use these databases by querying patent data employing a mix of keywords and specific criteria. NGO, governmental, and private patent databases are among the common types of databases that can be found.

Particularly, WIPO and EPO possess international databases for online patent querying, being them *PATENTSCOPE*[4] and *Espacenet*[5]. In the case of EPO, a regional database is available and includes exclusively European-only patents, namely *European Publication Server*[6], updated weekly since 2004.

Many states around the world index their patent records in government-owned databases as well. For instance, official Italian, American, and Japanese patents are stored in the UIBM[7], USPTO[8] *PatFT*[9], and *J-Plat-Pat*[10] databases, respectively. All of them are free-access and can be retrieved online.

Moreover, private companies offer online patent database services too. Some of these services can be either free access or pay-for-use. Google's *Google Patents*[11] is a free access tool that can be consulted online and has indexed different patent dates from several patent offices around the world. Clarivate Analytics' *Derwent Innovation*[12] is a pay-for-use database that offers advanced analytics for patent data analysis. For this study, the Derwent Innovation patent database has been chosen as the tool for querying the required patent data.

Derwent Innovation

Derwent Innovation is a patent research application privately owned by Clarivate Analytics, a company that provides access to global patent indexes and scientific literature. On their website, the tool is available directly for users. Clarivate employs AI and machine

[4] PATENTSCOPE: http://patentscope.wipo.int/
[5] Espacenet: https://worldwide.espacenet.com/
[6] European Publication Server: https://data.epo.org/publication-server/?lg=en
[7] UIBM Database: http://brevettidb.uibm.gov.it/
[8] USPTO: United States Patent and Trademark Office
[9] PatFT: http://patft.uspto.gov/
[10] J Plat-Pat: https://www.j-platpat.inpit.go.jp/
[11] Google Patents:https://patents.google.com/
[12] Derwent Innovation: https://clarivate.com/products/derwent-innovation/

learning driven software to curate patent data from different sources and performs search tasks; capabilities that render its online content-rich database highly innovative and reliable for patent data analysis.

The Derwent Innovation database operates by using Clarivate Analytics' DWPI[13]. Particularly, the DWPI is a global innovation tracker that collects the information found on regular patent document fields and stores them in the form of records. Currently, it is used by over 40 patent offices worldwide. Offering the advantage of actually getting the most of patent data without going through the entire document for research [54].

Generally, online database websites have a simple UI[14] that ensures that users are provided with a clear layout arrangement. The Derwent Innovation database has a user-friendly interface that is composed of many buttons and filters.

Innovation researchers can dispose of for the purpose of consulting patent records. When the single-user access to the tool from the login screen, is redirected to the front page where direct access to the search tool is found.

[13] DWPI: Derwent World Patents Index
[14] UI: User Interface

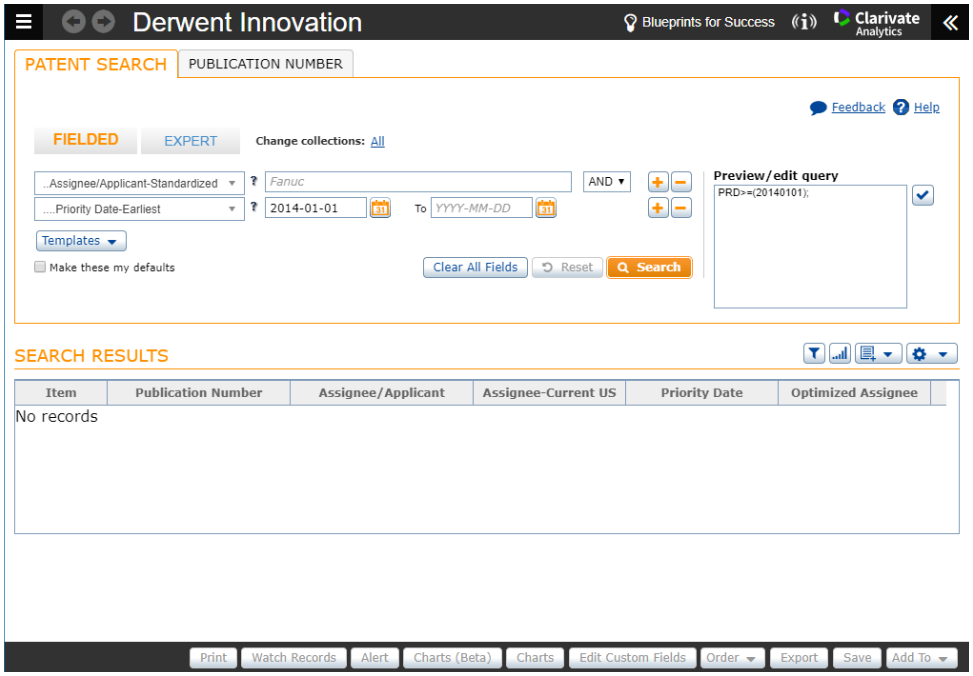

FIGURE 15. DERWENT INNOVATION SEARCH TOOL [55]

As reported in **Figure 15**, novice users can perform easy queries from a *Fielded* option that displays basic information filters related to the fields found in patent documents. These fields were explained in Section *2.1.2. Patents*.

On the other hand, the *Expert* option allows more proficient users to apply and create custom queries. After the patent query is requested, the database returns a dashboard with four graphs (bar, world map, bubble, and line) displaying such queried patent data.

Additionally, the raw patent data can be exported in different formats, and the query criteria can be saved for further review. Users can also create alerts that are generally run when new content is available so that automated reports are generated and sent to them via e-mail.

In order to develop the patent data study, this thesis will be focused on utilizing primarily the *Fielded* version of this patent search tool.

2.2. Search Strategy

2.2.1. Query structure

Up to this point, the technical aspects of the technology and its areas of applications (including future direction areas) have been described in Sections *1.1. Technical Aspects,* and *0. Blockchain Roadmap*, respectively, through exhaustive analysis of academic documents. These will be the building blocks of the search queries to be used on Derwent Innovation.

Furthermore, the search method to develop the study herein described consisted of defining single technological keywords. They aim to include the highest numbers of relevant patent data records around Blockchain's areas of application.

For instance, a single keyword like "blockchain" would be inserted in the search tool in order to retrieve a given amount of data records regarding Blockchain technology. However, even if a single keyword by itself would not be relevant, keywords roles become prominent as they are linked with one another by a series of search operators. In this thesis, the search operators used are AND, OR, NEAR, and ADJ.

- AND requires that two keywords are included within the patent field, regardless of their position with respect to each other.
- OR instead will look for either keyword, regardless of their position with respect to each other.
- NEAR requires that two keywords appear within one word from each other.
- ADJ fulfills the same function as NEAR but will only look for keywords in the order specified.

Keywords were grouped to define a unique *technology perimeter* and many *area tags*. Thus, at a high level and regardless of the area, queries show the following structure: **"perimeter" AND "area tag" AND "priority date."** The perimeter defines the sample of our study (i.e. Blockchain-related patents), and area tags are a way to cluster each of these patents in different areas of application for analysis.

2.2.2. Preliminary data checks

Timeframe check

The reason we included the field PRD[15] within our queries follows a timeframe check developed before performing any further query. In fact, PRD was chosen because it is the date closest to the "ideal" conception of the actual invention.

In order to determine which timeframe is relevant for this patent study, we used the keyword "blockchain" as the starting point. A simple query with the form `TAB=(blockchain);` was performed in order to extract the necessary data fields to make a decision.

The query mentioned above yielded a total of 5966 patents, from which the data fields "Application Number" and "Earliest Priority Date" were extracted. Thus, obtaining data ranging from the year 2003 to 2019. Using MS Excel, the frequency of Blockchain-related patents filed per year was calculated, and the results reported in **Figure 16**.

[15] PRD: Earliest priority year

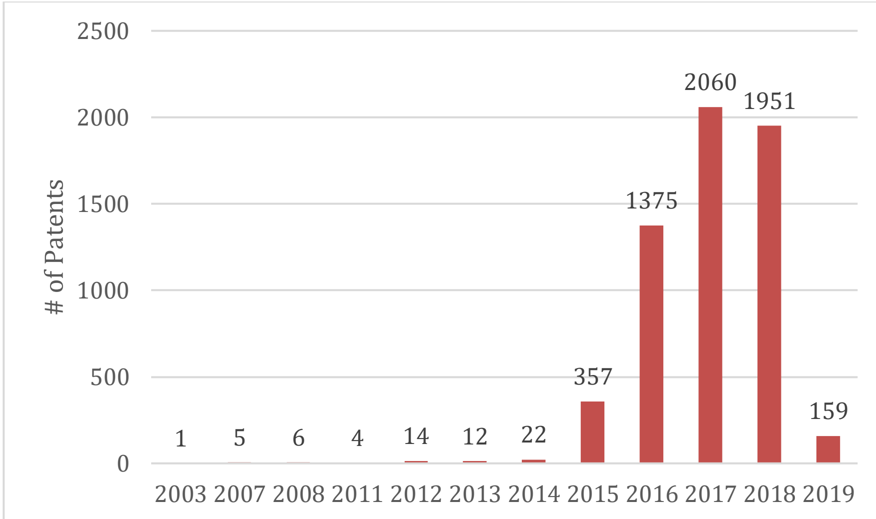

FIGURE 16. FILED PATENTS PER YEAR FOR RECORDS CONTAINING "BLOCKCHAIN" KEYWORD IN TAB FIELD WITHOUT DATE RESTRICTION

Taking into account what is reported in **Figure 16**, the final decision was to focus on recent events and thus ignore data from years < 2012. For that, the study was constrained to patents filed from 2012 and so on.

On top of that, another key event to highlight considers that Blockchain technology started theoretically in 2008, patent filings peaked some years later. This is explained by the Bitcoin boom in 2017, mentioned in *Section 1.2.3, Current market situation.* The circumstances incentivized inventors to accelerate innovative efforts (i.e., apply for more patents) in the field.

Moreover, if the reader would like to look closer at the results, an extended list with the performed analysis can be found in **¡Error! No se encuentra el origen de la referencia.**.

Relevance check

For every single keyword, trial queries were retrieved to check how many records they could return. The detailed check-up provided a general assessment of each keyword contribution to the search in # of patents. By all means, this preliminary check tests the relevance of a single keyword under certain conditions depending on whether it is a perimeter or an area keyword.

For perimeter keywords, the search query per keyword followed the structure: **"perimeter keyword" AND "priority date."** A simple example of this type of query for the "distributed ledger" perimeter keyword looks like this: `TAB=(distributed NEAR ledger) AND (PRD<=20120101);`. Such a query returned a total of 1074 records.

After every keyword was tested, the search perimeter[16] was created. It yields the intended sample size of our study and serves as the primary input for the relevance check performed per area tag keyword.

Conversely, for area tag keywords, ALL[17] fields are queried because we wanted to look for hints on every field about the area of application for each single patent document. The structure of the search queries was: "**perimeter" "area tag keyword" AND "priority date."** In this case, we used the combination of keywords that form the perimeter of our study followed by every single keyword. For instance, the query for the IoT area keyword "smart device" looks something like this: `TAB=(blockchain) AND (PRD<=20120101);`.

Keywords for both scenarios (perimeter and area tag) yielding zero records were, of course, dismissed. The final shortlist with all selected keywords, and their returned number of records is provided in **Appendix 2** and **Appendix 3** for perimeter and area tag keywords, respectively.

2.2.3. Data clustering

With the purpose of providing accurate analysis, the study focused on establishing a sample size by defining a technological perimeter. Subsequently, area tags were set to classify

[16] The criteria for the perimeter selection is explained in the following paragraph, *Technology perimeter*
[17] ALL: All text fields

records within this sample. **Figure 17.** Data clustering scheme for Blockchain provides a visual representation of the data clustering intended in this study.

The definition of general keywords for the main sample (i.e., Blockchain) and per area will provide enough records to enclose most of the patent data within the sample. For whatever reason, some of them might not be assigned an area. These records will be collected in a specific area named ‘Others.’

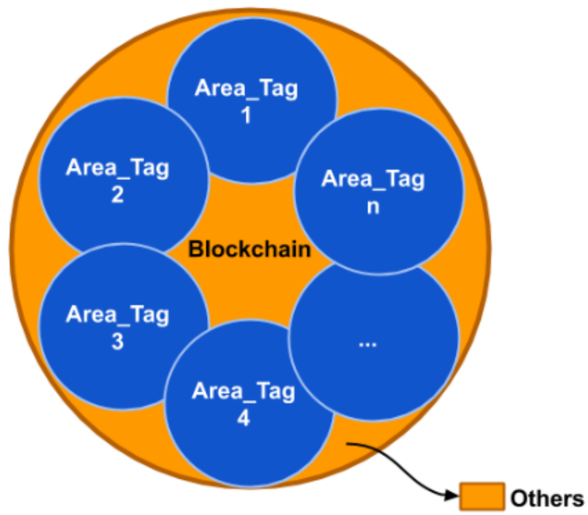

FIGURE 17. DATA CLUSTERING SCHEME FOR BLOCKCHAIN PERIMETER

The relevant keywords to form the perimeter (i.e., sample size) and areas of application for Blockchain technology were extracted from the literature review in Sections *1.2.4. Areas of application* and *1.2.5. Future directions for Blockchain and distributed ledger technologies*.

Defining the search perimeter

The technology perimeter covers the limits of the intended search. In other words, it defines the sample of this study. The methodology followed by this study defines that data clustering can be achieved by employing raw text (i.e., keywords) to identify concepts or phrases within fields in patent documents [47].

As reported in **¡Error! No se encuentra el origen de la referencia.**, the perimeter follows a detailed structured that includes a range of technology synonyms and components. Some keywords are broken down in different tiers that are chained by an operator. In this case, the operators NEAR and ADJ were used.

Tiers define the degree of complexity of a keyword. However, this does not imply that any keyword provides more records than the other – for the last, the proper use of search operators plays an important role in determining the number of records yielded.

Type	**Keywords**		
	1st tier	*operator*	*2nd tier*
Main	blockchain		
Synonym	decentralized	NEAR	database
	distributed	NEAR	ledger
	digital	NEAR	ledger
Component	consensus	ADJ	protocol
	proof	ADJ	of*
	digital	ADJ	signature
	block		
	hash		
	merkle	ADJ	tree
	nonce		
	smart	ADJ	contract
	timestamp		
	transaction		
	decentralized	NEAR	transaction

TABLE 1. LIST OF KEYWORDS FOR TECHNOLOGICAL PERIMETER

Synonyms are words that were used by different authors to refer to the same technology, in this case, Blockchain. Conversely, *technological components* refer to those elements of the technology that describe its structure and operation. For both synonyms and components, the corresponding keywords are connected using the operator OR.

In order to construct the perimeter, the logic followed was to query patents that included:

1. At least once the word "blockchain" on their title or abstract

2. Or at least one keyword from the technology synonyms that in turn must also include:

    a. at least the word "blockchain" once in any of the patent fields

b. alternatively, any technological component on the patent title or abstract

The query form of the technology perimeter that satisfies the logic mentioned above is `TAB=(blockchain) OR (TAB=(synonyms) AND (ALL=(blockchain) OR TAB=(components)))`. Despite providing a practical example, **¡Error! No se encuentra el origen de la referencia.** displays the actual query inserted in Derwent Innovation.

Arrangement	Query	# records
TAB=(blockchain) OR (TAB=(synonyms) AND (ALL=(blockchain) OR TAB=(components)))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND PRD>=(20120101);	6623

TABLE 2. TECHNOLOGY PERIMETER QUERY[18]

Clustering by area tags

After the sample is defined created, another goal remains clustering data within specific areas for further in-depth analysis. Following the literature review in Section *1.2.4. Areas of application*, different areas of application for Blockchain were identified.

A further relevance check (**Appendix 3**) revealed which area keywords were more predominant per area; hence, it is expected that most data per area come from these keywords. The area tags (i.e. clusters) were then defined. Namely:

- Artificial Intelligence & Big Data: related to all patents within the AI or big data domains.
- Cyber Payments & Cybersecurity: related to all patents within the payments or cybersecurity domains.
- Healthcare: related to all patents related to healthcare issues. Non precisely medical applications, but also inventions that enhance medical processes.

[18] Data retrieved on 29/08/2019. 9:00 PM CEST

- IoT & Cloud Computing: includes either Internet of Things or cloud computing-related records.
- Public Sector: related to any governmental-like transaction enhanced by Blockchain. May include voting or real estate transaction systems.
- Supply Chain & Logistics: related to any supply chain or logistics-related patents.

It is comprehensible if any of the patents within any area overlap across areas. To put it differently, it is expected that some data records are duplicated when compared parallelly with other areas. A single Blockchain patent may not only refer to one single category but may be shared with many others. [19]

For instance, a patent regarding the design of a decentralized database for patient health records might not only make part of the 'Healthcare' area but also to 'AI & Big Data' –to make a general example.

Accruing all efforts in defining the perimeter, the area tag queries are then defined. As mentioned earlier, they follow the structure **"perimeter" AND "area tag" AND "priority year."** The perimeter provides the data pool, and the area tag collects records based on the criteria specified by each area tag. Most of the area tags in this study follow a simple structure of **"keyword_1" OR … OR "keyword_n."**

In particular, area tags are focused on looking in all text fields of patent documents. Hence, why the ALL field is used for this part of the full query. An example of an area tag query is presented in **¡Error! No se encuentra el origen de la referencia.**. This corresponds to the AI & Big Data area tag, which yielded a total of 668 patents out of the total 6.623 from the sample. The rest of the area tags follow a similar construction, and its full query list including the corresponding number of records is provided in **Appendix 4**.

[19] Data retrieved on 29/08/2019. 9:00 PM CEST

Area of Application	Area Tag	Query	# records
Artificial Intelligence & Big Data	ALL=((artificial NEAR intelligence) OR (decentralized NEAR intelligence) OR (computing NEAR power) OR (machine NEAR learning))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND ALL=((artificial NEAR intelligence) OR (decentralized NEAR intelligence) OR (big NEAR data) OR (machine NEAR learning)) AND PRD>=(20120101);	668

TABLE 3. ARTIFICIAL INTELLIGENCE & BIG DATA AREA TAG QUERY

2.2.4. Data extraction

As mentioned in Section *2.1.2. Patents*, patents are made-up of data fields that contain relevant information about patented inventions. For analysis, not all but some specific patent data fields were selected for extraction. The same criteria are applied to all extractions done under the context of this thesis.

Furthermore, a shortlist of the patent data fields for extraction is presented. Namely:

- **Publication Country Code**; corresponds to a two-character code that represents the country of each patent document. It is part of the *Publication Number* field.
- **Application Year**[20]; refers to the year in the *Application Date* field (also called *Filling Date)*.
- **Publication Year**[21]; refers to the year in the *Publication Date* field. The patent was officially published by the patent office.

[20] More information in paragraph *Components of patent documents.*
[21] More information in paragraph *Components of patent documents.*

- **Earliest Priority Year**[22]; refers to the earliest year of a related patent concerning a single patent document. In some cases, it also corresponds with the *Application Year*.

- **Publication Number**[23]; it is the code assigned to the patent document published by the IP authority.

- **Optimized Assignee**; refers to one, or more entities or people who applied for a patent.

- **IPC Subclass**[24]; refers to WIPO's classification for patent documents. Each patent can be part of one or many of these codes.

First of all, the extraction started by inserting the corresponding perimeter query within the patent database search tool. Then, the queried data was extracted and saved following the criteria mentioned above. The total number of records for the sample perimeter was recorded and is reported in **¡Error! No se encuentra el origen de la referencia.**.

Secondly, area tag queries were inserted to extract data related to each area tag (defined in Section *2.2.3. Data clustering*). Again, the corresponding data was saved, and for each classification (i.e. area tag), the total number of records was recorded and reported in **¡Error! No se encuentra el origen de la referencia.**.

Altogether, 6.623 records were extracted using the perimeter query. Hence, defining the sample to build this study database. From the sample, a cumulative[25] total of 6.579 records were obtained from each single area tag query. Since there is only one perimeter (sample), there is no need to check whether there are duplicate records that would affect a possible comparison between different samples. Alternatively, it is expected that some patent records are included in one or more area tags. Still, it was imperative to check for possible duplicates[26] *within* the sample.

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[22] See paragraph *Components of patent documents* in Section *2.1.2. Patents*
[23] See paragraph *Components of patent documents* in Section *2.1.2. Patents*
[24] More information regarding this field can be found in Section *2.1.3. IPC Codes.*
[25] Because some records might be within one or many areas at the same time.
[26] More information can be found in Section *2.2.5. Data cleanup.*

2.2.5. Data cleanup

Generally, patent data is claimed to be disorganized and messy [47]. Usually, data mismatching comes from Assignee/Applicant and Inventor fields.

In order to deliver accurate results, it is necessary to promptly address and correct possible misspellings in the created Database. This must be done before any statistical analysis is performed.

The *WIPO Guidelines for Patent Landscape Reports* suggest different alternatives to fix misspellings for both Assignee and Inventor fields. Still, since we are only extracting Assignee/Applicant-related data, the focus remains to clean this specific field.

Patent Assignee/Applicant Cleanup

This is regarded as the most popular source of misspellings. Particularly due to different ways of writing company names. Figure 18 is an example of a typical error found in the sample. A single company may have different holdings that change the field discussed in this section. The clean-up can be achieved by automatic methods like bootstrapping[27] or manual methods such as PivotTables [47].

Optimized Assignee	Count of Publication Number
ACCENTURE LTD.	77
ACCENTURE LTD. | DIGITAL SECURIT	6
ACCENTURE LTD. | DSX HOLDINGS L	2
ACCENTURE LTD. | GSC SECRYPT LLC	17
GSC SECRYPT LLC | ACCENTURE LTD.	21

FIGURE 18. EXAMPLE OF TYPICAL ERROR IN PATENT DATA

Following this respect, a PivotTable was created with data from the sample perimeter to check whether any records showed errors in this field. This was done by simply placing

[27] A test that takes a given data set and replaces the data taking into account an estimation of its expected value

the "Optimized Assignee" field in rows and counting their corresponding "Publication Number."

In this fashion, the repeated "Optimized Assignee" records would group as one, showcasing possible misspellings. As expected, many records had to be manually handled in order to obtain a clean report. Consequently, the same procedure was applied to area tags data.

Duplicated records

After fixing Assignee/Applicant fields, an additional data check included scrutiny for duplicated reports within the main sample (i.e., perimeter). The procedure to clean this kind of mismatching involved using the "remove duplicates" functionality on MS Excel. However, no repeated records were found within the sample.

2.2.6. Assumptions

Assumptions were considered during the construction of this study. A brief shortlist is presented, namely:

- The perimeter of this study is made up of an extensive amount of Blockchain technology patent data available, and it is significantly abundant to perform these analyses.
- Area segments for Blockchain technology were identified from the literature review, but naming is ultimately proposed by the author of this study.
- The number of overlapping records across area tags is considerably small, hence, neglected.
- The search tool[28] used in this study provided up-to-date and accurate patent data.

[28] Derwent Innovation patent database

Chapter 3

3 Analyses Discussion

This chapter aims at providing a detailed discussion of the individual analyses performed with the extracted patent samples from Derwent Innovation for the Blockchain field and related subfields (the latter, identified in Section *1.2.4. Areas of application*). The different patent samples extracted from the patent repository were reworked following the criteria described in Sections *2.2.3. Data clustering*, *2.2.4. Data extraction* and *2.2.5. Data cleanup*. Finally, for each analysis, considerations labelled in *Sections 2.2.2. Preliminary data checks* and *2.2.6. Assumptions* are applied.

In particular, the first three analyses presented relate to studying general trends within the Blockchain technological field. The first, in Section *3.1. Patent Application Trend*, presents a study on the patenting frequency by year within the Blockchain field as of September 2019. The second, in Section *3.2. Technology Sample Share by Subfield* provides a dissection of the Blockchain technological field in order to analyse the sample share that each Blockchain subfield takes from the perimeter sample. The third, in Section *3.3. Patent Geographic Concentration*, presents an assessment of the frequency of patents published by location[29] in terms of concentration.

Moreover, from the fourth to eight analysis, the focus falls onto identifying and discussing the main players[30] within the Blockchain technological field. Particularly, the fourth analysis (Section *3.4. Top 4 Countries by Subfield*) presents a top 4 ranking of countries with the most patent publication frequency for every technology subfield. The fifth

[29] A location can be either a national, regional or international patent office.
[30] Location (country/patent office) and Applicant/Assignee

analysis, in Section *3.5. Top 10 Innovative* , presents a ranking of the top 10 entities[31]with the most count of patent publications in the general Blockchain field. The sixth analysis, in Section *3.6. Top 4 Innovative Companies by* , provides the identification of the top entities by subfield in terms of C4[32]. The seventh analysis, in Section *3.7. Top 20 Innovative Companies Matrix by Subfield*, provides a co-occurrence matrix including an assessment of the top 20 entities with most patent publication count in the general Blockchain field against its corresponding subfield's figures – a powerful analysis that brings up information about the relative level of maturity of each subfield, and each applicant on a particular subfield. Lastly, the eight analysis (Section *3.8. Top 6 Innovative Universities*) follows a similar structure that the study in Section *3.5. Top 10 Innovative* ; however, for this particular analysis filters are introduced in order to analyze top academic institutions only.

Finally, the ninth analysis (Section *3.9. Top 3 IPC Code*) presents the top 3 IPC subclasses used in Blockchain application filings. The scope of this study is to provide a basis for potential Blockchain stakeholders on which are the main standardized categories employed by patent applicants when filing a Blockchain-related patent.

[31] Applicant/Assignee
[32] Ranking of top 4 Applicant/Assignee

3.1. Patent Application Trend

Aiming at studying the overall patent sample, the first analysis follows a top-down evaluation of the patenting trend. Hence, first focusing the attention on a general application trend analysis and a subsequent detailed trend by area of application. Particularly, this type of analysis aims forward to study application trends along the time for the technology in question. In spite of doing so, the following data was taken into account:

- Application Year[33]
- Publication Number[34]

Firstly, the analysis started with the construction of a simple Pivot Table in MS Excel, reporting the *Application Year* field on the Y-axis (i.e., as Row Labels) and its corresponding count of *Publication Number* records on the X-axis (i.e. within the 'Value' box in the PivotTable settings). Obviously, the single Publication Number record itself does not provide any relevant data for this analysis, but to count it means to count the number of patent documents within the sample. The same procedure was done for preparing a detailed application trend analysis by area.

Then, the generated PivotTable provided inputs for preparing a bigger spreadsheet containing raw results for the overall sample and each area. This spreadsheet can be found in **Appendix 5** and **Appendix 6**. Afterward, the data was organized in four different columns. From left to right, namely: *Area*, *Application Year*, *Number of Patents* and *Variation w.r.t. first year >0*. The latter column was added after defining the year 2014 as the reference year for calculating the percentage variation ratio in the number of patents during a given year. So, for a given year n, this so-called variation ratio was calculated by dividing year n figures by year 2014 figures. Thus, for each year this variable was calculated and reported on the '*Variation w.r.t. first year >0'* column. With this in mind, the patent number variation rate was plotted by Application Year for Blockchain

[33] See paragraph *Components of patent documents* in Section *2.1.2. Patents*
[34] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

technology and its areas of application. The results are then presented in **Figure 19** and **Figure 20**.

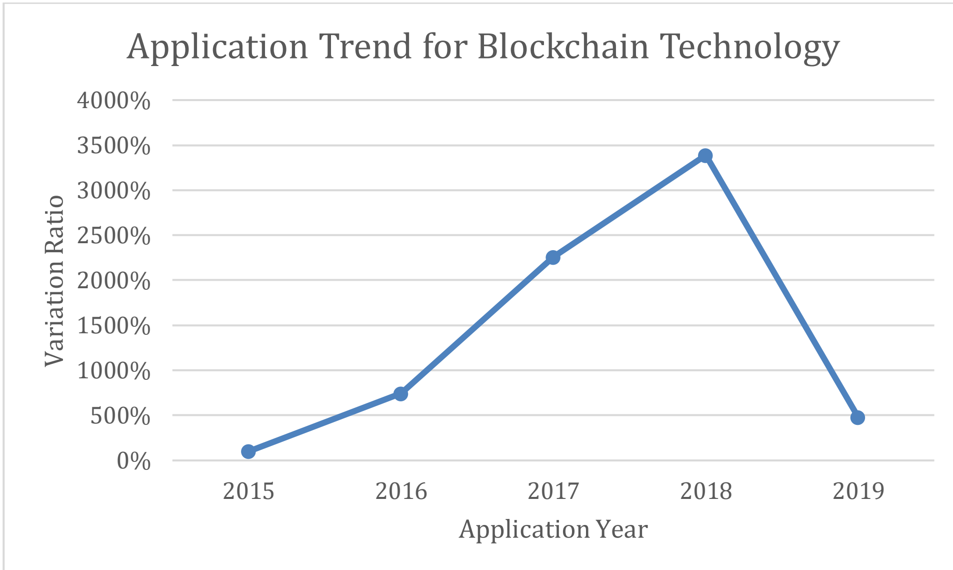

FIGURE 19. RELATIVE APPLICATION TREND FOR BLOCKCHAIN TECHNOLOGY

Firstly, **Figure 19** refers to a line chart depicting the patent application trend from the year 2015 until 2019. The structure of the graph shows the *Variation Ratio* percentage on the Y-axis and the *Application Year* reported on the X-axis. The timeframe responds to the data found in the patent database. That is, the data extracted contained only data from 2014 to 2019. Even if there were patents published for years < 2013 and the data extraction considered only patents published after 2012 (see *Section 2.2.2. Preliminary data checks*), application dates reported on the patent documents extracted dated from 2014 onwards.

Overall, the results shown demonstrate that Blockchain is a young technology steadily growing with fast pace since the first related patent application in the year 2014 (see **Appendix 5** and **Appendix 6**). It could be argued that this is a response to an ongoing increase of the perception of the possible benefits[35] that the technology could provide to businesses and society in general. Additionally, the reason why there are extremely high percentages is explained by the fact that during 2014, there was only one patent application

[35] See Section *1.2.1. Advantages*

– making the subsequent variation ratios very high since the reference year figures are almost infinitesimal relative to following year figures.

Moreover, it is known that the first[36] existing record of Blockchain-related content was published online in 2008. However, the graph shows that it was only after 2014 that there is patent data available. This might be explained —yet again— by how poorly the technology was known before the upheaval of Bitcoin cryptocurrency in 2013.

Now glancing the upcoming years, from 2017 to 2018, it can be seen how patent application rate decreased, yet it still shows positive growth. This does not say anything about companies leaving the Blockchain market, or anything else: applications are still being submitted year by year, but the change was not as big as it was during 2017.

Finally, in 2019, the patent application rate shows negative growth with a percentage lower than 2018 figures. So far, by today[37], it was expected that there is not a positive growth value for 2019 since the year has not yet ended. Another reason could be that the Derwent Innovation patent database has not updated current year records, yet. Then, figures could pick up by the end of the year.

[36] S. Nakamoto's whitepaper on Bitcoin [1]
[37] September 1st, 2019. 6:30 PM CEST

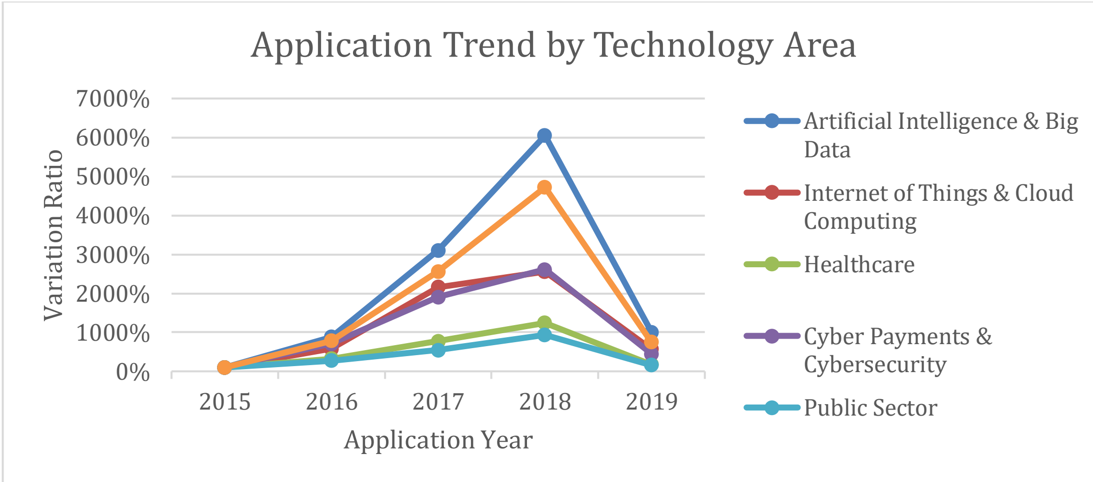

FIGURE 20. RELATIVE APPLICATION TREND BY TECHNOLOGY AREA

On the other hand, the same application trend analysis by area of application is presented above in **Figure 20**. Following a similar arrangement of data, the *Variation Ratio* (i.e., *Variation w.r.t. first year >0*) series is presented on the Y-axis and the *Application Year* on the X-axis. Furthermore, since there were no data records for any single subfield for the year 2015, the reference year for *Variation Ratio* calculation considered is the year 2015 (although there is one record from 2014).

By glancing the big picture, it can be seen that all subfields are steadily growing overtime since 2015. In particular, for the year 2014, there are no records for any single subfield. Thus, the growth is set to 0% by default. Consequently, the first applications for any of the technological areas happened during 2015. In fact, looking back at the year 2015 in **Figure 19**, it is interesting to note that even if all areas started more or less at the same pace, overtime until 2018, some became considerably more prominent than the others in terms of the relative growth of patent applicants. Particularly, AI & Big Data has been the sector that has grown the most relative to its first figures back in 2015, and the sector that has grown the less –yet has still shown positive growth– is the Public Sector. Moreover, the sharp negative valley during 2019, same as in **Figure 19**, is related to data being extracted for the current year which has not yet ended and thus the patent database is not completely updated.

Since the scope of this analysis is to compare figures from years different than 2015 w.r.t. to 2015 figures, the discussion will focus on the results reported from 2016 onwards in **Figure 20**. From higher to lower variation rate, in the first place, there is AI & Big Data (883%), followed by Supply Chain & Logistics (786%), Cyber Payments & Cybersecurity (707%), IoT & Cloud Computing (579%), Healthcare (320%), and Public Sector (278%). What highlights during this year, is that AI & Big Data have the highest patent growth rate but in general, it does not represent the biggest share of the total Blockchain patents sample obtained to realise this study (see *Section 0.*

Technology Sample Share by). Moreover, as the years passed up until today (i.e. 2019), it remains first with the highest patent application rate growth.

Still from the year 2016, focusing now on Supply Chain & Logistics; it can be seen that it is predominantly consistent with its position as second in the trend graph. Both AI & Big Data and Supply Chain & Logistics share this kind of leadership over time, and they are likely to keep growing, for what has been seen before, given that Blockchain is new technology in early stages of development. However, these trends might shift as market needs change as well.

Next, for Cyber Payments and Cybersecurity, it is noteworthy that while being the biggest[38] subfield within the entire Blockchain sample, it remains third for most of the trend until the current year, except during 2017 (1904%), when the relative growth was surpassed by IoT & Cloud Computing (2564%).

Furthermore, focusing on IoT & Cloud Computing, it can be noticed that it began as fourth from the year 2016 (579%), became third during 2017 (2564%) and eventually fourth during 2018 (2558%). Both Cyber Payments & Cybersecurity, and IoT & Cloud Computing share more or less the same trend, with a slight deceleration on patent applications in 2018. These results prove that contrary to popular belief, the subfields that are growing with a higher pace are AI & Big Data and Supply Chain & Logistics instead of Cyber Payments & Cybersecurity (which relate to cryptocurrencies and payments, in general – see *Section 1.2.4. Areas of application*).

Lastly, from the year 2016 and respectively, Healthcare (320%) and Public Sector (278%) start from fifth and sixth position in the trend graph. Finally, both end in 2018 with a modest 1240% and 933%, respectively. Their application trend position is particularly constant over time, both keeping their position, and steadily growing at a slower pace than other subfields.

[38] See Section ***¡Error! No se encuentra el origen de la referencia.***. ***¡Error! No se encuentra el origen de la referencia.***

3.2. Technology Sample Share by Subfield

The second analysis performed in this study showcases the patent concentration by the technology area for Blockchain. With the results presented, the goal is to analyze the frequency of technology areas in Blockchain. This is an important step in this thesis, as it provides insights on the share that each subfield takes from the overall technology sample. Additionally, this study may offer an overview of which is the area that has accumulated more innovative efforts over time until today.

In so doing, the following data fields were used to perform the present analysis:

- Number of Patents by Area
- Number of Patents in the Sample

First of all, the graph reported in **Figure 21** and **Table 4** were constructed using data collected from the queries discussed in Section *2.2.3. Data clustering*. The complete spreadsheet containing the query data in detail can be found in **¡Error! No se encuentra el origen de la referencia.**. Basically, **Table 4** was constructed using the numbers reported in the column '# of Patents' within the "Area Query" table. The sample size was collected from the figure reported in '# of Patents' within the 'Perimeter Query' table. Then, a percentage of such numbers w.r.t. entire sample size (6.623 records) was calculated. Finally, each magnitude was listed next to its correspondent area, and the pie chart (**Figure 21**) created based on the percentages reported in **¡Error! No se encuentra el origen de la referencia.**.

Area of Application	# of Patents	Sample Share
Cyber Payments & Cybersecurity	2658	40%
IoT & Cloud Computing	1432	21%
Supply Chain & Logistics	1249	19%
Artificial Intelligence & Big Data	668	10%
Healthcare	391	6%
Public Sector	181	3%
Patentes w/o Applicable Subfield	84	1%

TABLE 4. TECHNOLOGY AREA CONCENTRATION

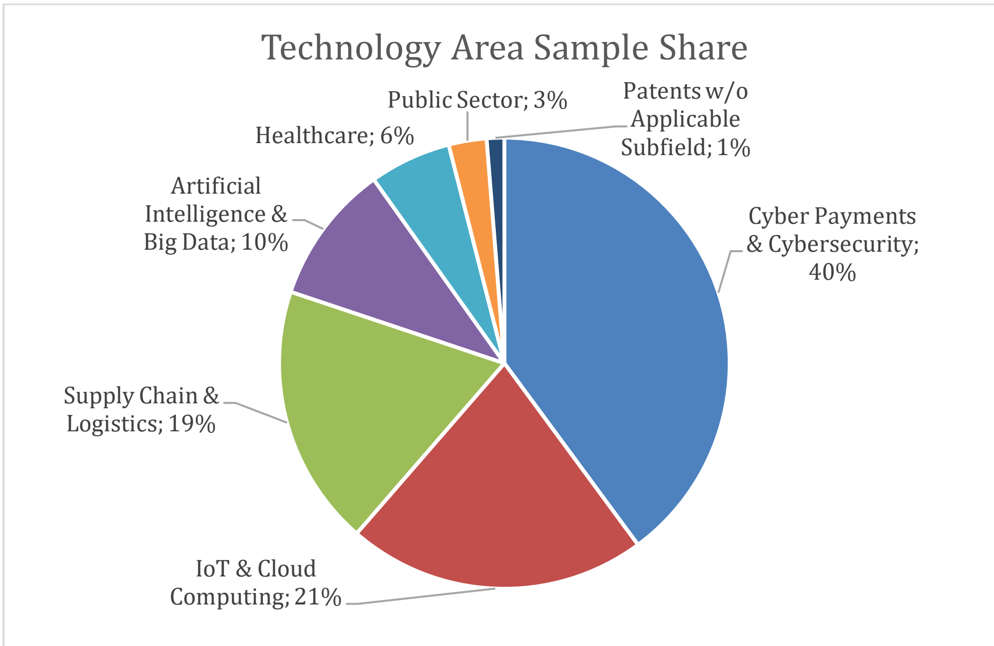

FIGURE 21. TECHNOLOGY AREA SAMPLE SHARE

The figure depicted above is a pie chart containing information about each subfield's share within the whole Blockchain sample, in percentage. A specific color is assigned to each field to difference one another. The subfields considered are, from highest to lowest sample share, Cyber Payments & Cybersecurity (40%), IoT & Cloud Computing (21%), Supply Chain & Logistics (19%), AI & Big Data (10%), Healthcare (6%), Public Sector (3%) and Patents without Applicable Subfield (1%). Moreover, these are not percentages based on the sum of each subfields' patent volume, but rather the share each subfield takes from the overall sample of 6.623 patents.

The first takeaway from the picture is that Cyber Payments & Cybersecurity (40%) accounts for the most patents within the technological field. Given that the first application of Blockchain technology known is the Bitcoin, it is expected that Cyber Payments is the area that holds a bigger volume of patents by today. However, this does not say that this is the most relevant area today — the analysis performed in Section *3.1. Patent Application*

Trend showed that nowadays the fast-growing subfields are others. However, it remains an important area within Blockchain.

Next, the red area corresponds to IoT & Cloud Computing (21%), which results surprising, as IoT & Cloud Computing is a fairly new sector within the industry. These results might be compensated by what has been seen in *Section 3.2. Technology Sample Share by*), when it was found that IoT & Cloud Computing has been growing steadily since 2015 with a positive slope (i.e., positive growth), which in turn, explains that many applications were submitted for this subfield during 2015 but, from 2017 to 2019, the change has not been as significantly high that it has been for say, areas like AI & Big Data or Supply Chain & Logistics – however, the absolute patents published have been very high.

Then, the green area corresponds to Supply Chain & Logistics (19%), occupying the third position in sample share percentage. In fact, citing in Section *1.1. Technical Aspects*, Supply Chain & Logistics, is considered one of the most important areas for Blockchain, due to their economic impact within markets worldwide. Hence, it could be expected to find this subfield among those frequent areas for Blockchain patents.

The next and smaller slices of the pie chart correspond to AI & Big Data (10%), Healthcare (6%) and Public Sector (3%). Surprisingly, AI & Big Data has been the subfield that has grown the most, yet, it remains a small piece within the entire sample. At first glance, the information might be misleading if it is not considered that AI & Big Data are also emergent fields within industries, compared to say, Healthcare and the Public Sector which exist for centuries. However –considering the latter–, even AI & Big Data sample share is smaller, it is of high importance to highlight that this subfield is growing faster relatively than others.

3.3. Patent Geographic Concentration

The following is the third analysis in this study, and it refers to a geographical[39] dissection of the Blockchain patent data sample, in terms of frequency of patents per location. With the result herein displayed, the goal is to understand in which magnitude certain countries accrue the most patents related to Blockchain technology.

The analysis follows, similar to the one discussed in Section *3.1. Patent Application Trend*, a top-down evaluation of the top countries (or patent offices[40]) in which patents were published. In order to develop this analysis, the following data were taken into account:

- Publication Country Code[41]
- Publication Number[42]

Firstly, the analysis started with the construction of a simple Pivot Table in MS Excel. The data analysis process follows a similar logic that the one reported in the previous section. In this case, the *Publication Country Code* field was extracted directly from the patent database. Although another way to extract it would imply to perform a simple conditional count (e.g., by Country Code) for the *Publication Number field* on MS Excel, it was simpler to extract the actual field from Derwent Innovation.

Consequently, the *Publication Country Code* composes the Y-axis (i.e. as Row Labels) and its corresponding count of *Publication Number* records on the X-axis (i.e., within the 'Value' box in the PivotTable settings). Again, the single Publication Number alone does not provide important data for this type of analysis, but its count provides the number of patent records for the criteria selected. The same procedure was done for preparing a detailed patent geographic concentration by area. Additionally, an 'Others' label was

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[39] Since patents can not only be submitted in local offices, this study includes also regional and international patent offices – See Section *2.1.1. IP & regulatory bodies*

[40] European Patent Office (EPO) or World Intellectual Property Office (WIPO)

[41] Two first characters of the *Publication Number* field; Derwent Innovation provides this field.

[42] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

included to represent the rest of the patent records published in other countries outside the top 10. Then, this data was organized in a spreadsheet in order to prepare the graph reported in **Figure 22**. The detailed work spreadsheet can be found in **¡Error! No se encuentra el origen de la referencia.**.

On top of that, **¡Error! No se encuentra el origen de la referencia.** was constructed using Clarivate's website, [43] which contains a list with each nation's *Publication Country Code*.

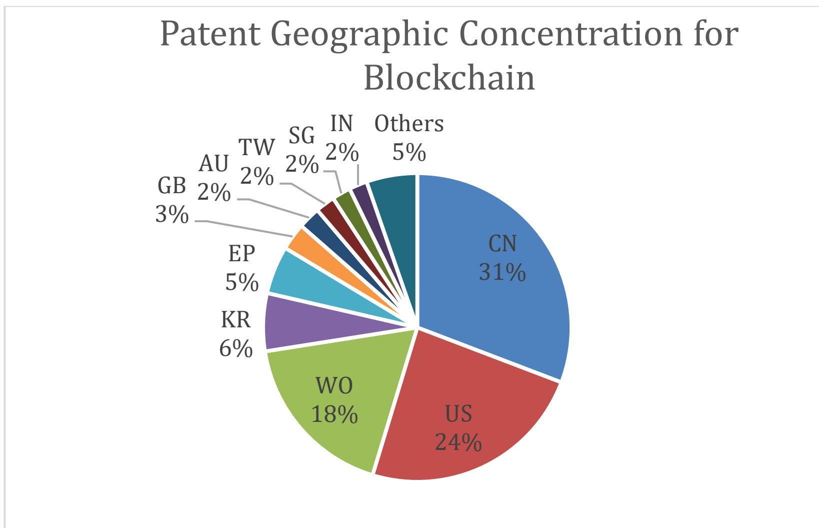

FIGURE 22. GEOGRAPHIC CONCENTRATION FOR BLOCKCHAIN PATENTS

Position	**Country Code**	**Country (or Patent Office)**
1	CN	China
2	US	United States of America
3	WO	World Intellectual Property Organization
4	KR	Republic of Korea
5	EP	European Patent Office
6	GB	United Kingdom
7	AU	Australia
8	TW	Taiwan
9	SG	Singapore
10	IN	India

[43] Publication Country Codes can be found here: http://ips.clarivate.com/m/pdfs/dwpicovkinds/wipo_codes.pdf

TABLE 5. TOP 10 INNOVATIVE COUNTRIES IN BLOCKCHAIN

In **Figure 22**, a pie chart depicting the patent sample share percentage by geographical location (i.e., patent concentration in terms of geography) for patents within the Blockchain perimeter is presented. By having a general overlook of the graph, top ten countries plus an 'Others' series are shown. In the chart, from highest to lowest sample share, the countries (and patent offices) presented are, namely: China (31%), United States of America (24%), the World Intellectual Property Office (18%), Republic of Korea (6%), European Patent Office (5%), United Kingdom (3%), Australia (2%), Taiwan (2%), Singapore (2%), India (2%) and Others (5%).

Blockchain innovation is highly concentrated in China and the US. In particular, it can be appreciated how big the blue and red slices (31% and 24%, respectively) are, compared with the rest of the 'sections' of the pie chart in **Figure 22**.

Additionally, a detailed list providing a cumulated assessment of the sample share for Blockchain technology is shown in **Table 6**. Under this context, the overall Blockchain patent innovative intensity can be evaluated by looking at the numbers in column 'Cumulated Share' – which is the sum of a given n country's sample share and the previous n^{-1} country's cumulated sum. The cumulated share is added starting from China (i.e., Top 1 country) and ends with the 'Others' section for a total 100% sample size.

Taking into account the information provided in **Table 6**, China (in the first place) and the United States (in second place) cumulated shared overtake almost over the entire Blockchain[44] sample. These are the principal innovative countries in Blockchain technology, each possessing 2.039 and 1.583 published patents, respectively, from a total of 6.623 patents in the sample. The latter suggests these geographical zones are the biggest powerhouses for Blockchain.

On the other hand, reported in **Table 7** can be found a thorough evaluation of China & the US cumulated percentage share against the rest of the sample, by area. This table has seven columns in the upper row. The first column, from left to right, refers to the country

[44] Refers to the entire patent sample perimeter

classifications which include the accrual of both China and the US patent sample share versus the cumulated results for the share of the rest of countries. On the remaining columns, the cumulated results for every single subfield by 'Country' classification are presented. This table provides an interesting outlook on how concentrated most areas are w.r.t. these two countries.

Position	Country Code	Sample Share	Cumulated Share
1	CN	30,79%	30,79%
2	US	23,90%	54,69%
3	WO	17,83%	72,52%
4	KR	6,07%	78,59%
5	EP	5,03%	83,62%
6	GB	2,82%	86,44%
7	AU	2,33%	88,77%
8	TW	2,04%	90,80%
9	SG	1,96%	92,77%
10	IN	1,90%	94,67%
…	Others	5,33%	100,00%

TABLE 6. COUNTRIES' CUMULATED SAMPLE SHARE FOR BLOCKCHAIN SAMPLE

Subfield / Country	*IoT & Cloud Computing*	*Cyber Payments & Cybersecurity*	*Public Sector*	*Healthcare*	*AI & Big Data*	*Supply Chain & Logistics*
China & US	64,04%	47,29%	62,43%	64,71%	64,22%	68,05%
Others	35,96%	52,71%	37,57%	35,29%	35,78%	31,95%

TABLE 7. US-CHINA CUMULATED CONCENTRATION BY AREA

In particular, the following are relevant points related to geographical concentration considering only the Blockchain sample. Namely:

- As shown in **Table 6¡Error! No se encuentra el origen de la referencia.** , only both China and the US hold a whopping 54% of Blockchain patents. This demonstrates how highly concentrated Blockchain patents are within these two countries, bearing in mind that this study took into account data from 34 different nations.

- As seen on **Figure 22**, it can be said that 'Others' (i.e., other countries outside the top 10) represent only 5% of the sample (with circa 353 records), again making obvious the fact that this technology's innovation landscape is very concentrated somewhere within the top 10 – particularly, in China & the US as seen before in **¡Error! No se encuentra el origen de la referencia.**.
- Yet in **Figure 22**, the UK, Australia, Taiwan, Singapore, and India make only 11% of the sample with a total of 732 patents (out of 6.632 patents). A number that is still inferior when compared to China and the United States.

Now, considering **Table 7** only, the following are relevant points related to geographical concentration in Blockchain technology's subfields for the US and China. Namely:

- China & the US concentrate more than half of the published patents for all subfields except Cyber Payments & Cybersecurity. Interestingly, being this one the biggest and widely known subfield in Blockchain technology, it is not surprising to find out that patents are less concentrated (w.r.t. China & the US).
- Supply Chain & Logistics is the field in which both China & the US concentrate the most published patents relative to the rest of the locations in the sample. Again, this premise is sustained by looking at the results in *3.4. Top 4 Countries by* , when it was found that China leads this subfield. Since it makes a big contribution to the cumulated result, it is expected that this particular field presents a higher concentration than the others where both countries are also ahead than the rest of the countries within the sample.

3.4. Top 4 Countries by Subfield

In the previous section, a general assessment of the geographic frequency for the sample and its subfields was presented. Here, a detailed analysis of the geographic concentration by area is introduced following the classic top-down approach of this study.

The fields presented below were used for this analysis; namely:

- Publication Country Code
- Publication Number[45]

Moreover, the same criteria employed in the previous section apply for the study herein described: a PivotTable on MS Excel using *Publication Country Code* field on Row Label (i.e., Y-axis) and *Publication Number* on the Value Field (i.e., X-axis) in the form count, however, the way in which the data is presented differs.

Particularly, this study aims at providing insights into which countries (or patent offices) are specializing the most in one specific technology area. The results are broken down below in the form of C4 and range from **Table 8¡Error! No se encuentra el origen de la referencia.** to **Table 13**. The corresponding work spreadsheet containing these tables can also be found in **Appendix 7**.

AI & Big Data			
Position	Country Code	# of Patents	Sample Share
1	US	293	43,86%
2	CN	136	20,36%
3	WO	129	19,31%
4	KR	27	4,04%

TABLE 8. TOP 4 COUNTRIES FOR AI & BIG DATA

[45] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

Cyber Payments & Cybersecurity			
Position	Country Code	# of Patents	Sample Share
1	US	854	32,13%
2	WO	657	24,72%
3	CN	403	15,16%
4	EP	184	6,92%

TABLE 9. TOP 4 COUNTRIES FOR CYBER PAYMENTS & CYBERSECURITY

Healthcare			
Position	Country Code	# of Patents	Sample Share
1	US	204	52,17%
2	WO	76	19,44%
3	CN	49	12,53%
4	EP	16	4,09%

TABLE 10. TOP 4 COUNTRIES FOR HEALTHCARE

Public Sector			
Position	Country Code	# of Patents	Sample Share
1	US	82	45,30%
2	WO	36	19,89%
3	CN	31	17,13%
4	EP	10	5,52%

TABLE 11. TOP 4 COUNTRIES FOR PUBLIC SECTOR

IoT & Cloud Computing			
Position	Country Code	# of Patents	Sample Share
1	US	611	42,67%
2	WO	306	21,37%
3	CN	243	16,97%
4	EP	87	6,08%

TABLE 12. TOP 4 COUNTRIES FOR IOT & CLOUD COMPUTING

Supply Chain & Logistics			
Position	Country Code	# of Patents	Sample Share
1	CN	442	35,39%
2	US	408	32,67%
3	WO	227	18,17%
4	EP	44	3,52%

TABLE 13. TOP 4 COUNTRIES FOR SUPPLY CHAIN & LOGISTICS

The following are important highlights from the tables presented above. Namely:

- The two predominant countries in all areas are China and the United States. Surprisingly, from **Figure 22**, it is known that China (with 2.039 patents) has a bigger frequency of patent publication in Blockchain technology than the US (1.583) – yet, the US takes advantage in every single area except for Supply Chain & Logistics. Where China takes the lead, concentrating 35,39% of patents and the US with 32,67% of patents, out of a total of 1.249 patens within this area.

- The latter, in turn, suggests that it is thanks to specializing in Supply Chain & Logistics that China has become a leader in Blockchain technology. Moreover, China's history of dominance in Supply Chain [56] is a well-known fact, and the idea of it being top 1 in Supply Chain & Logistics becomes obvious after recalling it– so to say.

- Conversely, the European region represented by the European Patent Office (EPO) takes the fourth place within IoT & Cloud Computing (with 6,08%), Cyber Payments & Cybersecurity (with 6,92%), Public Sector (with 5,52), Healthcare (with 4,09%), and Supply Chain & Logistics (with 3,52%).

- The Republic of Korea (with 4,04%) demonstrates its dominance over the European region (with 2,99%) in the area of AI & Big Data.

- Finally, the World Intellectual Property Office holds the second place within IoT & Cloud Computing (with 21,37%), Cyber Payments & Cybersecurity (with 24,72%), Public Sector (with 19,89%) and Healthcare (with 19,44%). And, the third position within AI & Big Data (19,31%) and Supply Chain & Logistics (18,17%).

3.5. Top 10 Innovative Companies

The fifth analysis refers to a ranking of the top 10 Applicants/Assignees[46] by the number of patents published from 2014 to 2019. The advantages of analyzing patent data include the possibility of determining which are the main players for a specific tech field and, spotting the organizations that have made significant investments in R&D in such field [47]; in this specific case, for Blockchain. Also, for a given technology, patent data can provide investors or researchers with vital information about potential partners for investments or research.

In order to develop this analysis, the following data from the sample (i.e., perimeter) database were considered:

- Applicant/Assignee[47]
- Publication Number[48]

Consequently, the extraction phase comprised not only the collection of the data mentioned above but also the cleanup of the Applicant/Assignee data fields. More on this step can be found in Section *2.2.5. Data cleanup*. After having ensured the quality of the fields, the procedure followed the creation of a PivotTable on MS Excel to group the data of interest. First, the *Applicant/Assignee* and *Publication Number* fields were sorted in the Row Labels and Value fields, respectively. Since the aim of this analysis is to find out which entities are the top innovators, the interest remains in counting the *Publication Number* fields to look at the number of patents by *Applicant/Assignee*. Again, the Publication Number by itself is not any source of information, however, by counting its records, the number of patents can be retrieved under given criteria – correspondingly, by *Applicant/Assignee* in this instance. Clearly, the *Applicant/Assignee* field implies that the entities retrieved during the data extraction part of this study include both patent

[46] Entities that can be either companies or individuals
[47] See paragraph *Components of patent documents* in Section *2.1.2. Patents*
[48] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

applicants[49] and assignees[50] – so to include all stakeholders involved in the Blockchain innovation landscape. Finally, after obtaining the number of patents by entity, the percentage sample share of patents by entity was also calculated on the basis of a total of 1.681 applicants/assignees found within the sample.

Consequently, the top 10 was listed, and the rest of the entities were grouped in 'Others' row. For more details, please refer to the analysis presented in **¡Error! No se encuentra el origen de la referencia.**. The final results drawn from the analysis are shown in **Table 14** and **Figure 23**.

Position	**Top Company**	**# of Patents**	**Sample Share**	**Cumulated Share**
1	NCHAIN HOLDINGS LTD	555	8,38%	8,38%
2	ALIBABA GROUP HOLDING LTD	353	5,33%	13,71%
3	IBM	242	3,65%	17,36%
4	MASTERCARD INC	226	3,41%	20,78%
5	BIZMODELINE CO LTD	104	1,57%	22,35%
6	COINPLUG INC	87	1,31%	23,66%
7	ACCENTURE LTD.	77	1,16%	24,82%
8	HUAWEI TECHNOLOGIES COMPANY LTD.	66	1,00%	25,82%
9	PINGAN TECHNOLOGY SHENZHEN CO LTD	60	0,91%	26,73%
10	WALMART STORES INC	56	0,85%	27,57%
…	OTHERS	4797	72,43%	100,00%

TABLE 14. DISTRIBUTION OF PATENTS AMONG MAIN PLAYERS IN BLOCKCHAIN TECHNOLOGY

Reported in **Table 14¡Error! No se encuentra el origen de la referencia.**, are listed the 'top companies' (*Applicant/Assignee* column– second column, from left to right) w.r.t. to their sample patent share (fourth column, from left to right) in the Blockchain data set. The list is sorted from the highest to lowest order, w.r.t. their number of patents (second column, from left to right). Subsequently, the sample share is calculated based on a percentage w.r.t. the total number of patents within the sample. Additionally, each top

[49] Entities that have submitted an application for a patent, but have not yet been assigned one
[50] Entities that have been assigned a patent

company is provided with a position number stating their position in the 'innovative' ranking (first column, from left to right).

As shown in **Table 14**, the technology field is not very concentrated among applicants, with its top four companies in the ranking holding only circa 20% of the total patent records. Hence, suggesting that Blockchain is still open to new entrants and there are no deeply involved players. Contrary to a mature technology where there are already strong main players established, Blockchain is still a young area with much free room for more stakeholders to join the market. This is expected for a tech field in the early stages of development.

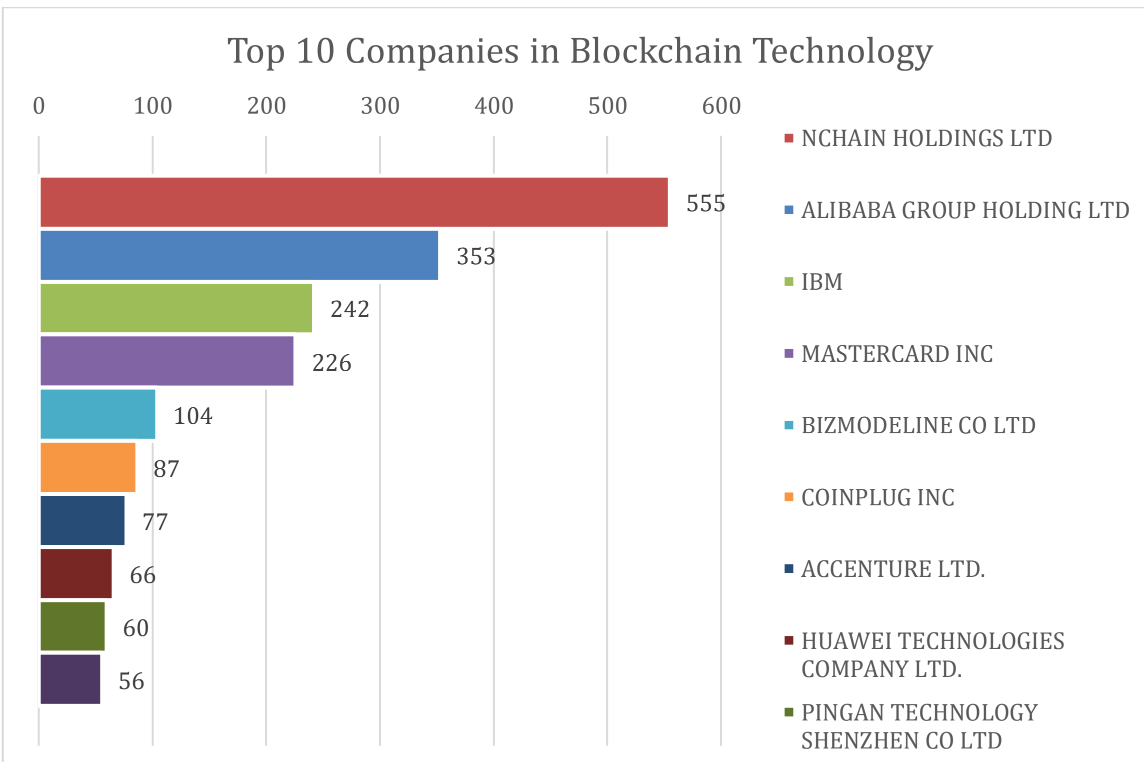

FIGURE 23. TOP 10 COMPANIES IN BLOCKCHAIN TECHNOLOGY

Conversely, in **Figure 23**, a bar chart depicting 'top companies' by number of patents is presented. The X-axis refers to the number of patents for a single entity. The Y-axis instead, refers to the top companies in Blockchain technology. Top companies (i.e., the X-axis) are sorted w.r.t. their total number of assigned or applied for patents in a higher to lower scale. The analysis was developed **Figure 22**. Geographic Concentration for

Blockchain Patentsbearing in mind that Blockchain is an emergent technology, industry knowledge is relatively scarce and that the data pool is small. Hence, slight differences may signify bigger implications.

In general, both **Figure 23** and **Table 14** suggest that NCHAIN HOLDINGS LTD. (first position, with 555 patents), ALIBABA GROUP HOLDING LTD. (second position, with 353 patents), IBM (third position, with 242 patents) and MASTERCARD INC (fourth position, with 226 patents) could be considered main players in Blockchain innovation and have, then, invested significant resources into R&D in this field. However, as mentioned above, they only concentrate around 20% of patents in the tech field. With the rest of the players in the ranking accruing for more or less the same share of patents within the sample.

The top continues with: BIZMODELINE CO LTD (fifth position, with 104 patents), COINPLUG INC (sixth position, with 87 patents), ACCENTURE LTD. (seventh position, with 77 patents), HUAWEI TECHNOLOGIES COMPANY LTD. (eight position, with 66 patents), PINGAN TECHNOLOGY SHENZHEN CO LTD (ninth position, with 60 patents), and finally WALMART STORES INC (tenth position with 56 patents).

In particular, from **Table 14**, CHAIN HOLDINGS LTD. leads the ranking with an IP portfolio that includes a whopping share of 8,38% of the total sample. It was founded in 2017 by self-proclaimed Bitcoin inventor Craigh 'Satoshi' Wright. The company focuses mainly on R&D in order to build a more stable version of Bitcoin that can hold massive scaling of data [57]. In an attempt of protecting its massive portfolio of inventions, the company has made it clear that it is adopting an aggressive position towards this goal. During 2019, they looked towards hiring a new law IP enforcement official that would focus on this task [58].

The second company in the ranking is ALIBABA GROUP HOLDING LTD. This Chinese conglomerate was founded in 1994 and is the world's fourth-largest internet company by revenue includes different subsidiaries, especially in retail and cloud service markets with Alibaba.com[51] and Alibaba Cloud[52], respectively, among many others. With a patent portfolio that comprehends 5,33% out of the total sample, it is currently working in important investment projects like integrating Blockchain within its vast IP filling system[53], providing Blockchain-as-a-Service (BaaS)[54] cloud-based services for enterprises like and prevent fraud[55] in retail using Blockchain-based solutions.

IBM is the third company in the ranking, with a modest patent share of 3,65%. The company's Blockchain division[56] focuses mainly on developing and providing services related to Blockchain-as-a-Service (BaaS), the food industry, cybersecurity, trade finance, and cyber payments. Under this context, IMB is currently developing enterprise cloud-based systems, system architectures for enhancing supply chain trust, provide decentralised identity management systems, and real-time transparent cross-border payments. Also, IBM is recently introducing a new network-based service that specialises in aiding SMEs[57] to form new trade partnerships. Finally, this company is incurring in many different aspects of business. The industries IBM is pairing with to provide Blockchain solutions are, namely: financial services, insurance, media & entertainment, retail, and supply chain.

The fourth company in the ranking is MASTERCARD INC., with an IP portfolio that comprehends about 3,41% out of the total patent sample. It is the second[58] leading credit card issuer company in the world just after Visa, with 191 million cardholders. Its R&D division is mainly focusing on leveraging Blockchain technology in providing proof-of-provenance and B2B cross-border payment systems. In order to create new opportunities for the digital transfer of value, MASTERCARD INC. is developing a Blockchain API[59]

[51] Chinese retail e-commerce marketplace *Alibaba.com*

[52] Subsidiary website for *Alibaba Cloud* services: https://www.alibabacloud.com

[53] For more information, please refer to the article: https://cointelegraph.com/news/e-commerce-giant-alibaba-to-integrate-blockchain-into-intellectual-property-system

[54] Alibaba BaaS enterprise platform: https://www.alibabacloud.com/products/baas

[55] For more information, please refer to the article: https://www.altoros.com/blog/alibaba-aims-to-prevent-retail-fraud-with-blockchain/

[56] IBM Blockchain division website: https://www.ibm.com/blockchain

[57] Small and medium-sized enterprises

[58] "*Credit Card Companies | 15 Largest Issuers (2019 List)*": https://www.cardrates.com/news/credit-card-companies/"

[59] Application Program Interface

that leverages a permissioned network. It claims to provide privacy, flexibility, and data scalability embedded within such network. Currently, such APIs are experimental and only available for testing with business partners.

The Blockchain technological field is attractive to companies operating in a wide range of sectors. Companies from position 5 to 10 operate in Fintech, Consulting, Telecomunications, Healthcare, Real Estate Services, and Smart Cities. Which is not surprising, as the tech field is relatively new – having started as a technology per se circa 2014 (*Section 3.1. Patent Application Trend*). Moreover, Blockchain is attracting attention from companies working in fast-paced environments, especially those that specialize in emerging fields like Smart Cities, Fintech, and Consulting.

3.6. Top 4 Innovative Companies by Subfield

The goal is to find out which are the main players within each technology area. Also, this analysis provides a closer look at which are relatively[60] most mature areas in Blockchain.

In order to develop this analysis, the following data from each subfield sample were considered:

- Applicant/Assignee[61]
- Publication Number[62]

Tables from **Table 15** to **Table 20**, were created from a PivotTable in MS Excel. The method follows the same data approach used in the analyses in Sections *3.2. Technology Sample Share by Subfield* and *3.5. Top 10 Innovative Companies*.

By looking at the cumulated share at the top 4 positions in each table, useful information about the relative maturity level of given subfield can be extracted. The corresponding analysis can be done by creating a line chart depicting the cumulated share data. However, it would be misleading to compare bigger subfields with more than 1.200 records, against subfields that barely reach 150 records. To attain this matter, it becomes necessary to split the analysis in two: a chart comparing subfields with a share greater or equal than 15%, and another one with subfields of share less than 15% from the Blockchain perimeter.

Tables from **Table 15** to **Table 20** depict a ranking of the top 4 companies with most filed and assigned patents for each Subfield. The tables are presented in the following pages.

The Tables show that IBM is consistently accruing knowledge in all subfields except for the Public Sector. In fact, IBM has dedicated an especial division within its company

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[60] w.r.t. their total number of records
[61] See paragraph *Components of patent documents* in Section *2.1.2. Patents*
[62] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

to develop and market Blockchain for different fields. It is then followed by the Alibaba group which is consistently investing in developing Blockchain innovation in all subfields except for the Public Sector and Healthcare.

Another important remark falls on the top 1 player in Blockchain NCHAIN HOLDINGS LTD. to be particularly interested in Cyber Payments & Cybersecurity and IoT & Cloud Computing.

The AI & Big Data sector is mainly attractive to companies working in the software industry. Including known players like Microsoft and IBM. Moreover, Cognitive Scale is a company that specializes in AI software. Therefore, it does make sense for it to be included within the ranking.

IoT & Cloud Computing				
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	IBM	135	9,43%	9,43%
2	NCHAIN HOLDINGS LTD.	71	4,96%	14,39%
3	ALIBABA GROUP HOLDING LTD.	70	4,89%	19,27%
4	ACCENTURE LTD.	36	2,51%	21,79%
…	OTHERS	1120	78,21%	100,00%

TABLE 15. TOP 4 COMPANIES IN IOT & CLOUD COMPUTING

Cyber Payments & Cybersecurity				
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	NCHAIN HOLDINGS LTD.	312	11,74%	11,74%
2	ALIBABA GROUP HOLDING LTD.	168	6,32%	18,06%
3	MASTERCARD INC.	75	2,82%	20,88%
4	IBM	70	2,63%	23,51%
…	OTHERS	2033	76,49%	100,00%

TABLE 16. TOP 4 COMPANIES IN CYBER PAYMENTS & CYBER SECURITY

Public Sector				
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	FIDELITY INVESTMENTS	13	7,18%	7,18%
2	CAMBRIDGE BLOCKCHAIN LLC	12	6,63%	13,81%
3	PHILIPS	10	5,52%	19,34%
4	PROCLUS TECHNOLOGIES LTD.	9	4,97%	24,31%
…	OTHERS	137	75,69%	100,00%

TABLE 17. TOP 4 COMPANIES IN PUBLIC SECTOR

Healthcare				
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	COGNITIVE SCALE INC.	16	4,09%	4,09%
2	ACCENTURE LTD.	14	3,58%	7,67%
3	IBM	14	3,58%	11,25%
4	CAMBRIDGE BLOCKCHAIN LLC	12	3,07%	14,32%
…	OTHERS	335	85,68%	100,00%

TABLE 18. TOP 4 COMPANIES IN HEALTHCARE

AI & Big Data				
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	IBM	30	4,49%	4,49%
2	MICROSOFT	22	3,29%	7,78%
3	ALIBABA GROUP HOLDING LTD.	19	2,84%	10,63%
4	COGNITIVE SCALE INC.	16	2,40%	13,02%
…	OTHERS	581	86,98%	100,00%

TABLE 19. TOP 4 COMPANIES IN AI & BIG DATA

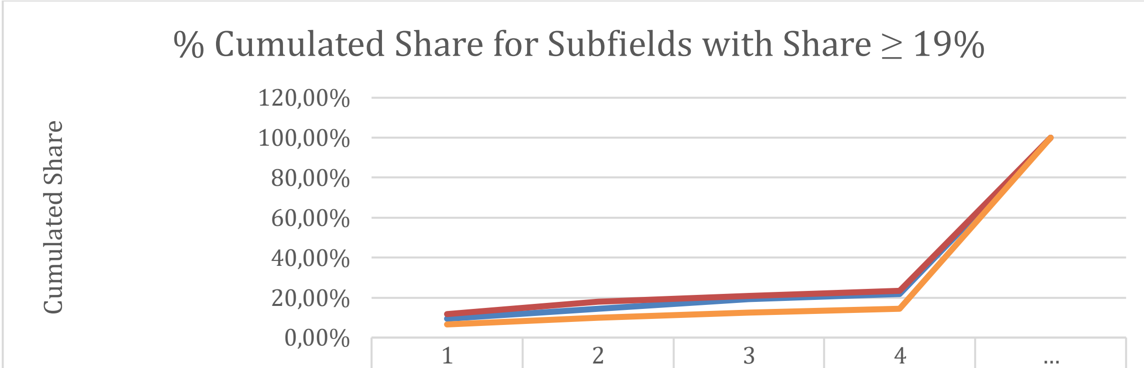
Supply Chain & Logistics				
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	IBM	82	6,57%	6,57%
2	ALIBABA GROUP HOLDING LTD.	43	3,44%	10,01%
3	ACCENTURE LTD.	30	2,40%	12,41%
4	WALMART STORES INC.	23	1,84%	14,25%
…	OTHERS	1071	85,75%	100,00%

TABLE 20. TOP 4 COMPANIES IN SUPPLY CHAIN & LOGISTICS

On the other hand, **Figure 24** and **Figure 25** show the percentage cumulated share for subfield with shares higher or equal than 19% and less than 19%. In both figures, the Y axis-represent the Cumulated Share with is the sum of the Sample Share for each Top Company. The X-axis represents the Top Companies, in order, from Top 1 to Top 4. Hence, for a given Top n, the Cumulated Share is the sum of Top n and Top n-1. For instance, for the Top 2, the Cumulated Share is the sum of Top 2 and Top 1 Sample Shares.

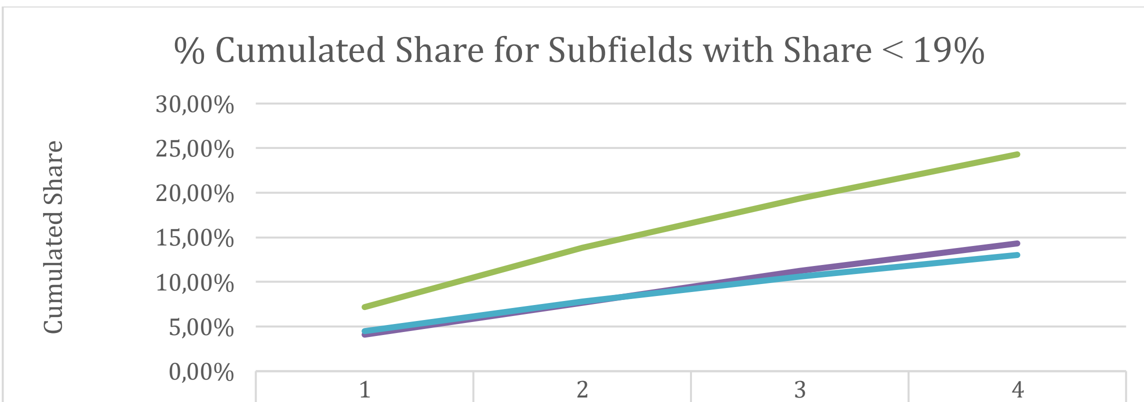
As reported in **Figure 24**, Cyber Payments & Cybersecurity appears to be the most mature subfield. With a concentration of circa 18% in C2 terms, it beats IoT & Cloud Computing and AI & Big Data to 4 and 8 percentage points. It is feasible to perform this analysis since these are the biggest data pools (high volume of patents), and results are statistically significant.

Conversely, from **Figure 25**, it can be said that the Public Sector is small (181 patents) but highly concentrated. It accrues for circa 14% of patents in C2 terms, doubling figures from Healthcare and AI & Big Data subfields. The fact that is the smallest subfield but with higher C4 concentration reinforces the idea that it cannot be a mature sector, rather, it is an extremely concentrated subfield that is not very attractive unlike, say, AI & Big Data. The latter being the one the fastest subfield to grow w.r.t. 2015 figures, as shown in previous analyses.



	1	2	3	4	...
IoT & Cloud Computing	9,43%	14,39%	19,27%	21,79%	100,00%
Cyber Payments & Cybersecurity	11,74%	18,06%	20,88%	23,51%	100,00%
Supply Chain & Logistics	6,57%	10,01%	12,41%	14,25%	100,00%

FIGURE 24. PERCENTAGE.CUMULATED SHARE FOR SUBFIELDS WITH SHARE ≥ 19%



	1	2	3	4
Public Sector	7,18%	13,81%	19,34%	24,31%
Healthcare	4,09%	7,67%	11,25%	14,32%
AI & Big Data	4,49%	7,78%	10,63%	13,02%

FIGURE 25.CUMULATED SHARE FOR SUBFIELDS WITH SHARE < 19%

3.7. Top 20 Innovative Companies Matrix by Subfield

The following analysis is the representation of a matrix containing the top 20 companies with most patents in the Blockchain field. For each company, the results are broken down by Subfield. Therefore, for each Subfield, the count of field and assigned patents is shown on the columns. This provides a glimpse of what are the specializations of the main players in the field, overall.

The following data was taken into account in order to prepare this analysis:

- Applicant/Assignee[63]
- Publication Number[64]

The results were obtained from a PivotTable in MS Excel. Where the top 20 companies and its subsequent count of patents were obtained from the perimeter sample. The patent count within the main sample is displayed on the 'Blockchain' column. Then, for each company, the count of patents was filtered from the subsamples using yet other PivotTables and the numbers listed on the 'Subfields' column.

A colour code that goes from green to red shows where is the biggest concentration of patents. For the Blockchain column, the range goes from the highest number (554 to 0 patents). For the Subfields, the range goes from 312 to 0 patents.

As reported in the matrix from **Figure 26**, the main players in Blockchain are focused on Cyber Payments & Cybersecurity sector. Something to be expected from the most mature sector. It is a more secure source of income than the other subfields – also the one that seems to be the more marketable, and widely known. In turn, the least attractive fields for the main players are currently the Public Sector followed by Healthcare.

[63] See paragraph *Components of patent documents* in Section *2.1.2. Patents*
[64] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

Astonishingly, even if AI & Big Data is the fastest-growing subfield in Blockchain, the main players have not yet concentrated efforts into developing innovation in this subfield. In fact, the matrix shows that IBM and Alibaba are only relevant players consistently patenting in this subfield. However, the rest of the total patents could come from new entrants with lower capital, say, startups.

Competition within AI & Big Data, Public Sector and Healthcare can be enhanced by startups entering the market. Generally, in within the Blockchain field there is still room for new entrants, as shown in previous analysis. However, the matrix shows this is particularly true for these three sectors.

Position	Top Company	Blockchain	Subfields						Company Preferred Subfield
			IoT & Cloud Computing	Cyber Payments & Cybersecurity	Public Sector	Healthcare	AI & Big Data	Supply Chain & Logistics	
		# of Patents							
1	NCHAIN HOLDINGS LTD.	554	71	312	4	1	2	11	Cyber Payments & Cybersecurity
2	ALIBABA GROUP HOLDING LTD.	353	70	168	2	5	19	43	Cyber Payments & Cybersecurity
3	IBM	242	135	70	8	14	30	82	IoT & Cloud Computing
4	MASTERCARD INC.	226	0	75	2	2	0	17	Cyber Payments & Cybersecurity
5	ACCENTURE LTD.	123	73	22	8	14	10	30	IoT & Cloud Computing
6	BIZMODELINE CO. LTD	104	0	0	0	0	0	0	N/A
7	COINPLUG INC.	87	14	9	0	0	0	0	IoT & Cloud Computing
8	HUAWEI TECHNOLOGIES COMPANY LTD.	66	16	18	2	2	3	16	Cyber Payments & Cybersecurity
9	PINGAN TECHNOLOGY SHENZHEN CO LTD.	60	4	11	2	3	4	7	Cyber Payments & Cybersecurity
10	WALMART STORES INC.	56	25	30	0	7	2	23	Cyber Payments & Cybersecurity
11	CHINA UNICOM GROUP CO. LTD.	50	4	8	0	0	0	6	Cyber Payments & Cybersecurity
12	INTEL CORPORATION	50	30	33	0	3	13	21	Cyber Payments & Cybersecurity
13	SIEMENS	49	9	40	0	2	0	3	Cyber Payments & Cybersecurity
14	MICROSOFT	46	14	33	4	10	22	16	Cyber Payments & Cybersecurity
15	NASDAQ INC.	44	0	43	5	0	0	15	Cyber Payments & Cybersecurity
16	BANK OF AMERICA CORP.	42	11	26	2	8	6	7	Cyber Payments & Cybersecurity
17	VISA INC.	41	4	35	0	5	0	7	Cyber Payments & Cybersecurity
18	BRITISH TELECOMMUNICATIONS PLC.	38	25	22	0	0	2	8	IoT & Cloud Computing
19	CLOUDMINDS SHENZHEN ROBOTICS SYSTEMS CO.	33	2	9	0	0	2	14	Supply Chain & Logistics
20	TENCENT TECHNOLOGY	33	3	12	1	1	5	12	Cyber Payments & Cybersecurity
	Total Patents	2297	510	976	40	77	120	338	

FIGURE 26. TOP 20 COMPANY MATRIX BY SUBFIELD

3.8. Top 6 Innovative Universities

The sixth analysis in this thesis includes the identification of six individual academic institutions[65] within the overall sample and rank them by their number of patent documents, assigned or applied for. Such an analysis is important because universities are considered main players in innovation as they instruct and thus, introduce industry standardization. This analysis aims at finding out which universities are making the most efforts in developing Blockchain-related inventions, and which are the country involved the most in academic research related to Blockchain.

For simplification purposes, all academic institutions found within the sample in this and subsequent related analysis will be referred to as *universities* or *academic institutions*.

In order to develop this analysis, the following data from the sample (i.e., perimeter) database were considered:

- Applicant/Assignee[66]
- Publication Country Code
- Publication Number[67]

In spite of grouping the relevant data mentioned above, two PivotTable were created in MS Excel. Since the focus this time was collecting data specifically about academic institutions, the criteria for data selection included applying filters to the *Applicant/Assignee* column in the complete sample database using corresponding keywords. Namely: "*university*," "*univ*," "*polytechnic*," "*poly,*" and "*college*." With the previous step, the analysis was now only considering universities. Hence, the data related to the *Applicant/Assignee* field was set in Row Fields, and thus each corresponding *Publication Number* count was added – a process that has been done before, yet, using different criteria. In order to study the concentration of academic patents by country, the

[65] Universities, polytechnics and collegues within the sample.
[66] See paragraph *Components of patent documents* in Section *2.1.2. Patents*
[67] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

count of *Publication Number* was used along with the *Publication Country Code* and another PivotTable was generated. The later study is similar to what was done in Section *3.3. Patent Geographic Concentration*, but only applied to academic institutions.

After the PivotTable was generated, the final results table was prepared accordingly count selecting the first 10 Applicant/Assignee with the most *Publication Number* count. Subsequently, an 'Others' category was created including a sum of every single *Applicant/Assignee* patent number (i.e., count of *Publication Number*) except from those in the top 10 with the most *Publication Number*. The 'OTHERS' section accounts for all patents of the rest of universities not considered within the top. On top of that, it is imperative to highlight that under this classification, universities have only less than six patents. The complete analysis output table is shown in **Appendix 8**.

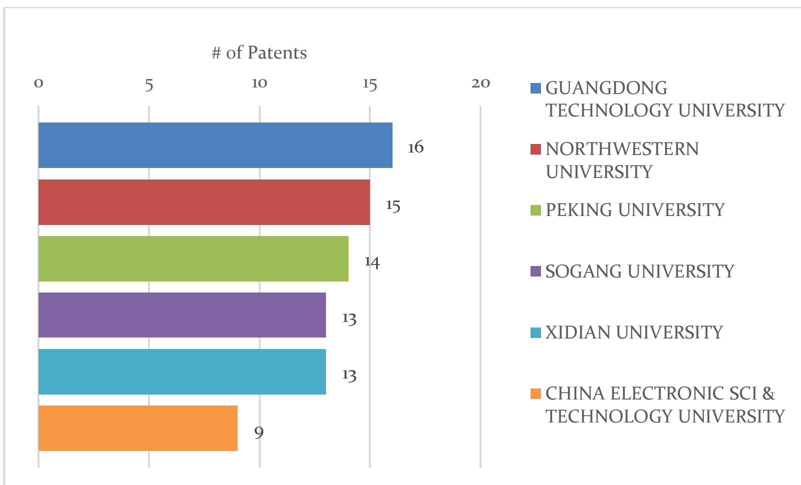


FIGURE 27. TOP UNIVERSITIES IN BLOCKCHAIN TECHNOLOGY

Reported in **Figure 27**, a bar chart, including the top 6 academic institutions that have patented the most Blockchain-related inventions is presented. The Y-axis refers to the 'Top Universities', which are –as mentioned above– the corresponding *Applicant/Assignee* records filtered from the main Blockchain sample (i.e., perimeter).

Conversely, the X-axis refers to the number of patents by Top University data from a total of 285 academic patents from 108 universities found within the Blockchain sample. The study took in to account all universities, polytechnics, and colleges around the world that have applied or been assigned a patent. This study does not discriminate them; rather, it provides a worldwide assessment of the efforts and interest of academic institutions into innovating on Blockchain technology.

Overall, there is no significant difference between the number of patents among the top 6 universities. Leading on the first position GUADONG TECHNOLOGY UNIVERSITY (with 16 patents), in second position NORTHWESTERN UNIVERSITY (with 14 patents), and finally followed by PEKING UNIVERSITY (with 15 patents) in the third position. Next, taking the fourth position, both SOGANG UNIVERSITY (with 13 patents) and XIDIAN UNIVERSITY (with 13 patents). Finally, CHINA ELECTRONIC SCIENCE & TECHNOLOGY UNIVERSITY (with nine patents) takes the fifth and last position.

Position	Top University	Country
1	GUANGDONG TECHNOLOGY UNIVERSITY	China
2	NORTHWESTERN UNIVERSITY	US
3	PEKING UNIVERSITY	China
4	SOGANG UNIVERSITY	China
4	XIDIAN UNIVERSITY	China
5	CHINA ELECTRONIC SCIENCE & TECHNOLOGY UNIVERSITY	China

TABLE 21. TOP UNIVERSITY BASE COUNTRY

Many of the academic institutions leading innovation on Blockchain technology are Chinese universities. According to the results, five institutions are based in China from a total of 6 top universities, and the only exception remains the American-based NORTHWESTERN UNIVERSITY. Given the results in Section *3.3. Patent Geographic Concentration*, it is obvious that the top universities could have been Chinese or American. In fact, based on the results, the Chinese expertise in the Supply Chain & Logistics area could have an influence in fostering interest within Chinese universities to commence R&D in Blockchain. Chinese universities could have shown interest in a technology that is of high interest for companies in the domestic market. Conversely, the US is still represented by NORTHWESTERN UNIVERSITY in the top 2 – a result that is consistent with what has been seen in Section *3.3. Patent Geographic Concentration*.

Next up, **Table 22** shows a list of all countries where institutions have filed a patent for. For each country, its count of patents and sample share are presented. As reported on this table, for a total of 285 academic patents, China leads with circa 75% of the sample share. Followed by South Korea (8%), United States of America (7%), WIPO (7%), United Kingdom (1%) and, Australia, EPO, Germany and Taiwan accruing for less than 1% each.

Country Code	Country	Count of Patents	Sample Share
CN	China	213	74,74%
KR	South Korea	23	8,07%
US	United States of America	21	7,37%
WO	World Intellectual Property Organization	19	6,67%
GB	United Kingdom	3	1,05%
AU	Australia	2	0,70%
EP	European Patent Office	2	0,70%
DE	Germany	1	0,35%
TW	Taiwan	1	0,35%
N/A	**TOTAL**	**285**	**100,00%**

TABLE 22. COUNTRIES WHERE ACADEMIC PATENTS HAVE BEEN FILED

However, these results only cover a global analysis of the nationality and amount of patents by institution. A more in-depth analysis to find which is the field of specialization of each university would require a thorough study that is not covered in this thesis.

3.9. Top 3 IPC Code

The goal of this analysis is to find out which are the most popular technological categories (i.e., IPC Subclass) that Applicants/Assignees use when requesting Blockchain patents. This analysis can serve as a reference for R&D analysts and related stakeholders interested into studying innovation in Blockchain.

The following list are the fields used in order to retrieve the data shown in **Table 23**:

- IPC Subclass[68]
- Publication Number[69]

The classic method of using a Pivot Table in MS Excel to organize the data from the main Blockchain sample was used. With the IPC Subclass field used in the Row Labels and the count of Publication Number provided in the Value Fields.

For each subclass the count of publications was listed in column '# of Patents' and the values in 'Sample Share' column are calculated as a percentage taken from the total patent size of 6.623 patents within the Blockchain field. The most common denominations are show in a Top 3 table, with the rest of patents that did not make it in the top accumulated in the row 'N/A'. The count for IPC Subclasses after G06F account for less than 1% of the Blockchain sample.

[68] More information about this field in Section *2.1.3. IPC Codes*
[69] See paragraph *Components of patent documents* in Section *2.1.2. Patents*

Table 23 depicts the most common IPC Subclasses used in Blockchain patent applications by frequency:

IPC Subclass	Description	# of Patents	Sample Share
G06Q	DATA PROCESSING SYSTEMS OR METHODS, SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL, SUPERVISORY OR FORECASTING PURPOSES	2530	38,20%
H04L	TRANSMISSION OF DIGITAL INFORMATION	1991	30,06%
G06F	ELECTRIC DIGITAL DATA PROCESSING	1125	16,99%
OTHERS	N/A	977	14,75%

TABLE 23. TOP IPC SUBCLASS SAMPLE SHARE PERCENTAGE

Chapter 4

4 Conclusions

This thesis is based on the statistical study of various Blockchain-related patent records extracted from the Derwent Innovation patent database. There are circa 6.623 patent records available online in the technology field – a number that comprises publications and applications. Then, the sample is broken down in subfields, from biggest to lowest, namely: Cyber Payments & Cybersecurity (2.658 patents), IoT & Cloud Computing (1.432 patents), Supply Chain & Logistics (1.249 patents), Artificial Intelligence & Big Data (668 patents), Healthcare (391 patents) and Public Sector (181 patents).

Blockchain is an emerging technology in which there is still a lot of research and development needed. It is still difficult to provide a precise definition of Blockchain since the technology is constantly reinventing itself. This is principally fueled by lack of industry standards, which are set to be ready by 2020. The latter does not mean that there is not significative literature available to the public. Generally, reviews are the principal source of technical information about the benefits of implementing Blockchain. However, it is generally big companies already providing Blockchain services who market the technology with terms found repeatedly in the literature available: decentralization, persistence, anonymity, and auditability.

Also, the technology landscape has some challenges to address in future research. There are many issues it faces in terms of data scalability, privacy, and energy waste. Some of the bigger companies in Blockchain technology, such as IBM and the Alibaba Group are addressing this matter. These companies usually market the Blockchain's value-added in terms of its *decentralized* nature, which is a source of trust for business partners in transactional exchanges (e.g. payee-payer or supplier-customer relationships).

The first reference to Blockchain dates from 2008. Ever since, the innovation trend has kept increasing, with patent applications soaring during the year 2017 with growth 1.5 times higher than in previous years. Regarding information extracted from the subfields' trend, the most attractive subfield for applicants is AI & Big Data, and the least attractive subfield is the Public Sector. Artificial Intelligence and Big Data are disruptive technologies that are becoming very popular among companies within the software development industry. Such industry and related sectors are utterly dynamic, whereas the Public Sector is a more conservative subfield.

Nevertheless, companies with the most patents in Blockchain technology have not focused their attention on AI & Big Data. The reason this is, yet, the fastest-growing field is explained by considering that it is mainly start-ups entering the market, which in turn, are specializing in filing AI & Big Data-related patents, hence contributing to this subfield's growth. On the other hand, Cyber Payments & Cybersecurity, is the most mature sector amongst bigger subfields like IoT & Cloud Computing, and Supply Chain & Logistics.

Overall, Blockchain technology has no deeply established players yet; hence, there is still room for new entrants to join the market. The first ten companies with most patents accrue for roughly 30% of the innovation in Blockchain, which shows how scarcely concentrated innovation is for this technology. Though, the majority of these companies show strong interest in not only applying for patents in one specific subfield but diversifying their innovation portfolio. Still, there are no deeply involved players.

Geographically, for Blockchain technology, China and the USA are the countries where innovation is strongly concentrated. Out of the total 6.623 Blockchain-related patents extracted, both countries accrued for little more than half of them (54%). This result is not surprising as both nations are known world superpowers. However, the results of these big nations are quite interesting when split by subfield. Data shows China has filed more patents overall, but the USA leads on patent number in all subfields except for Supply Chain & Logistics – where China leads greatly. This shows that most of China's cumulated innovative effort has been focused on Supply Chain & Logistics. Such results are coherent with the fact that China is a worldwide leader in supply chain matters, as many companies base their manufacturing side there due to the country's history of low costs for production.

When it comes to academic institutions, mainly Chinese universities are working in Blockchain innovation. Out of 285 academic patents, China accrues for circa 75% of them. According to the results, academic patents are only a small portion of the sample, consisting of only 4.3% of all Blockchain patents.

Finally, the IPC Subclass used the most when filing Blockchain patents is G06Q, with the title of "*DATA PROCESSING SYSTEMS OR METHODS, SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL, SUPERVISORY OR FORECASTING PURPOSES*". Followed by the IPC Subclasses H04L and G06F, which correspond to the Subclass titles "*TRANSMISSION OF DIGITAL INFORMATION*" and "*ELECTRIC DIGITAL DATA PROCESSING*", respectively.

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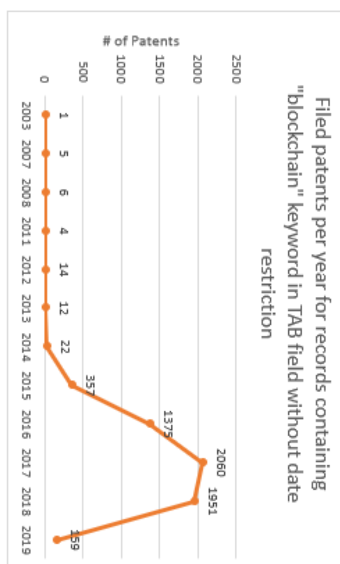
Appendix 1

TIMEFRAME PRELIMINARY CHECK		
Keyword	**Query**	**#records**
blockchain	TAB=(blockchain);	5966

RESULTS FROM DATA EXTRACTION	
Earliest Priority Year	**# of Records**
2003	1
2007	5
2008	6
2011	4
2012	14
2013	12
2014	22
2015	357
2016	1375
2017	2060
2018	1951
2019	159



APPENDIX 1. TIMEFRAME CHECK

Appendix 2

TECHNOLOGY PERIMETER KWs - Field: (Title/Abstract - TAB)				
Type	1st tier	operator	2nd tier	# records
Main	blockchain			5814
Synonym	decentralized	NEAR	database	26
	distributed	NEAR	ledger	1074
	digital	NEAR	ledger	44
Component	consensus	ADJ	protocol	87
	proof	ADJ	of*	5018
	digital	ADJ	signature	5918
	block			2136480
	hash			19465
	merkle	ADJ	tree	153
	nonce			741
	smart	ADJ	contract	1124
	timestamp			7910
	transaction			81006
	decentralized	NEAR	transaction	112

QUERY: TAB=(keyword) AND PRD>=(20120101);

1st related paper published in 2012 PRD>=(20120101);

APPENDIX 2. TECHNOLOGY PERIMETER KEYWORD RELEVANCE CHECK

Appendix 3

QUERY: "PERIMETER" AND ALL=(keyword) AND PRD>=(20120101);

AREA TAGS – Field: (Text Fields – ALL)

Area of Application	1st tier	Operator	2nd tier	Operator	3rd tier	# records	Tags
Artificial Intelligence & Big Data	**artificial**	**NEAR**	**intelligence**			**262**	(artificial NEAR intelligence) OR (decentralized NEAR intelligence) OR (computing NEAR power) OR (machine NEAR learning)
	decentralized	NEAR	intelligence			1	
	big	**NEAR**	**data**			**202**	
	machine	NEAR	learning			418	
Cyber Payments & Cybersecurity	**cyber**	**NEAR**	**security**			57	(cyber NEAR security) OR (fraud NEAR prevention) OR (cryptocurrency) OR (digital NEAR asset) OR (bitcoin) OR (ethereum)
	cryptocurrency					**1279**	
	bitcoin					2238	
	payment					2866	
Healthcare	**healthcare**					**272**	(healthcare) OR (health NEAR information) OR (electronic NEAR medical NEAR record) OR (pharmacy)
	health	NEAR	information			106	
	electronic	NEAR	medical	NEAR	record	86	
	pharmacy					95	
IoT & Cloud Computing	**internet**	**NEAR**	**of**	**NEAR**	**things**	**871**	(internet NEAR of NEAR things) OR (decentralized NEAR cloud) OR (smart NEAR device) OR (cloud NEAR computing)
	decentralized	NEAR	cloud			5	
	smart	NEAR	device			235	
	cloud	NEAR	computing			729	
Public Sector	**public**	**NEAR**	**sector**			**9**	(public NEAR sector) OR (smart NEAR government) OR (electronic NEAR ballot) OR (voting NEAR system) OR (land NEAR registry) OR (real NEAR estate NEAR transaction)
	smart	NEAR	government			7	
	electronic	NEAR	ballot			4	
	voting	NEAR	system			111	
	land	NEAR	registry			4	
	real	NEAR	estate	NEAR	transaction	53	
Supply Chain & Logistics	**supply**	**NEAR**	**chain**			**470**	(supply NEAR chain) OR (logistic*) OR ("manufacturing") OR (industry NEAR 4.0) OR (procurement) OR (supplier NEAR payment) OR (traceability)
	logistic*					**335**	
	industry	NEAR	4.0			7	
	procurement					206	
	supplier	NEAR	payment			9	
	traceability					692	

APPENDIX 3. AREA TAG KEYWORDS RELEVANCE CHECK

Appendix 4

TECHNOLOGY PERIMETER QUERY			
Arrangement	Query	# records	
TAB=(blockchain) OR (TAB=(synonyms) AND (ALL=(blockchain) OR TAB=(components)))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND	6623	Chosen arrangement

QUERY = "PERIMETER" AND "AREA" AND "PUBLICATION DATE"

AREA QUERY			
Area of Application	Area Tag	Query	# records
Artificial Intelligence & Big Data	ALL=((artificial NEAR intelligence) OR (decentralized NEAR intelligence) OR (computing NEAR power) OR (machine NEAR learning))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND ALL=((artificial NEAR intelligence) OR (decentralized NEAR intelligence) OR (big NEAR data) OR (machine NEAR learning)) AND PRD>=(20120101);	668
Cyber Payments & Cybersecurity	ALL=((cyber NEAR security) OR (cryptocurrency) OR (bitcoin) OR (payment)) NOT CL=((bitcoin) OR (cryptocurrency) OR (payment))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND ALL=((cyber NEAR security) OR (cryptocurrency) OR (bitcoin) OR (payment)) NOT CL=((bitcoin) OR (cryptocurrency) OR (payment)) AND PRD>=(20120101);	2658
Healthcare	ALL=((healthcare) OR (health NEAR information) OR (electronic NEAR medical NEAR record) OR (pharmacy))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND ALL=((healthcare) OR (health NEAR information) OR (electronic NEAR medical NEAR record) OR (pharmacy)) AND PRD>=(20120101);	331
IoT & Cloud Computing	ALL=((internet NEAR of NEAR things) OR (decentralized NEAR cloud) OR (cloud NEAR computing))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND ALL=((internet NEAR of NEAR things) OR (decentralized NEAR cloud) OR (cloud NEAR computing)) AND PRD>=(20120101);	1432
Public Sector	ALL=((public NEAR sector) OR (smart NEAR government) OR (electronic NEAR ballot) OR (voting NEAR system) OR (land NEAR registry) OR (real NEAR estate NEAR transaction))	(digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND ALL=((public NEAR sector) OR (smart NEAR government) OR (electronic NEAR ballot) OR (voting NEAR system) OR (land NEAR registry) OR (real NEAR estate NEAR transaction)) AND PRD>=(20120101);	181
Supply Chain & Logistics	ALL=((supply NEAR chain) OR (logistic*) OR (industry NEAR 4.0) OR (procurement) OR (supplier NEAR payment) OR (traceability))	(TAB=(blockchain) OR (TAB=((decentralized NEAR database) OR (distributed NEAR ledger) OR (digital NEAR ledger)) AND (ALL=(blockchain) OR TAB=((proof ADJ of*) OR (digital AND signature) OR (merkle ADJ tree) OR nonce OR (smart ADJ contract) OR block OR hash OR timestamp OR transaction)))) AND ALL=((supply NEAR chain) OR (logistic*) OR (industry NEAR 4.0) OR (procurement) OR (supplier NEAR payment) OR (traceability)) AND PRD>=(20120101);	1249
TOTAL RECORDS (out of 6623)			6579

Tech_Per | Area_Tag | Timeframe_TEST | QueryList | Tables | RES1_TrendAp | RES2_%ConcAre ...

APPENDIX 4. PERIMETER AND AREA QUERIES

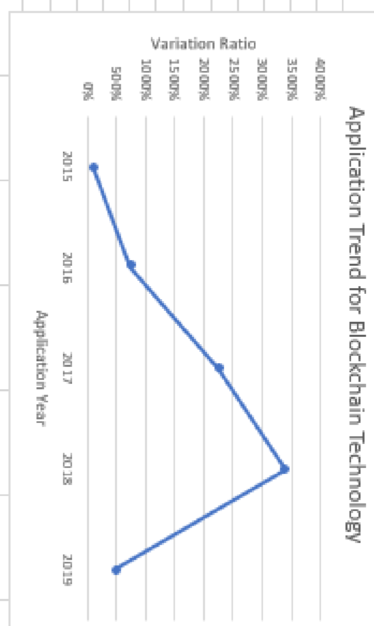
Appendix 5

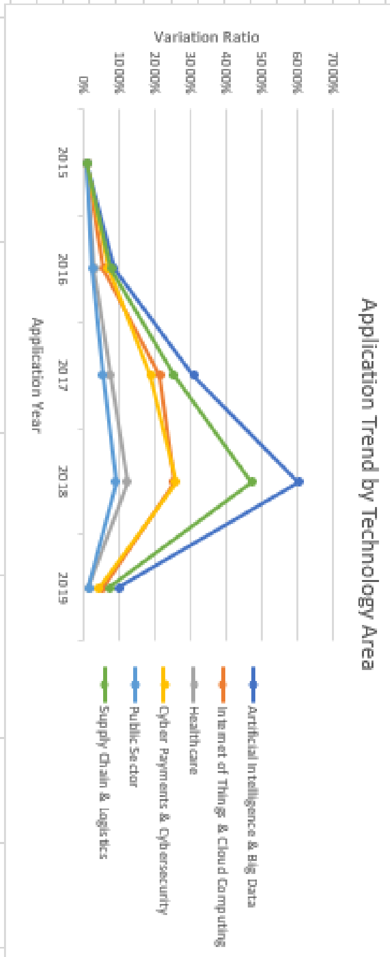
Area	Application Year	# of Patents	Variation w.r.t. 2015 [%]
Blockchain	2014	1	100%
	2015	95	100%
	2016	706	743%
	2017	2144	2257%
	2018	3219	3388%
	2019	457	481%
Artificial Intelligence & Big Data	2014	0	0%
	2015	6	100%
	2016	53	883%
	2017	186	3100%
	2018	363	6050%
	2019	60	1000%
Internet of Things & Cloud Computing	2014	0	0%
	2015	24	100%
	2016	139	579%
	2017	519	2163%
	2018	614	2558%
	2019	136	567%
Healthcare	2014	0	0%
	2015	15	100%
	2016	48	320%
	2017	116	773%
	2018	186	1240%
	2019	26	173%
Cyber Payments & Cybersecurity	2014	0	0%
	2015	46	100%
	2016	325	707%
	2017	876	1904%
	2018	1203	2615%
	2019	207	450%

APPENDIX 5. SPREADSHEET FOR APPLICATION TREND ANALYSIS – PART A

Appendix 6

Area	Application Year	# of Patents	Variation w.r.t. 2015 [%]
Public Sector	2014	0	0%
	2015	9	100%
	2016	25	278%
	2017	49	544%
	2018	84	933%
	2019	14	156%
Supply Chain & Logistics	2014	0	0%
	2015	14	100%
	2016	110	786%
	2017	359	2564%
	2018	661	4721%
	2019	105	750%





APPENDIX 6. SPREADSHEET FOR APPLICATION TREND ANALYSIS – PART B

Appendix 7

Blockchain

Position	Country Code	# of Patents	Concentration
1	CN	2039	30,79%
2	US	1583	23,90%
3	WO	1181	17,83%
4	KR	402	6,07%
5	EP	333	5,03%
6	GB	187	2,82%
7	AU	154	2,33%
8	TW	135	2,04%
9	SG	130	1,96%
10	IN	126	1,90%
...	Others	353	5,33%
	Total	6623	100,00%

IoT & Cloud Computing

Position	Country Code	# of Patents	Concentration
1	US	611	42,67%
2	WO	306	21,37%
3	CN	243	16,97%
4	EP	87	6,08%
5	KR	39	2,72%
6	CA	34	2,37%
7	AU	31	2,16%
8	IN	24	1,68%
9	SG	23	1,61%
10	GB	18	1,26%
...	Others	16	1,12%
	Total	1432	

Cyber Payments & Cybersecurity

Position	Country Code	# of Patents	Concentration
1	US	854	32,13%
2	WO	657	24,72%
3	CN	403	15,16%
4	EP	184	6,92%
5	KR	135	5,08%
6	SG	77	2,90%
7	AU	71	2,67%
8	IN	55	2,07%
9	CA	53	1,99%
10	DE	37	1,39%
...	Others	132	4,97%
	Total	2658	100,00%

Public Sector

Position	Country Code	# of Patents	Concentration
1	US	82	45,30%
2	WO	36	19,89%
3	CN	31	17,13%
4	EP	10	5,52%
5	AU	7	3,87%
6	CA	6	3,31%
7	KR	4	2,21%
8	SG	3	1,66%
9	IN	1	0,55%
10	JP	1	0,55%
...	Others	0	0,00%
	Total	181	100,00%

Healthcare

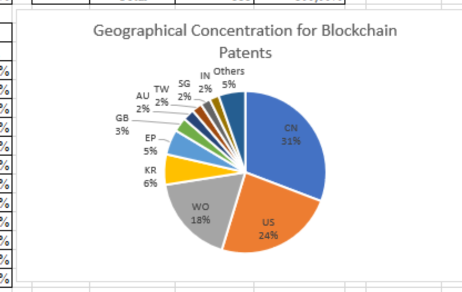
Position	Country Code	# of Patents	Concentration
1	US	204	52,17%
2	WO	76	19,44%
3	CN	49	12,53%
4	EP	16	4,09%
5	AU	12	3,07%
6	CA	9	2,30%
7	IN	9	2,30%
8	SG	6	1,53%
9	KR	5	1,28%
10	BR	1	0,26%
...	Others	4	1,02%
	Total	391	100,00%

AI & Big Data

Position	Country Code	# of Patents	Concentration
1	US	293	43,86%
2	CN	136	20,36%
3	WO	129	19,31%
4	KR	27	4,04%
5	EP	20	2,99%
6	AU	17	2,54%
7	IN	11	1,65%
8	SG	11	1,65%
9	CA	9	1,35%
10	GB	6	0,90%
...	Others	9	1,35%
	Total	668	100,00%

Supply Chain & Logistics

Position	Country Code	# of Patents	Concentration
1	CN	442	35,39%
2	US	408	32,67%
3	WO	227	18,17%
4	EP	44	3,52%
5	AU	39	3,12%
6	IN	18	1,44%
7	KR	18	1,44%
8	CA	15	1,20%
9	SG	14	1,12%
10	GB	8	0,64%
...	Others	16	1,28%
	Total	1249	100,00%



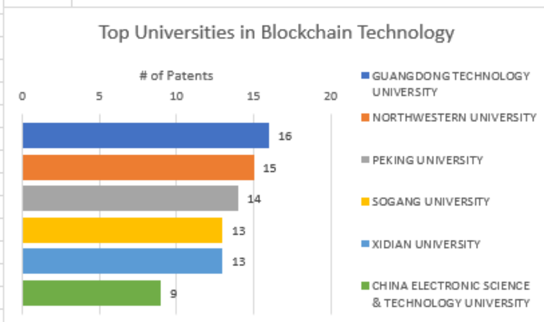
RES1_TrendAp | RES2_%ConcArea | RES3_%DistGeo | RES4_MainPlayers | RES5_TopUniv

APPENDIX 7. SPREADSHEET FOR GEOGRAPHICAL DISTRIBUTION ANALYSIS

Appendix 8

Position	Top University	Country	# of Patents
1	GUANGDONG TECHNOLOGY UNIVERSITY	China	16
2	NORTHWESTERN UNIVERSITY	US	15
3	PEKING UNIVERSITY	China	14
4	SOGANG UNIVERSITY	China	13
4	XIDIAN UNIVERSITY	China	13
5	CHINA ELECTRONIC SCIENCE & TECHNOLOGY UNIVERSITY	China	9
...	OTHERS	-	205
	TOTAL	-	285

Country Code	Country	Count of Patents	Sample Share
CN	China	213	74,74%
KR	South Korea	23	8,07%
US	United States of America	21	7,37%
WO	World Intellectual Property Organization	19	6,67%
GB	United Kingdom	3	1,05%
AU	Australia	2	0,70%
EP	European Patent Office	2	0,70%
DE	Germany	1	0,35%
TW	Taiwan	1	0,35%
N/A	**TOTAL**	**285**	**100,00%**



APPENDIX 8. SPREADSHEET FOR TOP 10 INNOVATIVE COMPANIES

Appendix 9

IoT & Cloud Computing

Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	IBM	135	9,43%	9,43%
2	NCHAIN HOLDINGS LTD.	71	4,96%	14,39%
3	ALIBABA GROUP HOLDING LTD.	70	4,89%	19,27%
4	ACCENTURE LTD.	36	2,51%	21,79%
...	OTHERS	1120	78,21%	100,00%

Cyber Payments & Cybersecurity

Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	NCHAIN HOLDINGS LTD.	312	11,74%	11,74%
2	ALIBABA GROUP HOLDING LTD.	168	6,32%	18,06%
3	MASTERCARD INC.	75	2,82%	20,88%
4	IBM	70	2,63%	23,51%
...	OTHERS	2033	76,49%	100,00%

Public Sector

Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	FIDELITY INVESTMENTS	13	7,18%	7,18%
2	CAMBRIDGE BLOCKCHAIN LLC	12	6,63%	13,81%
3	PHILIPS	10	5,52%	19,34%
4	PROCLUS TECHNOLOGIES LTD.	9	4,97%	24,31%
...	OTHERS	137	75,69%	100,00%

Healthcare

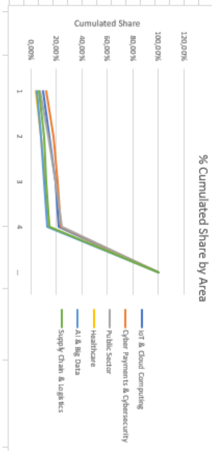
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	COGNITIVE SCALE INC.	16	4,09%	4,09%
2	ACCENTURE LTD.	14	3,58%	7,67%
3	IBM	14	3,58%	11,25%
4	CAMBRIDGE BLOCKCHAIN LLC	12	3,07%	14,32%
...	OTHERS	335	85,68%	100,00%

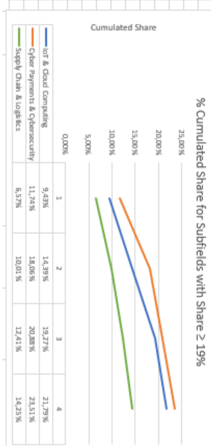
AI & Big Data

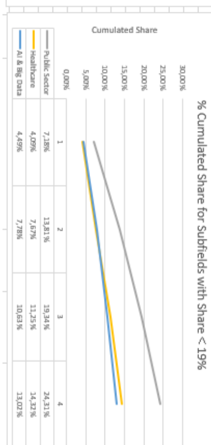
Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	IBM	30	4,49%	4,49%
2	MICROSOFT	22	3,29%	7,78%
3	ALIBABA GROUP HOLDING LTD.	19	2,84%	10,63%
4	COGNITIVE SCALE INC.	16	2,40%	13,02%
...	OTHERS	581	86,98%	100,00%

Supply Chain & Logistics

Position	Top Company	# of Patents	Sample Share	Cumulated Share
1	IBM	82	6,57%	6,57%
2	ALIBABA GROUP HOLDING LTD.	43	3,44%	10,01%
3	ACCENTURE LTD.	30	2,40%	12,41%
4	WALMART STORES INC.	23	1,84%	14,25%
...	OTHERS	1071	85,75%	100,00%







APPENDIX 9. TOP 4 COMPANY BY SUBFIELD SPREADSHEET