POLITECNICO
MILANO 1863

POLITECNICO DI MILANO

SCHOOL OF INDUSTRIAL AND INFORMATION ENGINEERING

MASTER OF SCIENCE IN MANAGEMENT ENGINEERING - FINANCE
ACADEMIC YEAR 2018-19

An empirical study of the efficiency of Initial Coin Offerings adopting a two-stage DEA model

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Abstract

English version

The rapid diffusion of the blockchain technology led to the development of new alternative solutions able to disrupt and innovate the business arena. One of them has to do with the recent adoption of the Initial Coin Offering (ICO). It is largely considered the most innovative solution to finance a venture outside traditional channels, especially for start-ups. In a short time and without large investments every company can present itself to the market with its fundraising and the related token. The use of ICO is a global phenomenon that involves many nations and several business industries.

At this stage, academic papers and professional reports are focused on the analysis of the factors that make an ICO successful. On the other hand, this work aims to fill the gap in this field by analysing those elements that affect not the success but the efficiency of this process. Hence, the methodology of Data Envelopment Analysis (DEA) has been introduced for the computation of the efficiency scores for each project. Then a two-stage approach has been set, with the goal to statistically investigate the related factors.

To assess this task we have collected a sample of more than 800 projects, from the beginning of 2017 to the mid of 2018.

Abstract

Versione Italiana

La rapida diffusione della tecnologia blockchain ha portato allo sviluppo di nuove soluzioni alternative capaci di alterare ed innovare il mercato. Una di queste ha a che vedere con l'adozione delle Initial Coin Offering (ICO). Sono largamente considerate una delle pratiche più innovative per il finanziamento di un progetto al di fuori dei canali tradizionali, specialmente per le start-up. In poco tempo e senza la necessità di grandi investimenti ogni azienda si può presentare sul mercato con la sua raccolta fondi e il relativo token. Quello delle ICO è un fenomeno globale che coinvolge molte nazioni e diversi settori di business.

Allo stato attuale, i lavori accademici e i report professionali sono focalizzati sull'analisi dei fattori che rendono una ICO di successo. Questo lavoro, invece, ha l'obiettivo di colmare il vuoto in questo campo, cercando di analizzare non gli elementi che influenzano il successo, bensì l'efficienza di questo processo. Per questo abbiamo deciso di applicare la metodologia Data Envelopment Analysis (DEA) per il calcolo dei punteggi di efficienza di ciascun progetto. Successivamente, utilizzando l'approccio *two-stage*, abbiamo portato avanti un'analisi statistica per individuare i fattori ad essi associati.

Per fare ciò abbiamo raccolto un campione composto da oltre 800 progetti, dall'inizio del 2017 a metà 2018.

INDEX

Executive Summary

In 1990 Tim Berners-Lee created the first World Wide Web page, with the aim to enable people to discover facts, create ideas, buy and sell things and much more. In the late 90s the first *dot-com bubble* was experienced, an evidence of how humans were incredibly convinced in the power of a big "centralized" system, able to instantly share information and, hence, connect people all around the world. The amount of data hugely increased and the business around Internet became the leading one in the world.
The world has grown at a rapid peace, with higher competitiveness and uncertainty. Everything evolves faster and faster. Products and services born, grow and die in few years, sometimes months. Thus, companies need to constantly reinvent themselves, fighting daily against the risk to be stacked by new players. Experience is no more enough. What they really need to sustain their business is adopting a new mindset aimed at innovating.
Hence the challenge of our time is innovation. Every industry, every business, every market, every company is subject to innovation. Everything can be innovated.
Sometimes this need emerges as a consequence of a special fact or event. For example, since 2008, the world experienced a strong financial crisis. Beyond the well-known economic implications, the main lesson learnt was understanding how the traditional financial system had the need to be innovated. There was something wrong, something that did not work. One of the main issues that we are still experiencing today is the so-called phenomenon of "credit crunch". Companies have the need to evolve, to change and to innovate. To do this they need money. But, traditional financial systems are no longer able to respond to their needs. There is no more the common idea to go to the bank asking for a loan. Banks and financial institutions become afraid to lend money, hence developing a more sensitive risk aversion.
The result was that many small and medium companies were not able to gain access to credit. This was even more troubled for newly founded firms, as start-ups.

Thus, given these difficulties, the need of innovation emerged. Meanwhile, technology was evolving at a peace never seen before, developing new possibilities.
Given these premises, alternative ways for raising capital have been introduced, with the idea to bypass banks and "old" financial institutions, directly addressing the crowd.
We started talking about *crowdfunding*. We learnt that going to the bank asking for a loan was no longer necessary. Almost everyone can access to a crowdfunding platform and launch its own campaign. Essentially everything can be "crowdfunded". The system seems to work. Billions of dollars have been raised. Only in 2018 more than \$5.3 billion have been collected (Statista, 2019), and the growth rates are still at two digits.
Meanwhile, in 2008, the still anonymous Satoshi Nakamoto published a paper, in which it was firstly conceptualized the blockchain paradigm, by writing that it consists of "*a purely peer-to-peer version of electronic cash that allow online payments to be sent directly from one party to another without going through a financial institution*" (Nakamoto, 2008).
This meant that the traditional system could be disrupted. There was no more the need to have a third party with the role of validating the transactions. From a *centralized* database managed by few giants (i.e. Amazon, Google, Facebook) we have been shifted to a *decentralized* world. With the advent of this new paradigm something has changed.
Since funding innovative ventures were one of the premier topics in entrepreneurial finance, the reasonable evolution was inventing novel forms of alternative finance based on blockchain technology. Hence, the Initial Coin Offerings (ICOs) have been firstly introduced in 2013. These constitute a new mechanism for funding highly innovative ventures that use Distributed Ledger Technology (DLT). Through ICOs ventures raise capital by issuing and then selling tokens to a crowd of investors. Similarly to an IPO process through which shares of the company are distributed among investors, an ICO emits tokens. A token is essentially the analogous of the shares, but not the same. Tokens are units of value intended to provide utility or to function as profit and property rights. Often these tokens are cryptocurrencies that are meant to function as a currency into the venture's own ecosystem (Fisch, 2019).

Literature Review

Our work aims to embody different concepts and considerations, from the technological perspective, by explaining the innovations behind ICOs, to more quantitative evaluations in order to obtain valuable information from the large sample of our database.

The literature review takes inspiration from a series of papers and Journals' articles. But, given the novelty of this phenomenon and the fact that it is not still largely investigated, beyond academic papers (i.e. Journal of Business and Economics, Journal of Business and Venturing), we also looked for relevant and more recent information on consultancy firms' reports (i.e. PwC, McKinsey), financial newspapers and crypto-forums (i.e. BitcoinTalk, Cointelegraph, Reddit). Our belief is that having an updated research with the last events and facts which impact on such evolving industry is fundamental.

Our analysis starts with a deep understanding of the underlying technology enabling the ICOs: the blockchain. Starting from the statement of its founder, Satoshi Nakamoto, back in 2008 (Nakamoto, 2008), we have proposed a complete definition, by explaining the main terms and concepts related to this technology (Mougayar, 2016).

In the second part, we have discussed about a series of fundamental concepts (i.e. Decentralized Distributed Ledger, The Consensus Mechanism, Ethereum, Bitcoin) which allow the reader to fully understand the power of blockchain. Without a clear understanding of such a disruptive innovation, we believe it is almost impossible to catch the real value ICOs can give as alternative source of financing.

Then, in the last section, with the aim to introduce the second chapter, we have broadly investigated the concept of smart contract (Szabo, 1997), the real ICO enabler, and the new form of blockchain crowdfunding.

Of course, a preeminent position is given to the topic of our work, the Initial Coin Offerings: beyond the definition (Adhami et al., 2018) and the different peculiarities when compared with the IPOs and the crowdfunding solutions, a relevant space has been dedicated to the description of Ethereum, the blockchain underlying more than 90% of ICOs, and the ERC-20, the protocol used for smart contracts.

Afterwards, bringing to light effective real cases, we have presented the role of the team, largely considered the real asset of the projects, and the white paper, the only document on which investors rely. Other relevant characteristics are the token price, the soft and the hard cap, the token utility and the social media adopted, which play an important role in the decision-making process (Hanh & Wons, 2018).
Later an overview of the ICO market is presented: under a geographical and industry sector point of view, we have shown in terms of number of projects and capital raised (IcoBench, 2019) how the ecosystem has changed in the past couple of years. Finally, a look at the future has been proposed, with the possible evolution of the ICO, aimed at overtaking the regulatory issues and a recent inverted negative sentiment, which have slowed down the growth of this market. The Initial Exchange Offerings (IEO) and the Security Token Offerings (STO) seem to be two valuable evolutions of the ICOs.

The third and last part of the literature review brings into focus the quantitative method used to evaluate the efficiency and the success variabilities of the ICOs. Being the Data Envelopment Analysis a quite unknown methodology, we thought it was necessary to propose a more academic introduction to this method which uses a set of both input and output data to give a value of efficiency per each unit. We approached the topic in two main ways: we firstly studied the main principles and techniques by referring to the related works and books, of which the leading authors are Charnes, Cooper and Rhodes, the ones who conceptualized many of the models and techniques on which DEA is based (Charnes, Cooper, & Rhodes, 1978). In particular, we have focused on the main techniques; we analysed radial (BCC and CCR), additive and slack-based measure models. For each of them we discussed about the mathematical forms, the real-life implications and the main pros and cons. Due to the complexity of the principles behind, many examples have been proposed.
Secondly, we have investigated related works, such as many papers that adopted this technique even in different industries or fields. From them, a study of the evaluation of sustainability and energy efficiency of tomato production was particularly interesting (Raheli, Rezaei, Jadidi, & Mobtaker, 2017). It seems to be very far from our research, but the principles and the basics behind are quite comparable. In particular, the application

of the *two-stage approach*, hence the investigation of the results through regression models, was particularly inspiring for our thesis.

Objectives and Methodology

The goal of our work is understanding which are those factors that affect the efficiency of an ICO process. So far, the most popular papers which investigated the ICO phenomenon with a quantitative approach were only focused on analysing the success factors. The great improvement of our research is, instead, studying the factors that make an ICO efficient.

The first step was identifying the methodology that best fit our need to assign an efficiency score to each project. The DEA resulted to be the most appropriate, as discussed in the dedicated section (Chapter 2 – *Data Envelopment Analysis*).

Once the techniques have been largely investigated, the main task was introducing measures of inputs and outputs. The selection was quite intensive and complex, thus many studies have been provided, by relying on the actual literature review. The main issue has been represented by the pioneering nature of our research. Indeed, being the first to introduce this approach for the study of the ICOs, we have deeply investigated the academic papers and related works. At the end, we have decided to consider the core team and advisor members combined with the mentions reached on Twitter as the three inputs. Indeed, according to the literature review, we have realized that the main assets of these ICO projects are the human resources and their ability to attract investors through social media. On the other side, the amount raised of US dollars has been set as the output of the model. In this case the decision was easier, but still largely discussed. Once these parameters have been set, the DEA model has been computed, with the assignment of an individual efficiency score to each project.

At this stage the task was understanding the leading factors able to impact on the score of each project. For this reason, the *two-stage approach* has been implemented, with the role of identfying those variables that affect the results of DEA scores. In particular, by focusing on our sample of 803 projects collected in our database, we have formulated five different hypothesis, stated to understand the relevance of some variables on the efficiency of a crypto-project: we were intended to demonstrate the positive relation between the efficiency score and the presence of the presale, the presence of an early bird as bonus scheme and the percentage of tokens distributed to external investors; conversely to these three, the other two hypothesis aimed to demonstrate the negative relation between the efficiency score and both the token price and the hard cap.

Given these premises, we have deeply investigated the variables and the data by computing univariate statistics and understanding their implications on different levels, as geographical and industry ones. We have found out different insights, usually in accordance with actual academic and professional works.

Then the model has been implemented. We have relied on the statistical methodologies of Welch's T-test, Correlation Matrix and Logit Regression model to define the relations between the five mentioned predictors and the dependent variable, the DEA efficiency score. Of the five main hypothesis that we have supposed in advance, two of them have been rejected, while the others confirmed the goodness of our considerations. We have largely investigated the results, also introducing additional T-tests, aiming to deeply understanding the populations of the sample collected. The aim was providing a general and synthetic overview, with the goal to link the results with real practice implications.
Then, aiming to validate and make our findings more reliable, specific robustness checks have been provided.

Given the lack of resources, part of the considerations provided came from our personal knowledge, while others have been inspired by the literature review of related topics, as crowdfunding and alternative forms of financing. Due to the pioneering nature of our study we believe to provide a valuable contribution to the research of the ICO phenomenon.

1
The Blockchain

1.1 Blockchain Paradigm

In 1990 Tim Berners-Lee created the first World Wide Web page by saying that: "*when we link information in the Web, we enable ourselves to discover facts, create ideas, buy and sell things, and forge new relationships at a speed and scale that was unimaginable in the analogue era*" (Murgia, 2015).

In that short statement, he predicted search, publishing, e-commerce, e-mail, and social media, all at once, by a single stroke. That simple idea, the link, has transformed politics, overthrown governments, led to the invention of today's best-known global businesses, and irrevocably changed our social interactions with the world.

If we ask anyone today what we associate with Internet, probably most will answer Google, Amazon, Facebook, Yahoo and others like them. The World Wide Web, with its billions of users, is now controlled by a handful of giant corporations that practically determine the rules of the game. They know what you love, what you eat, where you go, what you watch, and with whom you sleep. So everything is *centralized*, all the data are collected in a central database managed by few of the big giants.

But something has changed, or maybe will change. On the 31st of October 2008, Satoshi Nakamoto, an anonymous person, published on the mailing list "The Cryptography Mailing List", the following message:

> *I've been working on a new electronic cash system that's fully peer-to-peer, with no trusted third party. The main properties are: double spending is prevented with a peer-to-peer network, no mint or other trusted parties, participants can be anonymous, new coins are made from Hashcash style proof of work, the proof of work for new coin generation also powers the network to prevent double spending.* (García, 2019)

The pertinent paper starts with an abstract in which the author firstly conceptualizes the blockchain paradigm, by writing that it consists of "*a purely peer-to-peer version of electronic cash that allow online payments to be sent directly from one party to another without going through a financial institution*" (Nakamoto, 2008).
The work proposed a peer-to-peer electronic cash system, that allows users to make online payments directly to each other. Thus, there is no need for a bank to solve the problems of ownership and double-spending.
Normally, a bank is responsible for managing those transactions, since it is the one the guarantees the regularity of the payments, by relying on a centralized database. Thus, if everyone of us has to make a payment, the presence of a third party as a bank is needed. But with the advent of this new paradigm something changed.

Now the question is: what does it really mean blockchain?
By a technical point of view, it is a back-end database that maintains a distributed ledger that can be inspected openly. In business words, it is an exchange network for moving transactions, value, assets between peers, without the assistance of intermediaries. Legally speaking, the blockchain is a way for validating transactions and replacing previously trusted entities.

There were no previous paradigms for the blockchain. It is not a new version of an Internet Protocol. It is not another whole Internet either. Blockchain is a different construct. It is more of a new protocol that sits on top of the Internet, just as the World Wide Web sits on top of the Internet via its own technology standards. It is a database, a development platform, a network enabler. As an overlay on top of the Internet, blockchains can take many forms of implementations. It can be seen as a trust layer, an exchange medium, a secure pipe, a set of decentralized capabilities, and even more.
Moreover, blockchain is a type of technology that challenges other existing software technologies because it has the potential to replace or supplement existing practices. In essence, it is a technology that is able to change other technologies.

According to William Mougayar, the author of the popular book “The Business Blockchain”, another way to understand the blockchain is in seeing it as a combination of three main sciences that have always existed separately, but for the first time, they have together intersected harmoniously and transformed inside blockchain technology (Mougayar, 2016). These sciences are: *game theory*, *cryptography* and *software engineering*.

Game theory is the study of mathematical models of conflicts and cooperation between intelligent rational decision-makers. It is linked with blockchain because, initially, the popular blockchain cryptocurrency, the Bitcoin, had to solve a known game theory conundrum called the *Byzantine Generals Problem* (Lamport, Shostak, & Pease, 1982).
The implementation of this game is important because it starts with the assumption that you cannot trust anyone, and yet it delivers assurance that the transaction has travelled and arrived safely based on trusting the network during its journey, while surviving potential attacks.
There are fundamental implications for this new method of reaching safety in the finality of a transaction, because it questions the existence and roles of current trusted intermediaries, who held the traditional authority on validating transactions.
Thus, the main question is: do we need a central authority to ensure central trust, if we can accomplish the same trustworthiness when the transaction travels from one peer to another, via a network where trust is embedded in it? As the new paradigm states the answer is no.

Cryptography science is used in multiple places to provide security for a blockchain network, and it rests on three basic concepts: hashing, keys, and digital signatures.
A *hash* is a unique fingerprint that helps to verify that a certain piece of information has not been altered, without the need to actually see it.
The keys are used in, at least, a combination of two: a public and a private one. The *public key* is used by the sender to encrypt information that can only be decrypted by the owner of the *private key*. Of course the private key has not been revealed.

As Mougayar argues, "*cryptography is based on the public-private hegemony, which is the yin-yang of the blockchain: public visibility, but private inspection. It is a bit like a home address. The home address can be public, but it does not provide any information about what the home looks like on the inside. There is the need to have the private key to enter in a private home, and since it has been claimed that the address is unique and personal, no one else can claim a similar address as being theirs*."

Although the concepts of cryptography have been around for a while, *software engineers* are willing to combine it with game theory innovation, to produce the overall constructs of blockchains, where uncertainty is mitigated with overwhelming mathematical certainty.

1.2 Behind Blockchain Technology

In practical words, a blockchain consists of a distributed database of records, the so called distributed ledger (DL) or public register, where all the information of the transactions or events that have been executed are collected, and thus shared among participants. Each transaction in the public ledger has to be verified by consensus of the majority of users in the system. Once entered, information can never be erased. The system contains a record of every single transaction ever made, so that the ledger has to be certain and verifiable.
The most popular example based on this technology is Bitcoin, one of the leading cryptocurrency nowadays. According to its founder (Nakamoto, 2008),

> "*Bitcoin is a peer-to-peer version of electronic cash that allows payments to be sent directly from one party to another without going through a financial institution. The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work.*"

Even though the digital currency itself is highly controversial, the underlying blockchain technology has worked flawlessly and found wide range of applications in both financial and non-financial world. Indeed, it enables the development of a democratic, open and scalable digital economy from a centralized one. There are tremendous opportunities in this disruptive technology, and the revolution in this space has just begun.

First of all, a general overview of how the blockchain works has to be traced, with the aim of understanding the main features. Hence, we have illustrated the concept of this technology by explaining how Bitcoin works as the two concepts are intrinsically linked.
However, blockchain is applicable to any digital asset transaction exchanged online.
Usually, when we make a payment, we rely on a trusted third party, typically a financial institution (e.g. a bank), whose role is to validate, safeguard and preserve transactions.
Of course, a certain percentage of fraud is unavoidable, especially in online transactions, and that needs mediation by financial institutions. This results in high transaction costs.

Differently, Bitcoin uses cryptographic proof instead of the "trust in the third party" mechanism for two willing parties to execute a transaction through Internet. Each transaction is managed by digital signatures. Specifically, a *public key* is sent to the receiver, and it is digitally signed using the *private key* of the sender. Thus, according to this process, the owner of the cryptocurrency needs to prove his ownership of the private key. On the other hand, the entity receiving the digital currency then verifies the digital signature, which implies ownership of the corresponding private key, by using the public key" of the sender on the respective transaction.

In particular, public keys are publicly known and essential for identification while private keys are kept secret and are used for authentication and encryption. Indeed, the generation of a bitcoin address begins with the generation of a private key. From there, its corresponding public key can be derived using a known algorithm. The address, which can then be used in transactions, is a shorter representative form of the public key (Tanya, 2019).

Then, each transaction is broadcasted to every node in the Bitcoin network and is then recorded in a public ledger after verification. Two things have to be verified before recording any transaction:

- the spender owns the cryptocurrency, through the digital signature verification on the transaction;
- the spender has sufficient cryptocurrency in his account, by checking every transaction of its account, thus of its public key, that is registered in the ledger.

However, the transactions do not come in the same order in which they are generated, and hence it emerges the need for a system to ensure that double spending of the crypto currency does not occur. For this reasons there is the need to define a mechanism on which the network has to agree regarding the order of the transactions.

How to do it? Relying on the blockchain technology. The transactions are placed in groups called *blocks*. Then these blocks are linked each-other, like a chain, in a proper linear and chronological order with every block containing the hash of the previous block. From this peculiar mechanism comes the name of the technology, *block-chain*.

But there is still a problem: how does the network decide which block should be next in the chain? There can be multiple blocks created by different nodes at the same time. One cannot rely on the order since blocks can arrive at different orders at different points in the network. The solution is given by a mathematical puzzle.
Each block will be accepted in the blockchain if it is able to provide an answer to a very special mathematical problem. This is also known as *proof of work*.
This process of validating transaction is made by the "miners", those wo verify blocks. For instance, a node can be required to find a *nonce*[1] which, when hashed with both transactions and hashes of previous blocks, produces a hash with certain number of leading zeros. It does guarantee the continuity of the process.
All the network miners compete to be the first to find a solution for the mathematical problem that concerns the candidate block, a problem that cannot be solved in other ways than through brute force so that essentially requires a huge number of attempts. They compete against each other to complete transactions and get rewarded in bitcoin. The average effort required is exponential in the number of zero bits required, but, on the other hand, the process is very simple and can be done by executing a single hash.
This mathematical puzzle is not mundane to solve, and the complexity of the problem can be adjusted so that on average it takes ten minutes for a node in the network to make a right guess and generate a block. Hence, the probability that more than one block will be generated in the system at a given time is low. The first node, to solve the problem, broadcasts the block to the rest of the network. The network only accepts the longest blockchain as the valid one.

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[1] **Nonce** is an arbitrary number that can be used just once in a cryptographic communication. It is similar in spirit to a nonce word, hence the name. It is often a random or pseudo-random number issued in an authentication protocol to ensure that old communications cannot be reused in replay attacks (Wikipedia).

1.3 Main Features

With the aim of having a better understanding on the opportunities offered by blockchain, above a list of its main features are provided. These are: Cryptocurrency, Computing Infrastructure, Transaction Platform, Decentralized Database, Distributed Accounting Ledger, Development Platform, Open Source Software, Financial Services Marketplace, Peer-to-Peer Network and Trust Services Layer.

1.3.1 *Cryptocurrency*

The digital currency function is probably the most "visible" element in a blockchain, as it is one of the most popular phenomena of recent years. In few words a cryptocurrency is a digital or virtual currency that uses cryptography for security. The most popular and remarkable ones are Bitcoin (BTC) and Ethereum (ETH).

However, today there are thousands of alternative cryptocurrencies with various functions or specifications. Some of these are clones of Bitcoin while others are new cryptocurrencies that split off from an already existing one (Frankenfiled, 2019b).

Outside of the blockchain's operations, cryptocurrency is just like any other currency, as the fiat ones for example. It can be traded on exchanges, and it can be used to buy or sell goods and services. Cryptocurrency is very efficient inside blockchain networks, but there is friction every time it crosses into the real world of traditional currency. Indeed, one of the main challenge with cryptocurrencies is their price volatility, which is enough to keep most consumers away.

According to Robert Sams, "*the main volatility in Bitcoin comes from variability in speculation, which in turn is due to the genuine uncertainty about its future. More efficient liquidity mechanisms do not help reduce genuine uncertainty. As cryptocurrency gains more acceptance and understanding, in the future there will be lower uncertainty, thus resulting in a more stable and gradual adoption curve*" (Sams, 2015).

Indeed, as the chart below shows *(Figure 1)*, by analysing the 30-days *Bitcoin/USD Volatility Index* ("The Bitcoin Volatility Index," 2019), the volatility significantly decreased among the years. In 2011 the value was greater than 16%, while today is around 3%.

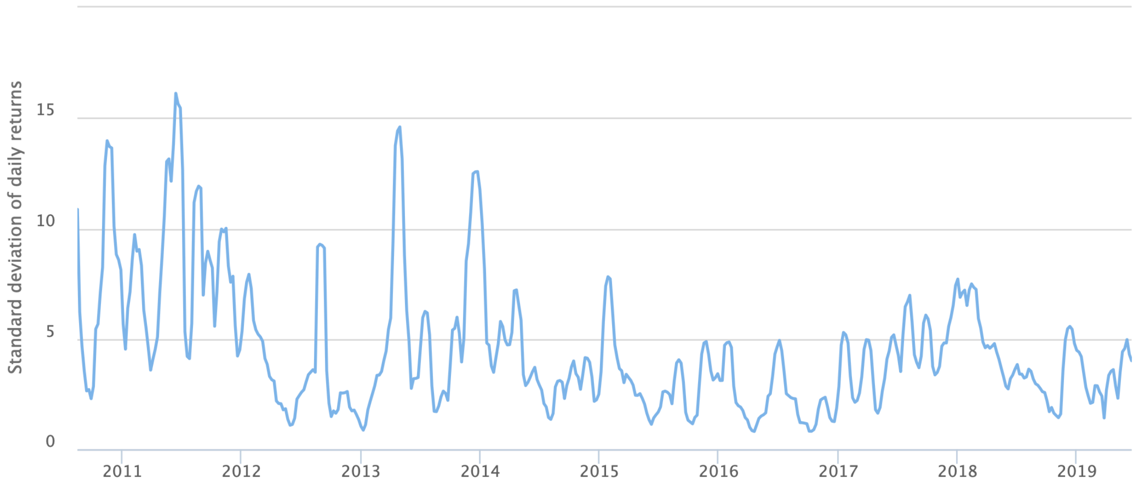

Figure 1 – 30-days Bitcoin-USD Volatility Index

1.3.2 *Decentralized Computer Infrastructure*

As mentioned before, one of the revolutions behind blockchain technology is the concept of *decentralization*. This is physically realized through the presence of computers that together commonly obey the same "consensus" process for releasing or recording the information they hold, and where all related interactions are verified by cryptography.
Networked computer servers are what really powers blockchains. But developers do not need to set up these servers, since it is part of the magic of the technology.

1.3.3 *Transaction Platform*

A blockchain network can validate a variety of transactions. Every time a consensus is reached, a transaction is recorded on a block. The system keeps track of them, that can be later verified as having taken place. Thus, the blockchain can be even considered as a giant transaction processing platform, capable of handling microtransactions and large value transactions alike.
In order to quantify the operational capability of the system, a unit of measure has been defined: Transactions Per Second (TPS).
As a benchmark, in 2015, VISA handled an average of 2,000 TPS on their VisaNet, with a peak rate of 4,000 TPS. If we consider the case of Ethereum, the leading cryptocurrency platform, it started with 10 TPS in 2015, edging towards 50–100 TPS in 2017, and

targeting 50,000–100,000 TPS by 2019 (K. Li, 2019). Of course there is still a considerable distance, but the potential to scale is huge.

1.3.4 *Decentralized Database*

The blockchain alters the paradigm behind the database-transaction process. It is like a place where you store any data in a semi-public way into a container, the block. Anyone can verify that you have placed those information, because the block has a peculiar signature stamped on, but only the user, or at least a program, has the power to unlock what is inside the container, because private keys to that data are needed.

So the blockchain behaves almost like a database, except that part of the information stored, its "header," is public. Admittedly, blockchains are not very efficient databases, according to William Mougayar (Mougayar, 2016). Their job is not to replace large databases, but rather, it is the job of software developers to figure out how they can rewrite their applications to take advantage of the blockchain's state transitions capabilities.

1.3.5 *Shared, Distributed Accounting Ledger*

The blockchain is also a distributed, public and accounting asset ledger that keeps track of every transaction ever made on its network, allowing a user's computer to verify the validity of each transactional process in order to avoid any double-counting. This ledger is shared across multiple parties, thus the network, and it can be private, public or semi-private.

Even though being a distributed ledger of transactions is a popular way to describe blockchains, according to the definitions of many authors and websites (Investopedia, Webopedia, Standard Chartered Bank, Google and Heptagon), it is only one of its characteristics.

1.3.6 *Software Development Platform*

For software developers and engineers, a blockchain is firstly and foremost a set of new and innovative software technologies. Clearly, it has a political and societal base, according to the decentralization paradigm, but it also brings some technological novelties. This new set of development tools is an exciting event for software engineers.

New breed of applications has been developed, with the main aim to be decentralized and cryptographically secure. Thus, blockchain can be also considered as a new way to build applications.
If blockchain is analogous to what internet was in the late 90s, then DApps, Decentralized Applications, are in an analogous stage to the early-days of the app stores. We are going to see massive growth in DApp software developers over the coming years (Konstantopoulos, 2018). It is a spread and popular phenomenon, so that the term DApp has become a popular buzzword, being awarded in January 2019 the "Word of the Year" of 2018.
Some of the potential impacts of DApps, that could potentially emerge, mainly concern with data ownership rights, IoT integration and Digital Security. Each DApp project provides on its own some exciting potential and they all roll up to create a more sophisticated digital ecosystem (Katalyse.io, 2018).

1.3.7 *Open Source Software*

Most robust blockchains are open source platforms, which not only means that the source of the software is public, but also that innovation can happen in a collaborative way. The main idea is having a common place where all the developers can work aiming to figure out new projects, thus fostering innovation in the ecosystem.
For example, the core Bitcoin protocol is open source. Indeed, thousands of independent developers innovate with complementary products, services, and applications that take advantage of the Bitcoin protocol robustness.
The fact that blockchain software is open source is considered a powerful feature. According with an economic analysis, the more open the core of a blockchain is, the stronger the ecosystem around it will become (Davidson, De Filippi, & Potts, 2016).

1.3.8 *Financial Services Marketplace*

Money is the heart of any cryptocurrency-based blockchain. Cryptocurrencies can be considered as a currency, since they are part of a financial instrument, leading to the development of a variety of new financial products.

Blockchains offer an incredible innovation environment for the next generation of financial services. But, as described in the section 1.5 (*The Impact of Blockchain Technology on Financial Industry*), new instruments and new applications have been created, as the one discussed in this thesis, the ICOs.

1.3.9 *Peer-to-Peer Network*

Decentralization is the word that better describes what blockchain is. There is nothing "central" about blockchains. Architecturally, it is based on a peer-to-peer network. Blockchain pushes for decentralization via peer processing at its node locations.
The network is populated by the computers. The user, i.e. their devices, are responsible for verifying each transaction at the peer-to-peer level. In essence, a blockchain could be appointed as a "cloud that is truly decentralized" (Malviya, 2016).
Users can reach and transact each other instantly, no matter where they are and when they operate. No intermediary is needed to filter, block, or delay a transaction between any two or more users, or between nodes that are consuming a transaction. Any node on the network is allowed to offer services based on their knowledge of transactions everywhere else in that network.
In addition, blockchain also creates a marketplace of users. Blockchain networks and applications on top of them create their own (distributed) economies, with a variety of sizes and vibrancy. So, blockchains bring with them a new economic model, enhancing coordination among users, reducing the information asymmetry and thus mitigating uncertainty. The blockchain, indeed, triggers segmentation of market and differentiation of agents in both the sell and buy sides of the market and it re-configures the asymmetric information (Aoyagi & Adachi, 2018).

1.3.10 *Trust Services Layer*

All blockchains commonly hold on trust. It is applicable not only to transactions but also be extended to data, services, processes, identity, business logic, terms of an agreement, or physical objects. It applies to almost anything that can be digitized as a smart asset with an inherent or related value attached to it.

According to Goldman Sachs, one of the largest US banks, it is considered the new technology of trust: “Blockchain has the potential to change the way we buy and sell, interact with government and verify the authenticity of everything, from property titles to organic vegetables. It combines the openness of the internet with the security of cryptography to give everyone a faster, safer way to verify key information and establish trust” (Goldman Sachs, 2019).

1.4 The Applications

The blockchain is based on decentralized transaction ledgers (DLT) that are part of a larger computing infrastructure that includes many other functions such as storage, communication, file serving, and archiving. Specific projects that are developing solutions for the distributed blockchain ecosystem include file (text, images, audio, multimedia) *storage* , file *serving* and file *archiving* (Swan, 2016).

First, in terms of *storage*, the most obvious requirement is having a secure, decentralized, off-chain system in order to store files such as electronic medical record or even any simple Microsoft Word document. For example, the Taipei Medical University Hospital has rolled out a blockchain-powered platform to improve medical record-keeping. The so called "Healthcare Blockchain Platform" was reportedly developed in order to support the government's Hierarchical Medical System policy, by improving patient referral services and integrating individual healthcare networks to enable people to access their medical records in an easier way. Consequently, to make a request for their records, patients can easily log into a password-protected mobile app (Alexandre, 2018).
File storage could either be centralized, like the service provided by Dropbox and Google Drive, or it could be in the same decentralized architecture as the blockchain.

Secondly, in the case of file *serving*, the IPFS project (IPFS, 2016) proposed an interesting technique for decentralized secure file serving. IPFS stands for Inter Planetary File System, which meet to the need for a global and permanently accessible file system to solve the problem of broken website links to files, well beyond the context of blockchain technology for the overall functionality of the Internet.
IPFS is a distributed file system that seeks to connect all computing devices with the same system of files. In some ways, it is similar to the original aim of the Web, but IPFS is actually more similar to a single BitTorrent objects.
IPFS could become a new major subsystem of the internet. If built right, it could complement or replace HTTP (Vasa, 2018).
In fact, the traditional internet protocol HTTP is considered great for loading websites, but it wasn't designed for the transfer of large amounts of data (like audio and video files).

These constraints possibly enabled the emergence and mainstream success of alternative file sharing systems like Napster[2] and BitTorrent[3].

Third, in the area of *archiving*, a full ecosystem would also necessarily include longevity provisioning and end-of-product-life planning for blockchains (Swan, 2016). We cannot assume that blockchains will exist over time, thus their preservation and accessibility is not trivial. For this reason, it emerges the need for creating a blockchain archival system to store blockchains, as the Wayback Machine of Internet Archive. This is a non-profit organization, whose activity is building a digital library of Internet sites and other cultural artefacts in digital form with the main mission of providing universal access to all knowledge (Archive, n.d.).
Not only blockchain ledgers must be preserved, but it is also emerged the need of recovering and controlling previously recorded blockchain assets at later dates since it is likely that certain blockchains will go out of business.
If blockchains will become the conventional archival mechanism for the whole of a society's documents, longevity, preservation, and access mechanisms need to be built into the value chain explicitly. Of course this is not the actual situation, but with the development of this technology it could represent in the future a possible threat.

Blockchain technology is developing at a rapid pace, so that the ecosystem around it is still unclear. For this reason, in order to address the evolution of this nascent technology, PitchBook[4] has created a blockchain market map consisting of 135 blockchain start-ups

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[2] **Napster** is a set of three music-focused online services. It was founded as a pioneering peer-to-peer file sharing Internet service that emphasized sharing digital audio files, typically audio songs, encoded in MP3 format (Wikipedia).

[3] **BitTorrent** is a communication protocol for peer-to-peer file sharing which is used to distribute data and electronic files over the Internet. It is one of the most common protocols for transferring large files, such as digital video files containing TV shows or video clips or digital audio files containing songs (Wikipedia).

[4] **PitchBook** is a SaaS company that delivers data, research and technology covering the private capital markets, including venture capital, private equity and M&A transactions. Within the PitchBook Platform, users can also use a variety of software and analysis tools to run targeted searches, build financial models, create data visualizations, and build custom benchmarks.

that have received the greatest amount of funding from angel investors and VC funds (Halford, 2018). There's been an increase of blockchain technologies and use cases in enterprise solutions, compliance, identity systems and tokenization of assets.
Below a brief description of leading market segments is provided:

- *Transactions and payment services*: this category contains start-ups whose primary use cases involve buying, selling or storing cryptocurrencies. Some examples are smart contract-based solutions, as Ethereum, cryptocurrencies and wallets;

- *Exchanges and trading*: crypto-exchanges are platforms for exchanging cryptocurrencies into other cryptocurrencies, fiat currencies or vice versa. In this case it has been developed many innovative solutions, as the ones based on P2P lending, crowdfunding and crowd investing platforms and crypto exchange;

- *Identity, authentication & security*: an inherent characteristic of a blockchain is the immutability of transaction records. The logic behind is that the decentralization of the system, the distributed ledgers, is able to provide this fundamental requirement. Start-ups' main applications, indeed, use digital ledger software to verify the authenticity of data, as well as assets or documents, and use blockchain identifiers to represent and/or authenticate tangible assets;

- *Enterprise blockchain solutions*: blockchain-based-firms operating in this category provide enterprise-level solutions to those firms that operate in sectors such as financial services, healthcare, insurance, compliance, supply chain, and advertising;

- *Social network and games*: these applications aim to leverage on distributed ledger to enable social networking platforms used for recruiting, classifieds, dating and loyalty programs.

For example, *CryptoKitties* is a blockchain-based video game platform that allows players to purchase, collect, breed and sell various types of virtual cats;

- *Ecosystem*: this category includes start-ups furthering blockchain technology via underlying infrastructure improvements and software development tools. The main applications concern with mining, hardware & data storage and Infrastructure & Application Development.

A report edited by McKinsey (Carson, Romanelli, Walsh, & Zhumaev, 2018) aims to analyse the strategic importance of blockchain technology for major industries. The chart (*Figure 2*) shows the blockchain opportunities for the main industry sectors according to two variables, the feasibility of applying the new technology and the impact it can have in their business.

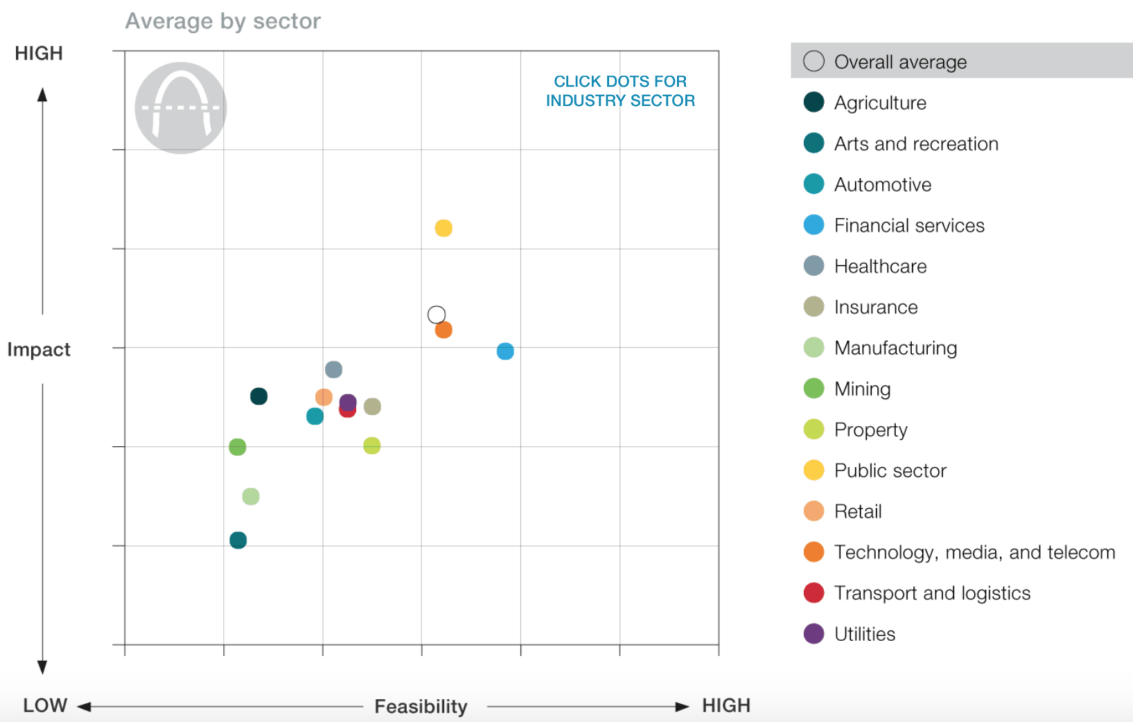

Figure 2 – Blockchain Opportunities Classified by Industry, (*McKinsey, 2018*)

The sectors with the greatest impact both in terms of impact and feasibility are public, financial services & technology and media & communication.

Because of its possible great clash in our daily life, the following paragraph is dedicated to the analysis of the public sector opportunities with the adoption of this technology.
Blockchain-based solutions have the potential to make government operations more efficient and improve the delivery of public services, while simultaneously increasing trust in the public sector.
According to Brian Forde, senior lecturer for Bitcoin and Blockchain at MIT and former White House Senior Advisor for mobile and data innovation during the Obama administration, "*what really local citizens will truly appreciate is the potential for better delivery of government services. You can look at this technology as a cryptocurrency, but you can also look at it as a notarization service, a timestamp of sorts, that validates the exact time an action takes place*". Moreover, Forde continues saying that "*today, you have to bring your documents in person and the relevant agency rubber stamps it. This is a hodgepodge, mistake-prone way to do business in a digital age; there are lots of unique opportunities for city and state governments to leverage blockchain technology*" (Laclau, 2018).
One of the possible application for the public sector is linked with the digital identity and thus the way in which citizens will interact with public entities. Each agency, indeed, tends to interact with citizens in its own way, and each one generally has different identity markers, many still paper-based. The lack of a unified identity, that means a combination of attributes forming a coherent, shared, and widely accepted identity, hinders these agencies from seamlessly entering a blockchain consortium (Henry & Armstrong, 2018).

1.5 The Impact of Blockchain Technology on Financial Industry

As we mentioned in the previous paragraph, blockchain technology has the potential to strongly shock the financial sector, making it more effective and efficient.

Blockchain development will create substantial changes in this industry and especially in the way how people conduct financial transactions. This may revolutionize the economy and has already impacted global financial services.

Technical innovations have improved the speed and processes necessary in the financial sector. The blockchain technology appears to be permanent and it is the power behind decentralized currencies.

Overtime, blockchain is becoming more recognized and accepted by financial institutions. Numerous financial institutions are exploring the possibilities potentially available with blockchain development. This may change the way business transactions will be conducted in the future.

In February 2019, JPMorgan Chase & Co, one of the largest US bank, announced its plans to launch its own digital coins, called “JPM Coin”, that customers will be able to use for instant transfer of payments over a blockchain network.

The bank, in its interview to Reuters (Saxena, 2019), said it believed in the potential of blockchain technology, and expects its new digital coin to yield significant benefits for blockchain use by reducing clients’ counterparty and settlement risk, decreasing capital requirements and enabling instant value transfer. Moreover, the organization plans to make the coin operable on all standard blockchain networks.

But not everyone agrees. The CEO of JPMorgan himself, Jamie Diamon, criticized the former high-flying bitcoin, calling it a “fraud” in 2017. Back then Diamon said that cryptocurrencies are “worse than tulips bulbs,” referring to a famous market bubble from the 1600s. He tempered his view a few months later, saying he regretted calling bitcoin a fraud, but maintained his disinterest in the cryptocurrency.

So there are still many scepticisms even inside the bank. Many bankers argue the need of regulation. For example, the Association of German Private Banks, Bankenverband, foresees that a need for new regulation may arise from the emergence of distributed ledger technology-based securities (Zmudzinski, 2019).

But, of course, although those legitimate concerns, banks are getting ready for this revolution. According to Richard Johnson, Vice President of Greenwich Associates, a US financial and insurance consultancy firm, one in ten of the banks and firms studied have blockchain budgets greater than $10 million, while the number of employees working on blockchain projects doubled in 2017. Indeed, investment by financial services firms in blockchain increased by 67% in 2017 from the previous year, up to a total of $1.7 billion. The data demonstrates that the financial services industry continues to be intrigued by blockchain technology, even though the progress remains still slow (Greenwich, 2018).
For example, the US based banking giant Goldman Sachs has led a $25 million strategic funding round for blockchain payments start-up Veem. The start-ups aims to increase the efficiency of small business payments by relying on digital ledger technology (Castillo, 2018).

Now the main question is: why financial institutions need blockchain? In which way are they impacted by this technology? The main applications are made with the aim of enhancing trust and efficiency, one of the main drawback of financial and insurance sector. Indeed, it provides chances for cost cutting, shortening settlement time, risk and cost of capital reduction. Payments and trade finance are the most common areas in which businesses are looking to apply blockchain and distributed ledger technology (DLT).
In particular, by taking the efficiency point of view, the duplicative and time-consuming post-trade processes that banks, brokerages and other financial operators daily undertake to reconcile multiple ledgers represent a very large cost of trust embedded in the existing system. For the top ten banks alone, blockchain technology could reduce infrastructure costs by 30%, translating into savings of between $8 and $12 billion. The figure would surely be significantly higher when applied to all institutions within the financial system (Casey, Crane, Gensler, Johnson, & Narula, 2018).
On the customer side, the cost of trust represents the main area of improvement and it plays out in many forms. These costs range widely, from those associated with vault doors, cybersecurity, settlement procedures, user identification, compliance teams, security guards and anti-fraud regimes, to the excess amounts that banks and other centralised institutions can charge customers. Trust exists in the fundamentals of deposit

banking, custody, insurance and secondary market trading. Depositors must trust the safety of their money at a bank. Market participants trust that their trades will be executed fairly according to a transparent set of rules. Financial institutions must trust costly back-office processes to reconcile centralised ledgers and accounting systems.
So trust represents for those firms one of the major source of spending but, at the same time, one of the major drawbacks, so that a change in the process is required.
According to a research made by many US academics (Casey et al., 2018), below are listed and described the main applications of the blockchain technology in financial sector. Those are: payments, digital identity and customer profiling, primary security issuance, securities clearing and settlement, derivatives clearing and processing, post trade reporting and trade finance.
Of course, all the applications listed have equal importance, but, for the purpose of our thesis, we will consider only the ones that most fit our topic. These are:

Payments: the cross-border payments are the ones that are mostly impacted by the application of the new technology. This is mainly due to the drawbacks that financial institutions have to face. The existing approach, indeed, is slow and expensive, tying up large amounts of liquidity. Moreover, payment processes are often opaque, affected by uncertainty and exposed to frauds and counterparty risks. Accordingly, remittances and foreign currency payments were one of the first potential applications of blockchain technology to receive attention.
Blockchain has the potential to resolve inefficiencies and provide a faster, cheaper and more secure alternative to the current system. Blockchain's business value-add is projected to grow to $176 billion by 2025 (Cook & Jones, 2018).
The main challenges of international payments through the actual channels are due to the complexity, the length and the number of intermediaries involved in the process.
Blockchain provides a solution by rationalizing the process and storing every transaction in a distributed ledger. As soon as a transaction is recorded, the receiving party has access to the payment, thus avoiding intermediaries, delays and costly fees (Khandaker, 2019).
Cross-border payments supported by blockchain provide significant advantages to businesses (B2B) and retailers (B2C). The new process is more efficient and effective,

fast, secure and transparent (Deloitte, 2019). Deloitte estimates that B2B and P2P payments with blockchain result in a 40% to 80% reduction in transaction costs, and take an average of four to six seconds to finalize (compared to two to three days using the standard transfer process).

Trade Finance: it consists of the financial instruments and products that are used by import and export companies to engage in international business trades. The function of trade finance is to introduce a third-party to transactions with the aim to protect against international trade's unique inherent risks, such as currency fluctuations, political instability, issues of non-payment creditworthiness (Kenton & Murphy, 2019).
In one of the first trade finance applications of the technology, Barclays, a UK multinational investment bank and financial services company, teamed up with Irish cheese-maker *Ornua* to process the guarantees and financing assurance for a transaction by selling a shipment of cheese to the Seychelles in September 2016. The blockchain technology provided an electronic record-keeping and transaction-processing system, which lets all parties track documentation through a secure network and requires no third-party verification. By relying on this innovative approach the companies were able to cut a process that normally takes 7-10 days to less than four hours (Kelly, 2016).
A somewhat different approach to the same problem has been developed by electronics giant *Foxconn*, best known for manufacturing Apple's iPhone, which taps thousands of very small suppliers to provide the parts it needs to make everything from iPhones to Hewlett Packard printers. Foxconn, whose venture arm has invested in a number of US-based blockchain start-ups, is encouraging its suppliers to submit data to a blockchain ledger of transactions so as to improve coordination of production schedules and availability of parts. In return, the company is shortening the payment terms or providing internal loans on its own account, boosting its suppliers' working capital and bypassing the role of banks altogether (Del Castillo, 2017).
As the examples reveal, there are great potentials for the application of blockchain technology in trade finance. In particular supply chain finance represents one of the sector more impacted by the new approach (London, 2018). Indeed, the primary function of a

supply chain is to facilitate exchange between a buyer and a seller to transform resources into a valuable product for the final customer.
The common aim is enhancing the efficiency, reducing the complexity and the number of third parties involved, enabling a serious cost cutting and, last but not least, speeding up the entire process, from days to hours.

Primary security issuance: several companies have recently tested blockchain-based systems to issue corporate loans, by taking the advantage that all parties have a shared and updated record of all the transactions. Also, the system can automate functions like the distribution of cash flows in accordance with the parties' legal rights via smart contracts. These processes are currently managed manually, with PDF copies of loan documents and any amendments often distributed by email, and with cash flows tracked and managed in databases (sometimes on spreadsheets) by a central trustee, thus wasting an enormous amount of resources.
For the reasons explained, a blockchain solution for security issuance would enable digitization, cost cutting and efficiency gain. For example, it could help the issuer to view a real-time list of investors and their positions.
According to Nasdaq[5], blockchain technology could significantly speed up the clearing and settlement of equity trades from the existing standard of three days in the US and two days in Europe to less than ten minutes (Arnold & Bullock, 2015).
We are in early stages as industry is still developing proof of concepts at individual level or in consortium to test and develop industry standards for blockchain. When all the participants will be able to cooperate each other on a unique platform, there will be large potential to increase efficiency by reducing costs (Vakta, Maheswari, & Mohanan, 2016).

Financial institutions will be challenged by the adoption of the blockchain in their "conservative and traditional" business models. Their default position will only slightly open the door, expecting to let as many benefits seep in, with the least amount of opening.

[5] **Nasdaq**: the Nasdaq Stock Market is an American stock exchange. It is the second-largest stock exchange in the world by market capitalization, behind only the New York Stock Exchange located in the same city.

The challengers, that are mostly start-ups, will try to kick that door open as much as possible, expecting to throw the incumbents off balance.
Much of the blockchain's technological innovation in financial services is driven by start-ups. Financial institutions, like any other industry, can innovate by applying that technology. In fact, they do not have the internal capabilities and resources to bring innovation inside, thus they have to rely on specialized parties, especially young and ingenious start-ups, signing with them partnerships and strategic alliances.
Today, the fintech firms represent one of the leading phenomenon. Of course not all of them are related with blockchain, but they already have a significant share. In fact, the fifth consecutive year of *Fintech 100*, a paper uncovering and evaluating the most innovative fintech companies globally, has seen a total of 16 cryptocurrency and blockchain related start-ups among their ranks (Mostowyk, 2018). The numbers are growing exponentially: by 2016, it has been registered a 70% increase in total funds for those ventures, reaching in 2018 an amount of $43.7 billion dollars.
Many of them are focused just on few popular areas: loans, wealth management, and payments. Some start-ups have gone as far as offering full banking services via mobile-only, an approach that is appealing to millennials. This proves that a new form of bank can be created from scratch, without legacy baggage.
Blockchains will not signal the end of banks and other financial services corporations, but innovation must permeate faster than Internet did in the 90s. The early blockchain years are formative and important because they are training grounds for this new technology, and whoever has trained well will win. We are still in the era of experimentation. Financial incumbents should not only see blockchain as a cost savings lever. It is very much about finding new opportunities that can grow their top line.
At the moment the existing financial system is complex, and thus risky. A new decentralized financial system could be much simpler, since layers of intermediation are eliminated. There are many opportunities that can be exploited. By moving money in different ways, it could generate different types of financial products, open up the financial system to people who are currently excluded, lower entry barriers and enable a greater competition.

There is also the chance to reduce systemic risk: like users, regulators suffer from opacity. Research shows that making the system more transparent reduces intermediation chains and costs to users of the financial system (Ito, Narula, & Ali, 2017).

1.6 Blockchain Crowdfunding and Smart Contracts

Another prime example of how financial services are being reinvented with blockchain-based decentralized models is crowdfunding. For this reason, we have decided to provide a general overview of it, revealing the main peculiarities of the actual stage. Indeed, the main object of this thesis are the ICOs, that can be considered as the evolution of the traditional crowdfunding due to the adoption of blockchain technology.
Its origin dates back in 2009. Several definitions of it exists. We decided to select the simplest one, provided by Firozi, Jalilvand and Lien (Firoozi, Jalilvand, & Lien, 2016):

"Crowdfunding is a practice in which start up entrepreneurs in search of funding sources may go directly to the general public (the crowd) by an internet platform to wholly or partly finance their projects."

From the definition it is possible to understand that crowdfunding implies a fund raising through an online public. Of course, a user will not only provide money, but it expects to receive something valuable in exchange for its donation, a sort of reward.
Thus, the presence of some sort of expected return implies a completely different approach towards crowdfunding introducing dynamics more relate to instruments such as debt and equity. Hence, we can distinguish a taxonomy of crowdfunding with four different branches (*Figure 3*):

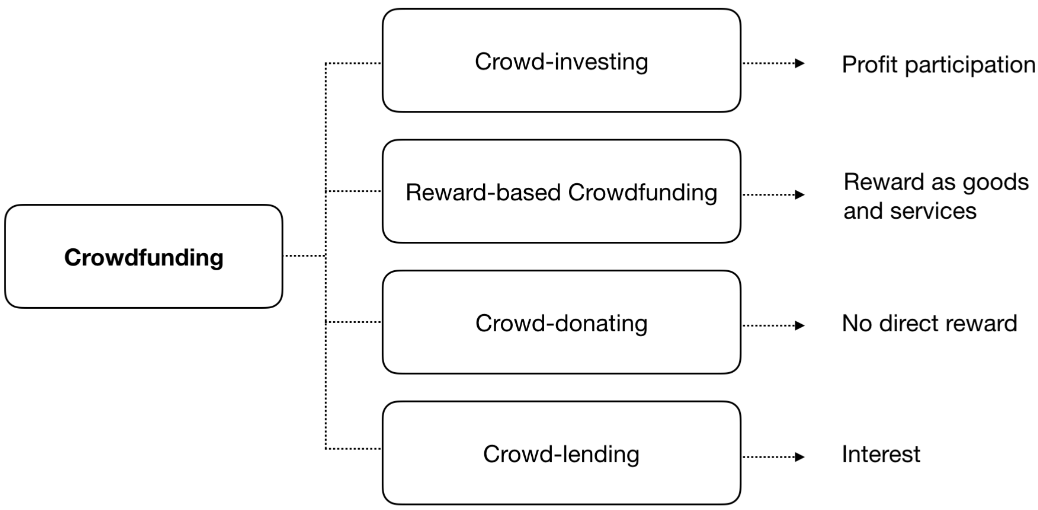

Figure 3 – A Taxonomy of Crowdfunding

Crowdfunding is a now quite popular way for enterprises to raise capitals during their earlier stages. In a seemingly nonstop recession wave, small businesses are struggling more than ever to stay afloat, and entrepreneurs are not facing great odds. Crowdfunding offers these individuals a chance at success, by showcasing their businesses and projects to the entire world (Prive, 2012).
This source of financing has been a valuable way for start-ups and SMEs to find capitals, especially during the shortage following the great global crisis of 2008, also thanks to the lack of regulation back then which made crowdfunding particularly appealing also thanks to the absence of costs related to the financial and not only due diligence for traditional capital queries.

According to the taxonomy shown in the figure above, one of the classical form of funding for entrepreneurial projects is the equity based one, also known as crowd investing. It is a category where the crowd obtain pieces of the backed company ownership through receiving stocks, hence control and participation of its profits. Differently, crowd lending or peer to peer lending does not compensate the crowd with stakes of the company but commit to release at specific moments pre-defined repayments plus interests.

Companies are moved towards crowdfunding for a wide range of different reasons, spawning from capital raising of course, to create a public awareness of their company and their value offer and to receive an early feedback about market appreciation of said value proposition months if not years before the actual marketization of it (Lambert, Schwienbacher, & Belleflame, 2010).
Macht and Weatherston also proposed, as a further benefit for those companies that opt for a crowdfunding solution, the facilitation effect for future fundraising. The presence of a successful crowdfunding campaign has the potential to attract capitals also from institutional investors such as business angels, venture capitals or banks for loans and lines of credit (Macht & Weatherston, 2014).
More generally, a great additional benefit to crowdfunding is its economical helping hand. Anything that aids in generating revenue is desperately needed in our sluggard economy,

and crowdfunding has proven to be a powerful force. Not only it is pumping small businesses with needed lifeblood, but it is also encouraging entrepreneurs to continue creating even in the face of these slow times (Prive, 2012).

In order to define the possible critical success factors of a crowdfunding campaign, we focused our analysis on two main sources, one from the School of Management of Politecnico di Milano and one from the Goethe-Universität of Frankfurt. Combining the two we came out with the following CSFs:

- *Presence of early contributors*: the number of users willing to invest in the first days of the campaign could have a strong impact for its successful. Indeed, if in the first day the project collects only few bids the probability to be unsuccessful is relevant. Instead, if it is close to the soft cap, the possibility to reach the final goal is significant.

- *Multimedia support*: it is linked with the ability of the team to provide graphical and video material in order to attract the investors and thus describing them the projects, purposes, objectives, ways of proceeding, and, finally, the project goal in detailed manner. It is proven that graphics could have a significant positive influence on webpage visit durations (Danaher, Mullarkey, & Essegaier, 2006).

- *Quality of the business plan*: project founders have the possibility to publish information related to their project within the project description in their business plan, and a smaller version, in their platform page. The amount and the quality of information published has a strong influence on the users. Founders, for example, can add more details on their project as well as on the specific steps leading to project realization. In particular, a more exhaustive description of the project risks also to increase the transparency and the reliability of it, thus leading to more trust and more funding success.

- *Mobilization of family and friends*: especially during the first days of trading, having a relevant user attraction, thus many investors, strongly matters. So that, lots of founders tend to engage in this process also friends and family members, with the aim to increase their visibility on the platform and thus attracting more funders.

- *Social media network*: a possible variable could be linked with the visibility on the social media as Instagram, Twitter, Linkedin and Facebook. In fact, to make a campaign successful, it is important to publicize and promote it on a large scale over social media. The success of a campaign largely depends on the networking skills and efforts of the creator. The creator himself needs to employ its network to mobilize people persuading them to donate. Typically, potential funders are impressed by a lot of friends, leading to the opinion that the founder must be trustworthy and successful.
  A model proposed by Harmeet Kaura and Jaya Gera confirms that social interaction and connectivity have a positive impact on the success of a campaign (Kaur & Gera, 2017).

- *Business trends*: trends in the industry strongly matter for funders, since the most popular ones are able to enhance profit-making opportunities. As it happened in the past during the dot-com bubble[6], the more a company is linked with the business momentum, the higher is the attention and the willingness of investors to fund the project. But sometimes those firms are not reliable and thus the risk of failure is relevant. Undoubtedly, the industry continues to move forward at light speed.
  According to different sources, the main trends in the crowdfunding industry for the year 2018 were: start-ups accelerator, equity crowdfunding, education, blockchain technology, events and non-profit.

[6] **Dot-com bubble** refers to an historic speculative bubble and period of excessive speculation mainly in the US that occurred roughly from 1994 to 2000, a period of extreme growth in the use and adoption of the Internet.

Today there are several crowdfunding platforms where entrepreneurs can ask for capital such as *Kickstarter*, *Indiegogo*, *RocketHub*, and investment platforms like *1000 Angels*. While each website offers their unique spin, the general concept is the same across the board. Project creators can create a profile, typically containing a short video, an introduction to their project, a list of rewards per donation, and some images to elaborate. The idea is to create a compelling message that readers will be drawn towards.
Today, robust platforms like Indiegogo are changing the concept of crowd-investing. The newest idea is shifting the focus from conventional crowdfunding to ICOs (Initial Coin Offerings), which is a sign of great globalisation of financial markets. The next paragraph and the entire work of this thesis is dedicated to the ICOs analysis, so that we will not spend more words on it.

1.6.1 *Smart Contracts*

As already discussed, when a company wants to raise capital for funding its project, such as launching a crowdfunding campaign, a third party is needed, like a specialised platform.
From the advent of the blockchain technology, many opportunities have been developed. One of them is the avoidance of intermediaries, due to the decentralized consensus approach. According to this vision, a new tool has been developed: the *smart contract*.
The concept and the idea behind are not new. Smart contracts, indeed, were initially proposed by Nick Szabo, a legal scholar and cryptographer, who coined the term. He introduced this concept in 1994, by defining a smart contract as "*a computerized transaction protocol that executes the terms of a contract*" (Szabo, 1997). Szabo suggested translating contractual clauses (collateral, bonding, etc.) into code, and embedding them into property (hardware or software) that can self-enforce them, so as to minimize the need for trusted intermediaries between transacting parties, and the occurrence of malicious or accidental exceptions. It underwent a long gestation period of inactivity and disinterest, because there was no platform that could enforce smart contracts, until the advent of the Bitcoin in 2009.
According to him, a smart contract is defined as a computer protocol whose aim is to digitally facilitate, verify, or enforce the negotiation or performance of a contract. When

signing a contract, the parties promise to follow each other through an action that will take place. This action is facilitated digitally to verify if the promise follows through. Smart contracts allow to create certain parameters that need to be met for an action to take place. For example, a company might execute a blockchain smart contract to pay a customer a digital asset if and only if a specific software clause is triggered by a mutually acknowledged change of state.
These tools promise to program our world on the head of blockchains, and potentially replace some of the functions currently executed by expensive or slow, legacy intermediaries.

For example, using smart contracts, VeChain, a global leading blockchain platform for products and information, allows manufacturers to assign unique identification numbers to products and keep track of their movements through the supply chain from anywhere in the world. This approach is so attractive that PwC, which is considered one of the “big four” global accounting firms, recently acquired a small stake in VeChain with the objective to develop the product further and bring it to a global marketplace (Alexandre, 2018).

According to Jerry Cuomo, Vice President for blockchain technologies at IBM, smart contracts will be used all across the chain from financial services to healthcare to insurance (Rosic, 2016). As we will show in the next paragraphs, they represent the core of the ICOs, whose are smart contracts solutions for money collection.

1.7 Benefits and Challenges

What are the benefits of blockchain technology? What problems does, or aim, to solve? Especially enterprises are the ones asking what the main advantages behind its adoption are, since the benefits are not necessarily obvious to them. For example, for large companies, the blockchain itself is presented as a headache initially. It was something they had not planned for.

Here's the sad truth about questioning the blockchain's benefits: if you are content with the status quo, then it will be thought that the blockchain does not add any value. True, the blockchain is not for everything. The company has to understand if the adoption of the blockchain could generate a positive impact on the business. Sometimes yes, but sometimes not. Typically, as it happened during the dot-com bubble in the 90s, there is the risk to overestimate the power of a new technology. At that time everything that was linked with Internet was considered valuable. Of course it was, but lots of businesses failed. And others didn't have a rapid success, as Amazon for example.

The actual trend for blockchain technology is quite similar. In fact, the landscape is a combination of incumbent financial institutions making incremental improvements and new start-ups building on top of rapidly changing infrastructure, hoping that the quicksand will harden before they run out of runway (Ito et al., 2017).

According to the already mentioned William Mougayar, the blockchain's benefits can be examined on a long list. All of them have the common goal to increase profits and boosting the growth of the company (Mougayar, 2016). These are:

- Direct and indirect cost savings;
- Speed up the process by removing time delays;
- Increase transparency by providing the right information to the right people;
- Better privacy by protecting consumers, businesses via more granular controls;
- Lower risk because of a better visibility, less exposure, less fraud and less tampering;
- More equitable access;
- Productivity by enhancing work output;
- Gaining higher efficiency because of faster processing and reporting;

- Higher quality due to less errors and more satisfaction.

Blockchain is often considered as a world-changing technology and in many ways, it is. However, there are still some issues and problems that should be tackled. According to Bernard Marr [7], the main challenges are:

1. *Energy and environmental cost*: in order to establish a decentralized consensus over a distributed network, complex algorithms must be run, which in turn require large amounts of computing power. For example, still in 2017 it was claimed that the computing power required to keep the network running consumes as much energy as was used by 159 of the world's nations. Specifically, the global average energy spent on bitcoin mining has far exceeded the electricity consumption in Ireland and most African nations (Galeon, 2017).

2. *Lack of regulation*: due to the lack of regulatory oversight, scams and market manipulation represents, unfortunately, a commonplace. For example, Onecoin is a case of terrible frauds. The start-up made up a Ponzi scheme which robbed millions from investors who believed they were getting in early on what would become the "next Bitcoin" (Penman, 2018).
   Thus, regulation is proving to be the most formidable barrier to the development and deployment of blockchain solutions in business contexts, according to a survey made by PwC (PWC, 2018).

3. *High complexity*: although its potentially revolutionary applications are apparent once one has made the effort to understand the principles of cryptography and distributed ledgering behind blockchain, it takes a while, and a good bit of reading, before a common man, the so called "man of the street" can see what makes

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[7] **Bernard Marr**: recognised by LinkedIn as one of the top 5 business influencers in the world, he is an international, best-selling business author having published over 15 books. He is also well known as a keynote speaker and strategic advisor to worldwide companies. He is one of the world's most highly respected experts when it comes to business performance, digital transformation and the intelligent use of data in business.

blockchains potentially so useful. Thus, it makes difficult the application also for large and structured corporations, as banks, that should rely on external tech-specialists in order to acquire those resources and capabilities that they actually lack.

4. *Some incumbents have a personal interest in blockchain failing*: as it usually happens in any change, there is who will gain and who will lose. Despite the huge interest in adopting blockchain technology from the established financial industry, there is who think that it would probably be better if it just quietly disappeared. Why? Because Banks make huge amounts of profit from playing as intermediaries, and because the cost is distributed among their millions of customers, the reason why end users normally pay very little individually.

The general and most diffused opinion is that, although these issues could pose significant hurdles, it is likely that blockchain technology will evolve over the coming years. After all, technological advancement, much like nature, has a way of finding its way around artificially constructed barriers (Marr, 2018).

2
Initial Coin Offering

2.1 ICO Definition

Traditional companies have few ways of raising money to finance their activities: they can decide to reinvest their profit or look outside to collect equity or debt funds, directly seeking to private investors or financial institutions as banks or private equity funds.
The development of new technologies in the recent years allowed to open up new possibilities to raise capital. Less than 10 years ago, for instance, crowdfunding platforms did not exist: with their birth they gave a new alternative for companies to raise funds for the launch or expansion of their business.
One of the most recent disruptive innovations in the field of technology and digitalization is the blockchain. It started being applied in lots of sectors, even though many academics agree on the fact that it is still not clear where it will be exploited the most in the future.

The blockchain, among the others, has the possibility to decentralize information storage and thus managing them among thousands of different servers (distributed ledgers) spread all over the world, avoiding the need of a central intermediary working as a trusted party to keep system's validity. This paradigm was particularly appreciated by the financial world, since it is one of the main industries with the higher need to innovate (Adhami, Giudici, & Martinazzi, 2018).
This interest made the basis for the creation of a new alternative for raising capital in order to finance the company's project, the Initial Coin Offerings (ICOs). An Initial Coin Offering can be defined as:

"*an open call for funding promoted by organizations, companies and entrepreneurs to raise money through cryptocurrencies, in exchange for a token that can be sold on Internet or used in the future to obtain products or services and, at times, profits»*
(Adhami et al., 2018)

When a company wants to raise money through cryptocurrency tokens by an ICO, it has to prepare a sort of business plan, shown in a document called *white paper*. This is a document that provides the information of the project that investors want to know and the details of the investment required, from the minimum investment accepted to the rights attached to the tokens. People interested in the project can buy these tokens with fiat or a specific virtual currency. The tokens purchased through the ICO process can be considered as the shares of a listed company, but their utility can vary from one ICO to another, according to the terms explained in the white paper. In the next paragraphs a proper analysis of the possible uses of the tokens has been included (Section 2.4.1).

The ICO process is considered unsuccessful if it is not able to collect a minimum amount of money, previously established, known as soft cap. In this case the capital collected is given back to the investors. Differently, in case of successful campaign, the crypto-tokens start being traded on a digital stock exchange.

The company holding the ICO can use the funds to further its goals, launch its new products or investment, or start its digital currency. What investors hope is that the company will grow in the future and the token will increase its starting value. As mentioned before, a token can be also considered as a security for traditional shares, so that investor will gain money when its value increases, so when the firm's value will be larger (Hayes, 2019).

The technology of blockchain allows the process to be fully automated by specific digital protocols, called *smart contracts* (Section 2.4.3), with no need of third trusted parties as intermediaries: the utilization of some specific algorithms based on Information Technology automatizes the transactions between the two parties.

The first reported ICO dates back to 2013: *Mastercoin* raised approximately 5,000 bitcoin between the 30th of July and the 30th of August, for a value around $500,000 at that time ("History and evolution of ICOs," 2019).

Since the first ICO, there has been a continuous increase with a boom of $11 billion funds raised in 2017, with a 23-fold increase compared to 2016 in the main market, the United States. According to IcoBench, one of the most truthful websites about ICOs, up to April 2019, 5,460 projects have been published and more than $25 billion funds have been raised (IcoBench, 2019a).

2.2 A Comparison with Alternative Sources of Funding

Before going deeper in understanding of how an ICO works, it would be easier to compare it with alternative sources of financing for both SMEs and large companies. A paper provided by experts of this topic have analysed the novel funding mechanism based on Blockchain Technology (Chanson, Zurich, Risius, & Wortmann, 2018). They argue that blockchain technology and blockchain-based ICO funding represents a unique and novel form of banking disintermediation, distinct from related concepts in the traditional financial industry (i.e. IPOs, VC, Crowdfunding). The solution can be considered efficient and effective, so that it is legitimate to compare it with traditional funding approaches.

In this section our purpose is not to analyse the main characteristics of a crowdfunding campaign or an IPO process, but we want to roughly define them in order to make a comparison with the ICO-based solutions. We will firstly consider the case of the IPO, and then we will consider the crowdfunding one.

2.2.1 *IPOs and ICOs*

An Initial Public Offering, IPO, is the process through which a private corporation offer shares to the public for the first time. The decision to go listed on a Stock Exchange is typically motivated by the need of capital to fund new investments or repay existing debts; another possible reason might be to change the ownership structure of the company, allowing owners to exit from the company and creating a floating capital, dispersed among small investors. This is the theory, but in practical terms the decision to go public is mainly pushed by reputational reasons.

According to a survey made by the CEOs of the 500 fortune companies, the main reasons is the reputation that managers can gain in working for listed firms. They have access to a larger network, and thus they can collect more money, hence making the company larger. Of course it is better to work for a large multinational company than a small local firm.

Relevant actors in this process are the underwriters, which are investment banks or consultancy firms chosen by the target company, whose role is mainly helping the firm in determining the best type of security to issue, the offering price, the amount of shares and the period established for the market offering (Hayes, 2019). They act as intermediaries between the IPO company and the investors, both retail and institutional. These, then, obtain a stake of the company according to the capital invested and hence, eventually, take part to the dividends' distribution. Generally, the portion that they can gain varies in a range of 20-25%, but there are some cases in which it is higher, as we have seen in the case of Pirelli, whose value reached the 40%.

The term Initial Coin Offering sounds familiar to the traditional Initial Public Offering. They are both used with the common aim to collect capital for financing project or the growth of a firm. The objective is the same, but the way in which it is achieved differs. Indeed, beyond the different technologies on which they rely on, there are substantial differences. The main ones are listed below:

- While an IPO is the process through which *shares* of the company are distributed among investors, an ICO emits *tokens*. A token is essentially the analogous of the shares, but it is not the same. Indeed, there are lots of differences between the twos. It does not exist a formal definition and the concept behind it is not easy, but it can be represented as the symbol of the contract. It is the result of the investment, but has more than the traditional role of a security depending on what is laid down in the white paper. Indeed, we can distinguish different kinds of tokens, according to the possibility of usage for the owners. For example, a utility token allows the investor to use the services provided by the company. Differently, for example, if the investor has the shares of Pirelli is not allowed to use the tires of the company.

- Moreover, IPO and ICO differ significantly in terms of *stage of the lifecycle* and *structure of the company*. IPOs are organized by private established companies with proven track of records in their maturity phase (or anyway advanced growth phase). On the other hand, ICOs are represented by small companies that raise money in their first investment rounds. In most of the cases, they don't have even a ready product to offer to the market. They conduct ICOs based on their ideas about some innovative solutions.

- Finally, IPO and ICO differ substantially in terms of their *regulatory frameworks*. IPOs have to comply with stringent regulatory guidelines and obtain approvals from different authorities (i.e. the Securities and Exchange Commission, SEC, in US or the European Securities and Markets Authority in the EU). Contrary, ICOs did not find many obstacles in their first years of life, being not even restricted by international border. "*ICOs can be even though as a way to bypass the regulated and rigorous capital raising process required by financial institutions or Venture Capitalists*" (PWC, 2018). Indeed, one of the main challenges for the future of ICOs, and more in general, for the blockchain-based technologies, is represented by the need of regulation, as discussed in the dedicated section (Section 2.9).

2.2.2 *Crowdfunding and ICOs*

A more recent form of funding, made available with the diffusion of Internet and new technologies, is the crowdfunding. By definition it can be seen as the practice of funding a project or venture by raising many small amounts of money from a large number of people, typically via Internet (Prive, 2012).

The crowdfunding platforms act as intermediaries, publish companies' projects and support them in the investment rounds by charging a fee. As previously mentioned in the dedicated section (Section 1.6) the models of crowdfunding differ in the way investors are rewarded and how the capital is invested in the project.

According to the general taxonomy, four main forms can be identified: donation, reward, pre-selling/royalty-based, lending or equity. Each country has its own regulation about the management of those innovative sources of funding. For example the Italian authority for market regulation, CONSOB, stated that crowdfunding is permitted just for SMEs and no more than €8 million per campaign can be collected (Consob, 2019a).

As far as crowdfunding is concerned, it has both similarities and differences with ICOs. As in crowdfunding, also in an ICO all kinds of private investors can take part to the offer

through digital channels and both campaigns are organized in the first investment seeds. Anyway, there are still some relevant aspects in which the two processes differ.
These are mainly two:

- crowdfunding is only an investment round which finishes at its conclusion. On the contrary, after the end of an ICO, tokens are traded on *cryptocurrency exchanges*: there can be an increment or a drop in the value of the tokens, generally according to the crypto-market trend and the success of the products of the company linked to the tokens. It is by the change in the value that speculators and investors can have a capital gain, as it happens for the traditional market for securities.

- crowdfunding projects use crowdfunding platforms, which are external entities, as *intermediaries* to help collecting fiat money through traditional payment channels (i.e. banks, credit cards). That’s not the case for ICOs: due to the blockchain technology, they are out of a centralized control and do not need a platform to rely on. They offer tokens directly to the investors (Adhami et al., 2018).

2.3 The ICO process

The process through which an ICO is structured is not as complex and costly as the one of the IPOs. Indeed, as previously mentioned, there is no need to rely on external intermediaries or third parties. The process is simpler and is articulated in few steps that should be followed to make the bid online. The following general representation (*Figure 4*) figures out the main stages:

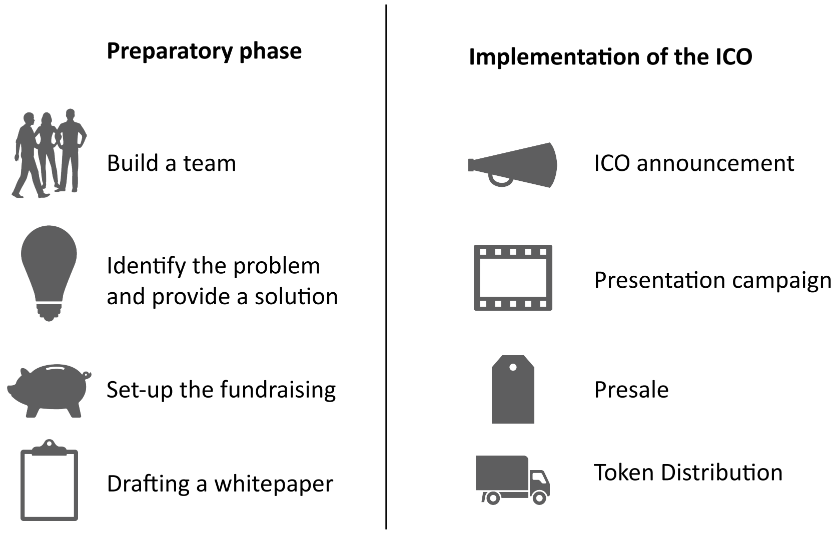

Figure 4 – A General Representation of the ICO Process

The process consists of two main macro-phases: a *preparatory phase* that includes the creation of a team, the identification of the problem and the related solution, the setup of the fundraising and the white paper draft, and then a second phase, the real *implementation of the ICO*.

2.3.1 *Preparatory Phase*

The preparatory phase of the ICO campaign is made up by four main phases: the creation of a team, the problem and solution identifications, the fundraising set-up and the white paper draft.

1. *Build a team*: when a company starts working on an ICO, the first step is the creation of a heterogeneous team which will take care of all the activities. If there is not a company behind the ICO, but it is an upcoming project born from scratch, obviously the team is composed by the people taking part to this project. The typical way of establishing a team is having a core team, whose role is managing the venture and the daily activities, and a team of advisors, typically experts of blockchain and digital technologies, that take part to the development of the project and act as supporters, hence providing advices for the growth of the project.

2. *Identify the problem and provide a solution*: even if the team will have to establish and organize a blockchain structure for the project with all its technicalities, what first needs to be determined is the problem that the team project or the venture wants to address. The decision of investors to entrust capital is primarily motivated by the problem that is faced and, of course, by the way the company faces the issue. It has to be a real solution which can give real benefits to the people. The blockchain architecture and all the technologies adopted are just enablers, not the solution of the problem.

3. *Set up the fundraising*: once it is clearly defined the objective and the activities needed, the team needs to work at the definition of the best offer to possible investors: the team starts working on the blockchain underlying the system and the rules protocol, the smart contract.
ICO projects use either existing platforms or custom blockchain platforms. Most projects use existing platforms, as for example Ethereum, the leader by far. In the case of custom blockchain platforms, they need to create a network, attract miners and pay for transaction confirmation (Chanson et al., 2018).

4. *Drafting a white paper*: when the decision of engaging in an ICO process is taken, a special document has to be drafted. In particular, all the technicalities and the related aspects of the ICO are laid down in the *white paper*. This document contains all the data about the company, the team, the solution to the problem and the financial characteristics of the tokens. Of course it needs to be attractive and clear in order to catch most people

interest. It has to take into consideration also the feedbacks that the company will obtain in meetings and events, organized for the launch of the project.

2.3.2 *Implementation of the ICO*

The effective implementation of the ICO is made up by four main phases: the announcement of the project, the presentation campaign, the presale and the token distribution.

1. *ICO announcement*: in this phase, which generally lasts few weeks, the team announces the ICO project in the communities of cryptocurrency investors. The majors are Bitcointalk and Reddit. The purpose is to explain the essence of the projects to future possible investors and receive the first feedbacks which allow to understand the viability and feasibility of the whole project.
In order to evoke the greatest possible interest, companies announce their projects also through social media (i.e. Twitter and Facebook) and ICO websites, where interested people can interact in community forums.

2. *Presentation campaign*: in this phase there is the presentation of the offer to investors at various conferences around the world. As it happens for IPOs, road-shows are organized to meet and talk with potential major investors and analysts. The specifics of the token (i.e. token utility, price, number of tokens available) are disclosed. Also business angels and participants to crowdfunding programs are often interested and participate to these road shows. This phase can last 2-3 months, according also to the feedbacks received about the offer proposed. According to them, late modifications to the offer on the white paper can be done.

3. *Presale*: this phase is not run by all the ICO companies. It consists of a first sale of just a minor portion of the tokens, sometimes restricted to few private investors, at a price which is generally lower than the sale price.

4. *Token distribution*: in this phase the tokens are available to be purchased by all the investors at the terms and conditions described in the white paper. In order to buy tokens, the purchasers need a virtual wallet holding the accepted cryptocurrencies. A minimum amount of money (soft cap) needs to be collected by the venture to go on with the crypto-project. The issue period lasts some weeks or a few months, unless the maximum amount of money collectable set by the company (hard cap) is achieved.

Lendingblock and *Block Collider* are clear examples: both these two projects raised funds equal to the hard cap in the first days, immediately shutting down the ICO period.

Lendingblock, a platform that facilitates peer-to-peer borrowing and lending of cryptocurrencies and digital assets, raised $10 million between the 15th and the 18th of April 2018. *Block Collider*, alike, a project aimed to create a high-speed distributed ledger built on sets of blocks from other blockchain solutions and enabling many cross-chain features, raised $7 million between the 13th and the 16th of April 2018.

The investors, once the ICO has ended successfully, can utilize the tokens to participate in the ecosystem of the project or trade them in the crypto-exchanges and make profit by them.

2.4 The Distinctive Attributes of an ICO

If the ICO process can be considered approximately clear, there are still some distinctive attributes which characterize ICOs. We just named them quickly, but they deserve to be explained more in depth. These attributes are the token, Ethereum (the blockchain underlying the system), the smart contract, the white paper and the crypto-exchanges.

2.4.1 *Token*

The token, the primary object of an Initial Coin Offering which links the company (token emissary) and the investors (token addressees and purchasers), can be also defined as a "*special kind of virtual currency tokens that reside on their own blockchains and represent an asset or utility*" (Frankenfiled, 2019a).
The token, beyond its name, contains also a *ticker*, a distinctive code of three or four capital letters (that usually contains the first three consonants of the name), which distinguishes it from the other tokens, whose may have a similar name. It is the identification code of the ICO project.

Tokens may have different functionalities according to what the company gives them. So, for example, we can see a token that gives accessibility to a gaming platform or a token through which the purchaser can contribute to the creation of a new encyclopaedia.
The variety of the token utilities is characteristic of ICOs and that is why for investors is of paramount importance to read the white paper in order to understand what they can do by purchasing them.

Anyway, before going deeper in the main functionalities, it is important to figure out the main properties. According to Li and Mann, a token has two main properties (J. Li & Mann, 2017):

- *No intrinsic value*: tokens cannot be used outside the platform: they cannot be used to purchase other goods or services. Their value is strictly related to the underlying platform and "*are designated as the medium of exchange*" on the said platform. They exist only in the form of registry entries in their blockchain and are tradable and transferable only among the various participants of the blockchain;

- *Transparency*: platform users can clearly observe the aggregate number of tokens sold by checking the smart contract of the ICO. Of course, as it happens in the case of crowdfunding, the more are the investors and the funds collected, the more the attractiveness of the operation increases.

As previously argued, the functionalities of a token differ a lot each other. For the purpose of our analysis, we consider five different token roles:

1. *Currency*: token used as a currency.
2. *Payment and access*: token used as an internal currency and for access to the services of the platform.
3. *Governance and voting rights*: token used to take part in the corporate governance to different extents.
4. *Profit rights*: token used as means to allocate profits of the company.
5. *Contribution rights*: token used in order to contribute to the project with different roles.

To summarize, according to the set of functions and roles given, these tokens can be classified into three main macro-groups:

- *Utility tokens*: these tokens have a specific utility within one blockchain-based infrastructure or platform. The utility token is the most commonly used form in the context of ICOs issued tokens, as it gives the right to access into a digital network with determined services available. Generally utility tokens do not include profit or governance rights, and the token is not a digital currency.

  An example of utility token is given by *Moover*: this ICO project aims to create a sharing economy (sell or buy) of excess mobile data, which goes beyond the boundaries of contracted communication carriers. According to its white paper, the token purchasers can have access to the following services: deposit; sale of surplus GB; obtain incentives granted for new actions, contribution to the rating system, answering surveys; participation in promotional campaigns (Moover, 2017).

- *Payment tokens*: these tokens are digital currencies (or virtual currencies) meant to be a purely digital store of value. It is a digital figure of value not created by a central bank or authority, but constituting the tool through which a person can pay within a certain blockchain based ecosystem.
  Streamity, a project able to raise more than $4 million, is a clear example of payment token: it is a peer-to-peer exchange of cryptocurrency for fiat money without intermediaries (ICORating, 2018).

- *Asset tokens*: they have securities- or equity-like traits, and are comparable to share or equity investments. The asset token is thus a vehicle to invest in the company itself, often with profit rights and, sometimes, participation rights within the company.
  The purpose of an equity token lies in the ability to use the token as an investment vehicle able to give profits to investors (Hahn & Wons, 2018).
  An example of asset token is *Pecunio*: token holders own a crypto-card by transferring cryptocurrencies or fiat money into their account and they can decide whether to spend it via the crypto-card or rather exchange and invest cryptocurrencies into Pecunio's investment products (Pecunio, 2018).

Beyond these three types of token there are many others, that are the results of different possible combinations of the five token roles. For example, it is possible to find consensus tokens, through which the blockchain nodes that guarantee data validation are remunerated, or a sort of work tokens which allow users to receive a compensation for the completion of certain actions or the exhibition of certain behaviours (Bo, 2019).
Majority of the tokens are based on the Ethereum protocol *ERC-20*, a technical standard typically used by smart contracts on the Ethereum blockchain for the implementation of

tokens. It defines a common list of rules that all Ethereum tokens must meet. The next section (2.4.2) is dedicated to the study of this protocol.

Usually, the term token is not only used to refer to the medium of exchange on a cryptocurrency blockchain (e.g. ICO tokens on the Ethereum blockchain), but also to indicate the cryptocurrencies themselves (e.g. Bitcoin, Ethereum, Litcoin, etc).
These cryptocurrencies are digital coins, assets native to their own blockchain. Each of these coins exists on their own blockchain and is primarily used as a medium for digital payments. Bitcoin operates and functions on the Bitcoin blockchain, Ether operates and functions on the Ethereum blockchain, and so on.
Transactions of digital coins can be made from one person to another. However, no physical coins move when you send and receive them. On the contrary, tokens are created on existing blockchains, such as Ethereum. But there are also others, as NEO, Lisk and Waves (King, 2018).

2.4.2 *A Blockchain Underlying the System, Ethereum*

Ethereum is an open-source platform based on blockchain technology that enables developers to build and deploy decentralized applications and operating system featuring smart contract functionality.

Technically speaking, the applications on Ethereum are run on its specific token, *Ether*: this token is used broadly for two purposes: as a digital currency exchange like other cryptocurrencies and, inside Ethereum, to run applications and monetize work (Ethereum, 2019).

As the graph below shows (*Figure 5*), up to April 2019, most ICOs have been managed through Ethereum platforms. Waves, the second underlying system in the ranking, manages less than the 3% of ICOs compared to Ethereum (IcoBench, 2019b).

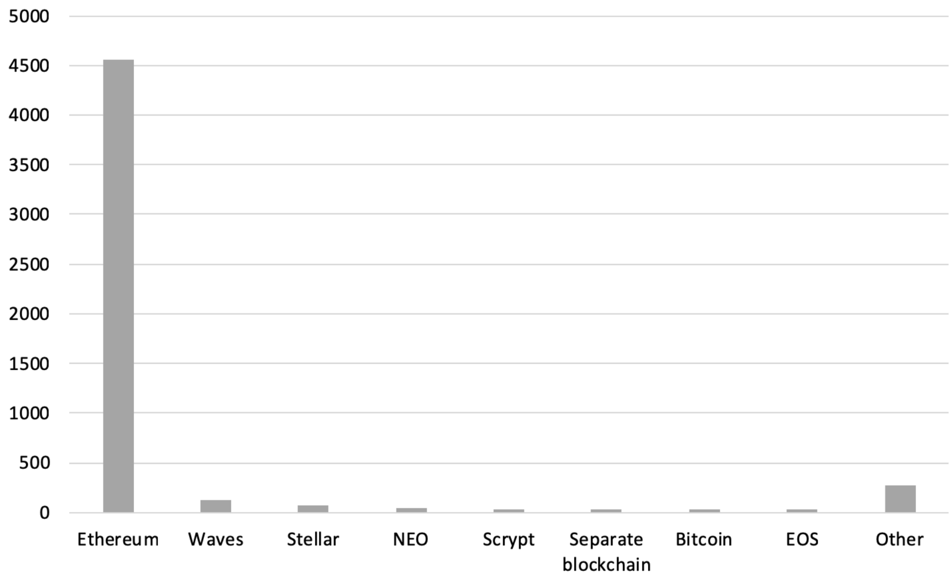

Figure 5 – Number of ICOs per Platform

Most smart contracts run on the Ethereum blockchain, in particular through ERC-20 token Standard Contracts. The figure below (*figure 6*) shows an example of the code for this protocol (Wikipedia, 2019):

```
// ----------------------------------------------------------------------------
// ERC Token Standard #20 Interface
// https://github.com/ethereum/EIPs/blob/master/EIPS/eip-20.md
// ----------------------------------------------------------------------------
contract ERC20Interface {
    function totalSupply() public view returns (uint);
    function balanceOf(address tokenOwner) public view returns (uint balance);
    function allowance(address tokenOwner, address spender) public view returns (uint remaining);
    function transfer(address to, uint tokens) public returns (bool success);
    function approve(address spender, uint tokens) public returns (bool success);
    function transferFrom(address from, address to, uint tokens) public returns (bool success);

    event Transfer(address indexed from, address indexed to, uint tokens);
    event Approval(address indexed tokenOwner, address indexed spender, uint tokens);
}
```

Figure 6 – Code of the ERC-20 Protocol

Over the past couple of years, the standard ERC-20 has played a key role for the growth of the entire cryptocurrency industry, by creating a suitable environment for ICO developers. So far, more than 180,000 ERC-20 compatible tokens exist on Ethereum main network (Reiff, 2019).

The ERC-20 empowers developers by defining a common list of rules that all Ethereum tokens must meet. This simplifies developers' tasks, since they know that every new project won't need to be done again every time a new token is released, as long as the token follows the rules.

The term *ERC* stands for *Request for information from Ethereum*. The standard of this protocol requirements are divided into six method-related functions and two events (Quora Community, n.d.). The functions are:

1. *Total Supply*: determine the total stock of tokens;
2. *Balance*: allow the address owner to receive a balance of another address account;
3. *Transfer*: define the number of tokens transferred to another account;
4. *TransferFrom*: perform the action of the sum of the values of tokens sent from one address to another address;
5. *Approve*: perform actions with respect to transactions;
6. *Allowance*: show the balance on the account.

The two *events* are:

1. *Transfer*: executed when tokens are transferred and the information about these transfers is sent from one account to another;
2. *Approval*: executed when tokens are sent. It means to approve the sender function.

Together, this set of functions and signals ensures that Ethereum tokens of different types will uniformly perform in any place within the Ethereum system (Reiff, 2019).

Since the ERC-20 standard is still relatively young, it happened few times that the systems have been attacked by hackers. The most memorable was the case of *DAO* in 2016. It was one of the major ICOs related to the Ethereum Blockchain at that time. It was a Decentralized Autonomous Organization (DAO), created on the Blockchain Ethereum (based on the ERC-20 structure of smart contracts), which was supposed to disrupt the modern corporation by making it leaderless.
The project has been very successful and within months it managed to collect about $150 million. Nevertheless, the 18th of June 2016, it was violated and within a few hours about $60 million were lost.
Afterwards, the SEC, the US Financial Market Authority, had some difficulties in cataloguing what actually happened due to the lack of regulations related to the blockchain technologies, especially how a token should be treated, if as an investment security or another kind of product (Kaminska, 2016).

2.4.3 *Smart Contract*

Even if we already explained the general concept of smart contract in the first chapter (Section 1.6), now a deeper and more technical analysis is proposed.
Smart contracts, even if with a different name, were already proposed in 1994 by Nick Szabo, an American computer scientist, legal scholar and cryptographer, known for his research in digital contracts and digital currency. He was the father of a virtual currency called *Bit Gold* in 1998, 10 years before the invention of Bitcoin by Satoshi Nakamoto.

As previously mentioned, preceding blockchain technology, Szabo defined smart contracts as "*computerized transaction protocols that execute terms of a contract*".
In his paper, Szabo also proposed the execution of a contract for synthetic assets, such as bonds and derivatives. He wrote:

> *"These new securities are formed by combining securities (such as bonds) and derivatives (options and futures) in a wide variety of ways. Very complex term structures for payments can now be built into standardized contracts and traded with low transaction costs, due to computerized analysis of these complex term structures"* (Szabo, 1997).

This, as other Szabo's predictions, became true in the following years. For example, the trading of derivatives is mostly conducted through computer networks using complex term structures.

In a modern definition a smart contracts can be defined as a "*self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code"* (Frankenfiled, 2019c). They are protocols using algorithms linked to specific conditions between the two parties, the events which are the variables of these contracts. It transposes in code a contract, in order to automatically verify the fulfilment of these conditions and consequently execute automatically the programmed actions. The great strength is that smart contracts do not require human control or a third trusted party as a financial institution to ensure legal certainty. This leads to the reduction of transaction costs and thus an efficiency gain. There is no need to sustain the high costs of the intermediaries.
As a standard contract, they need legal support for the drafting, but not for the verification and activation. Thanks to its properties, a smart contract allows trusted transactions and agreements to be carried out among anonymous parties with no need of a central authority. The transactions carried out on smart contracts are traceable, transparent, and irreversible.

Bitcoin, even if limited to the currency use and with a restrictive language, was the first cryptocurrency supporting smart contracts, transferring value between two parties. Ethereum, instead, created a language, the *Turing Complete*, allowing developers to write their own programs, their own smart contracts, thanks to the support of a greater set of computational instructions.

The main functionalities of a smart contract are (Hertig, 2019):

- Function as 'multi-signature', so that the funds are spent only when a certain percentage of people agree on it;
- Handle different types of agreements between the users;
- Provide utility to other contracts;
- Store info related to the applications. For instance, it could be the domain registration information or the membership record.

2.4.4 *White paper*

The white paper is a document that contains information on IT protocols, the public blockchain adopted, the amount of token supply, the token price, the distribution mechanism and further details on the project to be developed. Eventually a business plan, including a team description, could be also included in this document (Adhami et al., 2018).

It can be considered the equivalent of the IPO-based prospectus prepared by companies who want to go listed on a Stock Exchange. Actually, it is much shorter, addresses only possible investors, and, additionally, is under the control of the market authorities.

Being based on a start-up or a new project willing to raise capital on a blockchain platform, users do not know what kind of products or services they want to offer yet, so the white paper has also the function to present the company and the team members.

It does not include only how much money the ICO wants to raise, but also more technical information as the consensus algorithm the project decides to use on the blockchain platform or the token system.

Investors can usually rely only on this document to evaluate the goodness of an ICO project, that is what makes the white paper an essential building block for a successful ICO. The more detailed and clear the business plan is, the more confidence is built up to potential token purchasers.

In addition to the white paper, many ICO projects provide partial or complete sets of programming codes on specific websites (especially GitHub.com), which are tangible pieces of information on the viability of the project for potential contributors and investors, who can learn about previous efforts of the project team. On the other hand, it may be argued that making the source code available could lead to a higher chance of hacking (Adhami et al., 2018).

As previously argued, there is lack of regulation, hence there are no authorities obliging ICO projects to provide a certain set of information about the company and the said project. Hence ventures are free to include whatever they prefer. Nevertheless, the data listed may strongly influence the choice of investors whether to buy tokens or not. Typically, a white paper includes the following information:

- Definition of the problem
- Project’s technical solution
- Applications of the project
- Roadmap
- Tokenomics
- Team and advisory board
- Legal disclaimer

It is important that investors dedicate time to read those sections, especially if it is something never heard of before. The first fours are obviously completely different from project to project and explain concretely what the company would like to raise funds for. They need to be technically detailed and easy to understand even for people who maybe have not specific competences about those topics. The last four set of information are described in detail below.

a. *Tokenomics*

Tokenomics consists of two words, *Token* and *Economics*. It consists of the set of information related to an ICO-token and the quality of it, which will convince investors to fund it and help build the ecosystem around the underlying project of that token. Tokenomics is a broad subject and includes a variety of components. These are: team, token allocation, public relation and branding, business model, real world utility, legal aspects and token types. More broadly, the tokenomics includes the token functionalities, the sale and everything related to the token offer. It needs to include plenty of information to be exhaustive. The most relevant are:

- *Token role*: it is important to explain the rights attached to the token buyers, so that investors can evaluate the offer in a broader way. We already explained the different functions a token can have and its possible combinations in section 2.4.1 (*Token*).

- *Protocol and platform*: investors want to know also if it is based on the Ethereum blockchain with ERC-20 smart contracts as most ICOs are, or on other blockchain platforms.

- *Soft and hard cap*: they represent the minimum and maximum amount of funds, respectively, required to start the project. Both are established in fiat money or cryptocurrencies, according to the exchange rate during the ICO.

Of course the capital raised represents the main goal of an ICO process, the one under which the operation can be considered successful or not. In general, the amount of total funding to be raised by a project can differ substantially, from low amounts up to several hundreds of million dollars (e.g. *Telegram*, *Tezos*). Reaching the soft cap, hence, is the minimum requirement. Under this level, the company has to pay back the investor and the risk to draw back is considerable high.

On the other hand, if the hard cap is reached before the end of the period, the ICO terminates before with success. Sometimes it happens that the hard cap is not set.

In general, when discussing about the economics behind tokens, some main concepts have to be defined. These are the typical data that any website about ICO trading (i.e. IcoBench and IcoDrops) shows:

- *ICO period*: it is the span of time available to buy tokens. It can last a few days or also months. It is the analogous of the issue period for the right issue case or the IPO.

- *Token price*: it is typically expressed in both the underlying blockchain (e.g. Ethereum and Bitcoin) and the fiat currency, usually US dollars. In most of the cases, it is set also a minimum and maximum number of tokens available to be purchased by a single investor.

- *Presale*: some ICOs give also the possibility to buy tokens before the ICO period. This offer can be restricted to few private investors and the price is lower than the token price during the ICO period.

- *Bonus*: the price of a project-specific token may increase, remain constant or decrease during an ICO, according to the presence of bonuses. There are two main kinds of bonus offered to the investors: *early bird* and *major contributor*. In the first case it means that during the ICO period there are sub-periods with increasing price.

  Major contributor means that investors can obtain discounts if they buy a high number of tokens. The greater the number of tokens purchased, the greater the discount.

- *Token distribution*: not all the tokens issued by the company are available to investors. Indeed, tokens are split among different actors. These are:

    - *The project team*: team and advisors;
    - *Bounties*: proportion given to people who help with the marketing of the ICO campaign (e.g. translating the ICO documents and posting in different languages);
    - *Community*: a portion of tokens sometimes is kept giving lately to the people who contribute to the improvement of the project or as a reward;
    - *Crowdsale*: this is the stake available for external investors. It is usually the majority of the total tokens issued;
    - *Reserves*: sometimes a part of tokens is not given away, but is kept for a second round of ICO or other future activities.

    While the crowdsale always takes part to the token distribution (otherwise it would not be an Initial Coin Offering), the other items sometimes are not taken into consideration.

- *Use of funds*: a section of the white paper, sometimes provided as main data in the specific trading websites, is devoted to explain how the company is going to use the funds raised. Even if not all the ICO projects consider this aspect in the white paper, investors could be interested in it, in order to understand and evaluate the next steps of the project after the end on the ICO. Usually, the five main categories in which the funds raised can be used are: software development, operations, marketing activities, reserves and legal activities.

b. Team and Advisory board

The main asset of a project, and hence the critical factor for the success of the ICO process, is the team behind it. It is therefore essential to have a strong project team with internal or external people, also to give transparency to the project.

The team board is composed by the founders, the chief officers and all the other figures at the corporate and operating level.
The advisory board, sometimes missing or not included in the white paper, is composed generally by people outside the company making the projects. They are typically experts of blockchain or experts of the problem the project is trying to solve, as sometimes happen academic researchers or professors.
The following areas of competences should ideally be covered by the whole team: project management, business development, IT knowledge (blockchain, smart contracts), website development, token sale advisory; marketing and public relations, legal advice, tax and accounting (Hahn & Wons, 2018).

c. *Legal disclaimer*

Every ICO team provides at the beginning or at the end of its white paper a section in which it is claimed the set of responsibilities and rights related to both the team and the investors. It is typically said that the information on the white paper is only for community discussion and it is not legally binding. About regulations, it is usually written that no regulatory authority has examined or approved any information. It is generally also highlighted if there are citizens from some countries which are not allowed to take part to the ICO.

2.5 Crypto-Exchange

The tokens issued during the ICO are lately traded in an exchange, or, is better to say, a cryptocurrency exchange, similarly to the stock exchange trading after an IPO, as Milan Stock Exchange and NYSE.

A cryptocurrency exchange, also known as digital currency exchange (DCE), can be defined as "*any system that operates on the basis of trading cryptocurrencies with other assets. Like a traditional financial exchange, the cryptocurrency exchange's core operation is to allow for the buying and selling of these digital assets, as well as others*" (Leighton, 2019).

A cryptocurrency exchange can be a market maker that typically takes the bid-ask spreads as a transaction commission for its service or, as a matching platform, simply charging fees. Basically, cryptocurrency exchanges work just like traditional exchanges. On many of these web-platforms cryptocurrency buyers and sellers can place orders, and the brokering process works like it would for any other kind of asset. Hence, the cryptocurrency exchange helps with the transaction and collects the fees. What differs substantially from the traditional financial exchanges is what is traded: not conventional fiat money, but cryptocurrencies, whose value is inherently unstable. The market is still young and the level of speculation is really high; the consequence is a huge volatility of the prices. Moreover, the role of those exchanges is to provide liquidity to the assets, allowing buyers and sellers to trade assets like traditional stock exchanges.

In 2018, *Bloomberg* and *Statista* reported the largest cryptocurrency exchanges. Their results were based on the volume and the estimated revenues data collected by *CoinMarketCap*. According to their surveys, the top three cryptocurrency exchanges are *Binance* from Malta, *Huobi*, from Singapore, and *Upbit*, from South Korea (Russo, 2018).

2.6 The Role of Social Media

Since an ICO runs purely digitally, the success of the project depends fundamentally on the marketing strategy chosen for the ICO and the specific marketing measures adopted. The marketing usually accounts for a big portion of the pre-ICO costs and it should be diversified on several channels in order to reach the greatest number of interested people. It is therefore important to create an active community at early stages. It is still difficult to estimate the importance of social media in promoting ICOs, but it is clear that this vector of marketing plays a decisive role (Hahn & Wons, 2018).
As a matter of fact, one of our sets of data analysed in our work is the spread of information on the social networks between the ICO period and the month before.

The main social media channels where the ICO's data are published are Facebook, Telegram, LinkedIn, Twitter, as well as crypto-based channels like Bitcointalk or Reddit. The promotion based on these channels can help projects to expand so that more people can read and learn more about them. To accomplish this task both paid and free promotion are used.
ICO listings and ratings lists are published also on various websites, such as *Coinschedule* or *CoinMarketCap*. Furthermore, there are sort of ICO rating agencies who give ratings to the ICO projects on websites like IcoBench. In this last case the rating is under the indicator of *benchy*. What follows is a short analysis of the social networks and crypto-channels typically used (Bixtrim, 2018):

- *Facebook*: ICO advertising has been banned from Facebook since January 2018, but it is still possible to build a strong dynamic community through pages and groups. Facebook has 2.4 billion monthly active users. For promoting ICOs, valuable news about the projects are daily posted.

- *LinkedIn*: it is one of the most popular media platforms in the crypto-community. There are blockchain groups that have thousands of members, including professionals and experts in crypto-technologies. People can access for free.

- *Twitter*: it is possible to draw attention and convey ICO messages by using hashtags and tweeting. It has been used for marketing activities since long time and it has been considered probably the most comfortable platforms. On Twitter it is easier to draw the attention of many Blockchain influencers with a large following.

- *Telegram*: this platform has a “secret chat” facility. It enables crypto-enthusiasts to get in touch through conversations with end-to-end encryption and other security options. Telegram is very important for an ICO and should be definitely taken into account.

- *BitcoinTalk*: it is the biggest of all the specialized crypto-forums. It is very important to update BitcoinTalk regularly, post news and keep in touch with interested people who can ask questions and reply to the posts.

2.7 Success Factors of ICOs

Tokens are young products. Investors do not have so much experience with them and can be not very good in estimating their value. In addition, blockchain is a relatively new and complex technology and "*there is a great deal of uncertainty over how much potential for profit there is and which sectors are the right ones to invest in*" (Conley, 2017).

To evaluate the goodness on an ICO it is of paramount importance to read the white paper and other possible disclosures on social networks or specific websites and remain constantly updated. The main parameters which should be taken into consideration for an objective and sufficient evaluation are the following:

- *Business model*: it is important to understand which kind of innovation this project would bring in its specific market sector, identifying both strengths and drawbacks. Another key point is the token: which kind of services and rights does the token give to its buyers? A competent investor should consider all of them, as well as the blockchain technology impact on the project.

- *Project team*: an analysis of both team members and advisory board is useful to understand which kind of background the project organizers have, and also if they have proven track record in the blockchain industry or previous experiences with other ICOs.

- *Community feedback*: as we previously said, ICOs spread information and news on social networks and websites. Investor should read and remain updated on all the channels around ICOs. Checking both community forums and ratings given by trustworthy rating websites can lower the investment risk. It is important also to be aware of paid reviews that can remunerate people to spread positive information about a certain ICO.

- *Current product state*: ICOs which are still at an initial phase are usually considered less reliable and with less chances of growing than the ones closer to their product completion. It is then also relevant to check the current stage and the scheduled roadmap of the project after the ICO (Burns & Moro, 2018).

An ICO is considerable successful if it can raise at least the soft cup established. The indicators that validate the success or not after the end of the ICO are the Return on Investment (ROI) and the token price on the cryptocurrency exchange. A positive ROI and a higher token price are symptoms of a successful project. On the contrary, unprofitable projects have negative returns and lower token prices.
The failure of an ICO is considered as such if the minimum funding goal, the soft cap, is not reached. In this case the project finishes before starting with the refunding of contributors. After an ICO, even if the necessary capital has been raised, a project can fail with the suspension of all the activities related to the project.

This is only a general overview of the success factors. Some studies have been proposed basing on a more quantitative approach. Given the specificities of them, their detailed review is directly proposed in first section of chapter 4 (Section 4.1).

2.8 Current Contest

The market of ICO was born in 2013, when the first ICO, *Mastercoin*, was published between the 30^{th} of July and the 30^{th} of August, raising $576,000 (IcoHolder, 2013).
In the period 2014-16 there have been just few projects which raised a not considerable amount of money, at least if compared to 2017 and 2018, in which there has been the boom of ICOs and the greatest ICOs ever, which raised more than $1 billion.
In the last months of 2018 and in the first quarter of 2019 a strong decrease has been observed, both in terms of number of projects relying on blockchain technology and in terms of funds raised. The latest annual ICO report from PwC Strategy indicates that the overall landscape is experiencing a "*sustained phase of maturity*", whereby quality projects are in ascendancy (PwC, 2019).

The authorities with their new regulations probably have been affected by the ICO market, so that they made available new opportunities to raise funds with the blockchain. In particular, we are speaking about the emerging growth of *IEOs* (Initial Exchange Offerings) and *STOs* (Security Token Offerings). A more detailed description is provided in dedicated section (Section 2.10).

In almost six years many things happened for a market that is still relatively young, and the future is really uncertain and difficult to predict. It is not easy to say if the ICO market has already passed through both a growth phase and a maturity phase and now it is definitely declining leaving space for new updated technologies to raise funds, or if it is just a period in which regulations are slowing down the growth of this promising market. By analysing the past years and the regulations adopted to arrange this new market, we have tried to understand the advance of this alternative finance method and its future possible evolutions.
The research of trustworthy data on the internet has not been so easy. There are plenty of websites which give data about both single ICOs and on aggregate, but almost all of them do not collect complete data but they consider just a part. As a consequence, we have decided to rely on the well reputed work proposed by Dmitri Boreiko, University of Bolzano, and Dimche Risteski, Max Planck Institute, which evaluated the most popular

websites for ICOs and give them a rate (Boreiko & Risteski, 2019). We have started by looking at these websites and then, in retrospect, we made a rank of them, according to our personal considerations. These data have been also used to draft a general schema adopted in our work, that is presented in chapter 4 (Section 4.2).

Before going deeper in the analysis of the past events, it would be better to compare the ICO market with the closest "competitor" markets, hence by benchmarking it with Venture Capital and Crowdfunding, in order to evaluate the size and the relevance of the whole ICO market.
The total amount raised in 2018 was almost \$11.4 billion, against little more than \$10 billion during 2017, with a mere 13% growth (Pozzi, 2019).
In 2018, in the VC market more than \$100 billion have been collected, of which 55 in US alone (McBride, 2019), thus scoring a new record. Meanwhile, in order to have a rough idea, up to December 2017, the two most popular crowdfunding platforms, Kickstarter and CrowdCube, raised \$3.9 billion combined.
From these numbers we can state that the ICO market is still small if compared with the well-established VC market, especially if considering the US. In contrast, it is not the same if comparing the ICOs with the Crowdfunding, which actually has lower investments.

2013-15 - Let's now focus on the growth of the ICOs in these last six years. Said that the first ICO has been published in 2013, in the years 2014 and 2015 the pioneering projects have been released. Both the ICO and the blockchain technology notions were not largely spread among investors. The main highlight was *Ethereum*, which raised about \$19 million in the summer of 2014 (Elementus.io, 2019).

2016 - In this year, also due to the large adoption of the new ERC-20 contract, many projects have been implemented. In May there has been the resounding case of *DAO*, a project able to raise more than \$160 million, setting the record for the largest crowdfunding campaign in history. Just a month later, a hacker managed to exploit some

vulnerabilities in the code and stole about $60 million, more than one third of the total raised. *DAO* was delisted from trading before the end of the year.
This dramatic event shocked a market which was thought to be totally safe. Investors had perceived it as a secure investment in a promising technology which is detached by intermediaries or legal entities. Actually, "*cryptocurrencies aim to eliminate the need for trust in financial systems, and in Ethereum case, in legal systems too. But what they are actually doing is replacing trust in bankers and lawyers with trust in coders. But coders are people too, and they are not infallible*" (Coppola, 2016). After that, some modifications to the codes have been implemented in order to avoid new *DAO* cases. At the same time, the most important authorities, the SEC especially, started investigating, but not only on *DAO*. They wanted to classify the ICOs and regulate what was still an unregulated market.

2017 - During the twelve months there has been the boom of ICOs, especially in the second six. According to the *ICO Market Analysis of IcoBench* for the first quarter of 2019 (IcoBench, 2019c), 718 of 970 ICOs have been ended and raised funds for more than $10 billion. The biggest were *Tezos*, a new platform for smart contracts and decentralized applications, with $236 million, and *Filecoin*, a blockchain-based storage network and cryptocurrency, with $257 million.
This unexpected success of ICOs can be partially explained by the crazy rally of the Bitcoin, which grew from the $979.19 of the 1st of January to the astonishing $13,318.80 of the 31st of December 2017. The Bitcoin gave to all the blockchain businesses a strong push and to investors a credible alternative to more traditional investments. The graph below shows the 2017-19 trend in terms of funds raised (*Figure 7*):

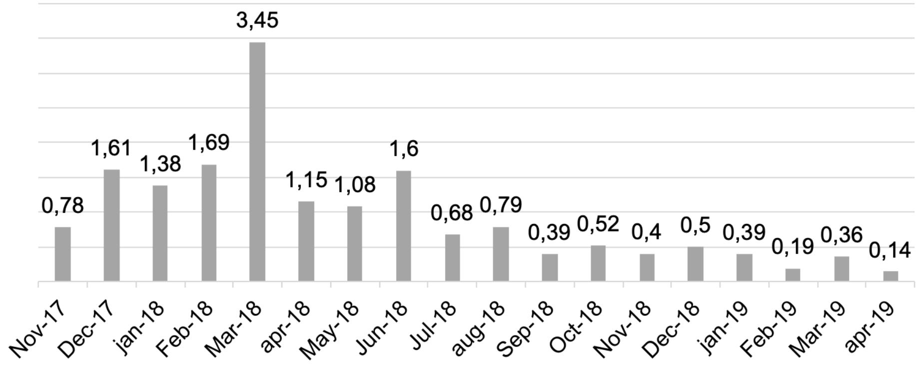

Figure 7 – Amount of Funds Raised in Billion Dollars on a Monthly Base

2018 - The 2018 started as the year before was ended. The first six months registered the biggest ICOs so far and in all the six months at least $1 billion has been collected. The only two ICOs able to raise more than $1 billion were *EOS* and *Telegram*.

EOS is a US project based on a software that utilizes a blockchain architecture to enable vertical and horizontal scaling of decentralized applications. This is achieved through an operating system-like construct upon which applications can be built. It has been able to raise more than $4 billion between June 2017 and June 2018, in one of the longest ICOs ever.

The well-known messaging-based *Telegram Open Network*, a platform relying on a scalable and flexible blockchain architecture that consists of a master chain and plenty of accompanying blockchains, has been developed by a Russian team of the established company Telegram Messenger. It raised $1.7 billion in only two weeks in March 2018 (IcoBench, 2019c).

In the second half of the year, also due to the bitcoin fall, the funds raised diminished even if the number of ICOs published did not decrease so much. At the end of the year, more than 2,500 ICOs (3.5 times compared to 2017) have been ended, according to *IcoBench*.

2019 - The PwC annual report has stated that after the hype of 2017, in 2018 the ICO sector became more mature and stable, with a better focus on legal practices and investor relations (Diemers, Arslanian, McNamara, Dobrauz, & Wohlgemuth, 2018). In the first four months of 2019 the negative trend of the second half of 2018 continued. In the first trimester there were twice less ICOs projects that have raised funds than the last trimester in 2018. The reasons need to be found in a closer attention by the authorities with stricter regulations and a general decrease of investors' hype.

2.8.1 *Industry Analysis*

Let's now focus on the industry sectors with the most innovative ICO-based projects in the last three years. If we make an analysis on the number of ICOs, as shown in the graph below, (*Figure 8*) we have observed that almost 3,000 projects are about the blockchain *platform*, followed by *cryptocurrency* and *business services*. Beyond technologies and financial services, *entertainment* and *communication* are other two popular sectors for ICOs.

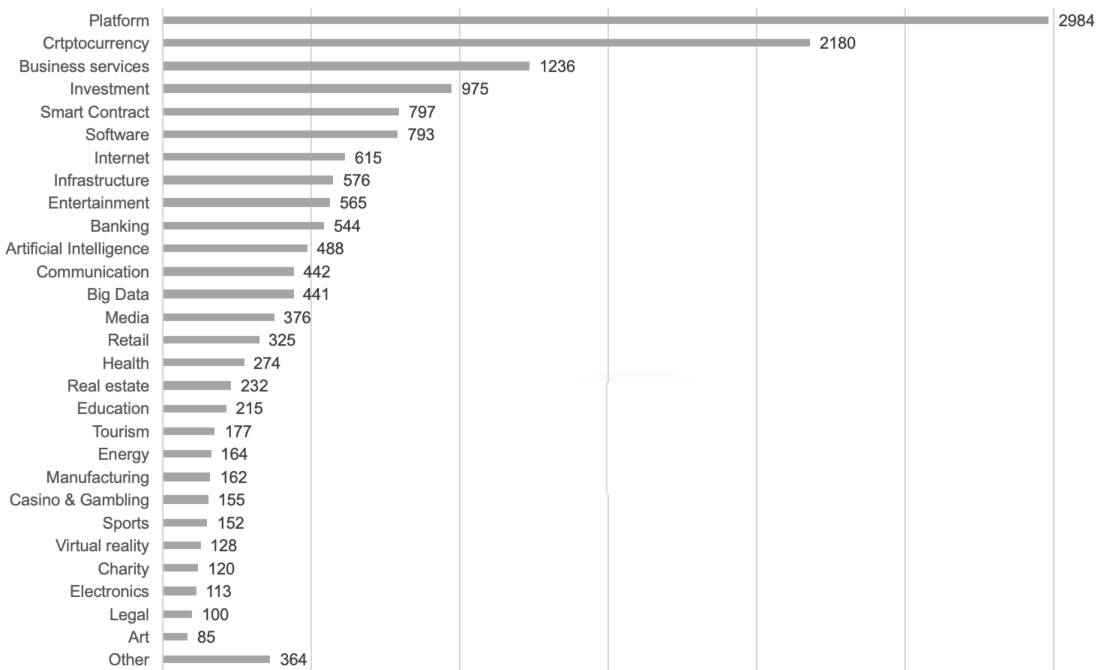

Figure 8 – Number of ICOs per Industry Sector

In terms of funds raised, despite the 804 projects less, the ICOs working on *cryptocurrencies* managed to raise $1.1 billion more than *platform* projects, reaching at more than $13 billion collected. *Cryptocurrency* and *Platform* combined raised approximately the 40% of all raised funds. The following graph (*figure 9*) shows the funds raised per industry sector in details.

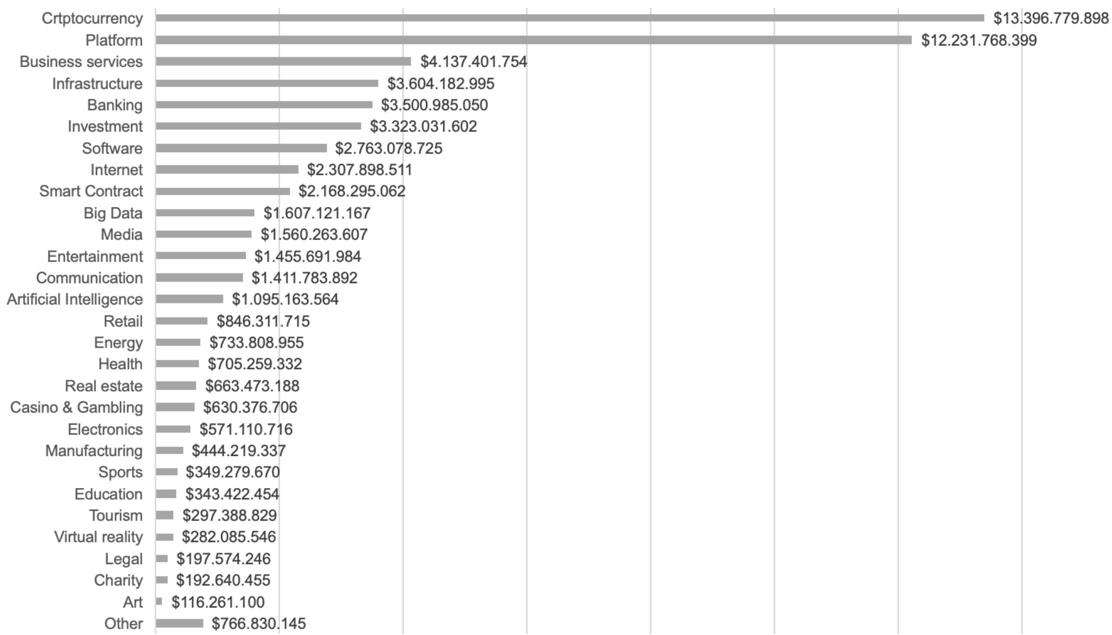

Figure 9 – Funds Raised per Industry Sector is US Million Dollars

On the basis of those data provided by IcoBench (IcoBench, 2019e), a possible consideration is that the number of projects decreased, but the amount of funds collected increased, meaning that, in general, projects collect more money individually. Because of the high variability, it is not useful to provide an average value.

2.8.2 *Geographical Analysis*

In terms of geography, the distribution of ICOs in the world is strongly determined by the different regulations adopted by local authorities. Two of the biggest potential markets as China and South Korea have banned ICO projects, while other markets as United States and the Baltic Republics are favourable to this new financial alternative. US is the leader country for both number of ICOs and funds raised. In Europe, countries such as Switzerland, Russia and the Baltic Republics lead the ICO market, while in Asia they are developed mainly in financial districts like Singapore and Hong Kong. Detailed data are provided in the tables below:

	Number of Projects
United States	740
Singapore	547
United Kingdom	487
Russia	326
Estonia	273

Table 1 - Leading Countries per Number of Projects

	Funds Raised [Billion USD]
United States	7.4
British Virgin Islands	2.4
Singapore	2.3
Switzerland	1.8
United Kingdom	1.3

Table 2 - Leading Countries per Funds Raised

2.9 Market Regulation

As we already said, the ICOs evolution has been strongly influenced by market regulation authorities. Being a phenomenon with a great presence in US, the Securities and Exchange Commission (SEC) plays a crucial role. It is not uncommon for innovations in the financial sector to get ahead of those rules which are supposed to regulate the market. In this sense, ICOs got so far ahead of rules that they started, boomed, peaked and declined before finding fitting rules by the authorities.

The decline of ICOs in the second part of 2018 and especially in the first months of 2019 is due not only to crypto-prices being far from their peaks, but also to a stringent position taken by the SEC with some enforcement actions. As typically happens in case of innovative solutions, there are still no specific rules about ICOs, but only some hints about how to interpret the security laws (Levine, 2019).

As Li and Mann, academics from George Mason University and UCLA Anderson School of Management respectively, reported that "*these utility tokens are surrounded by controversy over both their legal status and their true economic value, if any. Accordingly, responses from regulators across the globe have been vastly different, ranging from promotions to case-by-case investigations to outright bans*" (J. Li & Mann, 2017).

In its website, the SEC states that "*while these digital assets and the technology behind may present a new and efficient means for carrying out financial transactions, they also bring increased risk of fraud and manipulation because the markets for these assets are less regulated than traditional capital markets*"(SEC, 2019).

More in general, one of the major risks of cryptocurrency is the absence of third parties and, hence, the inability for the authorities to trace the capital flow. This leads the space for frauds and black markets, thus the introduction of a specific regulation for those products is required. An efficient regulation would enhance the trust and the reliability of the market, hence generating benefits from both investors and companies.

Beyond the benefits deriving by the adoption of blockchain technology, another key success of the ICOs has been the "simplicity" of their creation, with no need of particular documents which must be read and approved by financial authorities. Entrepreneurs and project teams could manage to raise big quantities of capital disclosing just a limited set of information without an official prospectus.
On the contrary, investments in financial industry (i.e. IPOs) require professional due diligences in order to offer investors a comprehensive financial analysis of both the company, the product sale and the related risks.
An ICO white paper presents only a summary presentation of the company or the project. Sometimes happen that financial data are missing.
So there is a grey area that needs to be clarified. The opacity on which those projects operate make the validation activities for market authorities difficult, so something of course has to change. Today we are still in the time to understand which is the right direction. Indeed, the main local authorities started analysing ICOs only two years ago, in 2017, when their boom made them a significant market in the financial sector.
The first thing they tried to assess was if ICO tokens could be considered as some kinds of security or not. Specifically, in the report of US SEC of July 2017, it was described when a digital token counts as a security. If a token is considered as a security, then the ICO issuer must register the token like any IPO, or make sure that the tokens are sold only to accredited investors. In both cases, there would be issues related to the disclosure of financial statements documents or a limited participation to the token offer (Levine, 2019). After the *DAO* case, the US authority warned investors about ICOs and its related risks, stating that *DAO* tokens were considered as securities and, thus, subjects to federal laws. Later, the SEC started charging those ICOs which had placed unregistered securities.

In Europe the discussions about ICOs began only in 2018, when the European Commission published a document under the supervision of ESMA authority (*European Security and Market Authority*), in which it stated that ICOs may be an innovative way of raising capital funds, but, at the same time, present clear risks to investors (Authority, 2019). Anyway, in EU this market is still un-regulated.

Beyond the partial reluctance of US and Europe, there are other countries which adopt a friendlier approach. With the purpose to attract fintech start-ups, some countries as Singapore, Hong Kong, Switzerland and the Baltic Republics are favourable to crypto-initiatives as ICO projects. Despite their small size, they are in the first positions for both number of ICOs and funds raised.
On the contrary, there are countries such as China and South Korean that banned all kinds of ICOs: in September 2017 they declared them illegal, stating that all the fundraising activities had to be stopped immediately and the capital refunded to contributors (Forbes Technology Council, 2017).

By a *taxation* point of view, no specific guidelines have been issued by competent authorities. It is typically applied the set of existing tax rules which may refer to some kinds of securities. Nevertheless, many areas about that are still uncertain. However, an ICO can try to achieve a very low tax rate at issuance and even after the ICO, during the trading and subsequent operations. The choice of the country, thus, is critical: the company wants to minimize corporate and indirect tax leakage. It should be both open to new financial innovations as ICOs and be tax efficient (EY, 2018). That is why in the white paper of many ICOs, despite an American or European team, we often observe as jurisdiction some tax heavens as for instance, some Caribbean islands, Malta, Singapore or Hong Kong. In some cases, a team of lawyers work together to find the most suitable jurisdiction.

2.9.1 *An Eye to Italian Regulation*

In March 2019 the *CONSOB* published a document to start debating the topic of initial offers and crypto-exchanges (Consob, 2019b). The intent of the *CONSOB* is to create the conditions so that a competitive Italian market is developed, in order to favour the return in Italy of who had to go abroad to work on an ICO and to attract other fintech start-ups as well. The focus is especially on how to protect investors from crypto-risks. Their work is aimed at enhancing regulation not only for the process of token issuance, but also for the trading activities, thus allowing investors to properly liquidate the financial product (Negri Della Torre & Bosisio, 2019).

2.10 The ICO Life-Cycle

In the last two years, new finance alternatives, inspired by ICOs, have been developed: *Security Token Offering* (STO) and *Initial Exchange Offering* (IEO). They were born as a solution to solve the main issues came up with the ICOs. Up to April 2019, the numbers are still small, but growing month by month.

2.10.1 *Security Token Offering (STO)*

A Security Token is a crypto-token offer which, in exchange of money, entitles the investor of a share of the profits of the business or some other form of reward.

The crypto-token represents an investment contract registered on the blockchain with an underlying asset, as in the case of stocks, bonds or real estates. However, it is still not clear if STOs will be able to replace the ICOs or not.

Investors are more protected with STOs, they are backed by tangible assets, hence preventing fraudulent business activities. STOs, as the name can hint, are treated as securities by local market authorities. Those financial products have to be compliant with both the laws of the issuer and investors' countries. They need to provide a clear description of the company and its business purpose, a description of the offered security and information about the management structure. It means that the accountability of the company is disclosed publicly. A legal support is indeed required to comply with all of this.

STOs can be seen as a sort of hybrid version in the middle between ICOs and IPOs. These security tokens, like ICOs, allow a large participation by investors with low entry barriers and are better cost efficient than a traditional issuance. Like IPOs, instead, they are regulated according to local security laws and the investors have ownership, voting and dividend rights (PwC, 2019). All the requirements listed can take away some of the original positives of ICOs, but at least the transparency of the market is enhanced.

The number of STO projects increased in the last months as its popularity among people. Only in the second half of 2018 almost 120 STOs have been completed and together raised more than $500 million (IcoBench, 2019d).

2.10.2 *Initial Exchange Offering (IEO)*

IEOs refer to those projects which do not go through an ICO and are directly listed on a crypto-exchange. Developers create the token of the project and send it to the exchange, which sell the tokens to investors. The currency typically adopted for these transactions is the Ethereum (ETH).

In IEOs the exchange platform has bigger power and can be considered as administrator and a sort of intermediary between the two parties, the project team and the investor. The fundraising is conducted in the exchange platform instead of the website of the token issuer. The smart contract is not managed anymore by the start-up conducting the token sale, but by the cryptocurrency exchange, with the contributors creating an account on the exchange and making transactions through that. Another difference is that, in IEOs, after the crowdsale, there's the automatic token listing, while in ICOs the start-up has to reach out to exchange its tokens.

This new configuration should enhance the transparency and security of the whole process for both the project team and the investors. On the customer side, the protection given by the requirements set by the exchange that the project team must comply with to conduct the IEO; in addition, the exchange hosting the IEO performs a due diligence before launching the token sale. For project teams, the cryptocurrency exchange takes care of some operations as the verification through *KYC* and *AML* regulations. Then, it can provide liquidity and also help on marketing promotions.

Binance, a leading crypto-exchange platform, has been the first cryptocurrency exchange offering this kind of service with the token sale platform *Launchpad*.

Being new, the IEO market is still relatively small with a low amount of data available. Up to April 2019, less than 70 IEOs have been listed on IcoBench with funds raised for $266 million. Currently, the Asian market leads in terms of both number of IEOs and funds raised through that. Hong Kong is indisputable leader by funds raised with more than $65 million. On the other hand, Singapore is the leader by number of projects with its eleven IEOs presented (IcoBench, 2018).

3
Data Envelopment Analysis

3.1 The Reasons Behind the Application of DEA

The purpose behind our work is evaluating the efficiency of the ICO process and the related factors that affect its performances. In particular, we want to understand in an empirical way which are those variables that affect the efficiency of the projects collected in our database. Hence the technique of DEA has been selected for the computation of the efficiency scores. While the technical and specific process of our research will be addressed in the next chapter, here a discussion about the DEA methodology adopted is provided.

The *performance measurement* approach constitutes a required function for the survival of a business in the contemporary changeable business environment. It could be generally defined as a dashboard of KPIs to assess how well an organization or business is achieving its desired objectives. Effectiveness, efficiency and productivity are typically used within the framework of performance measurement. In particular, the measurement of efficiency has been popular for seven reasons: the changing nature of labour, the rise of competition, the particular initiatives of improvement, the national and international quality awards, the change of organizational roles, the mutable, external demands, as well as the power of information technology (Farantos, 2016).

Generally, the typical measure to assess efficiency stated in the form of a ratio like output/input. For instance, when assessing the productivity of a workstation, a possible KPI is "output per worker hour" or "output per worker employed". Such measures are sometimes referred to as *partial productivity measures*, whose terminology is intended to distinguish them from total factor productivity measures, which take into account all the outputs and inputs available.

Of course, the higher the number of variables considered, the higher will be the reliability and the accuracy of the analysis. Indeed, moving from partial to *total factor productivity measures* by combining all inputs and all outputs to obtain a single ratio helps to avoid gains to one factor (or one output) that are really attributable to some other inputs (or outputs). For example, having a limited number of variables results in the risk to mistakenly attribute to an input an increase in an output.
But, as in many situations, there is a trade-off. In fact, the adoption of *factor productivity measures* encounters difficulties such as choosing the inputs and outputs to be considered and the weights to be assigned for each of them.
In our database a significant number of inputs have been taken into account, so that the issue as the one already described would have been faced. For this main reason, and others that will be considered in the next stages, we have decided to opt for the methodology of *Data Envelopment Analysis*, usually abbreviated in DEA. In particular, the main reasons supporting our choice are:

- DEA does not require the user to prescribe weights for each input and output, as in the traditional approach, and, also, it does not require prescribing the functional forms that are needed in statistical regression methodologies.

- This method utilizes techniques such as *mathematical linear programming* which can assess a large set of variables and relations, thus relaxing the requirements that are often encountered when one is limited to choosing only a few inputs and outputs. So it is easier to deal with complex problems that are likely to be confronted in many managerial and social policy contexts.

- DEA provides a number of additional opportunities, such as collaboration between analysts and decision makers in choosing the inputs and outputs to be used and the type of "what-if" questions to be addressed. For example, it is interesting understanding how the competitive scenario could change when an input varies. Alternative methodologies are the ones related to the benchmark analysis, whose goal is "assessing the level of the provided services based on the benchmark, the ideal level of performance, taking into account a set of input and output, usually intermediate, measured in physical units" (Peacock, Chan, Mangolini, & Johansen, 2001). Examples of those techniques are Simple Ratio Analysis and Unit Cost Analysis.

- According to a research published by the *Journal of Data Envelopment Analysis and Decision Science*, by measuring the efficiency with non-parametric methods (i.e. DEA) and parametric analysis methods, such as benchmarking methodologies, it is proved that non-parametric methods have better dispersion of results than the parametric models (Farantos, 2016).

The legitimate question now is: how can be defined DEA? According to the already mentioned journal, a possible definition is the following:

Data Envelopment Analysis is a <u>*non-parametric*</u> *method of the linear programming for the measurement of systems efficiency of a* <u>*decision making unit*</u>*, DMU.*

Firstly, the method is non-parametric since it evaluates efficiency in accordance with the dimension between the organization and the best unit that trades in the field.
What is under evaluation is the decision making unit. Generically a DMU is considered as the entity responsible for converting inputs into outputs. In managerial applications, DMUs may include banks, department stores and supermarkets, car makers, hospitals, schools, public libraries and so forth. In engineering, DMUs may take such forms as airplanes or their components such as jet engines. In our work, as we will better discuss in the next paragraphs, DMUs are firms or projects that decided to engage in an ICO campaign.
One of the aspects that mostly makes DEA different from other methods is the way in which inputs and outputs are converted when measuring efficiency. It attempts, indeed, to compare the overall input and output of various units with each other and not, as the most traditional methods, to discover a function of production that can combine inputs with outputs.

When applying this methodology, one of the main decision that has to be taken is about the inputs and outputs selection, which will be used to perform the analysis. In particular, the selection of input is widely considered the most important and perhaps the most difficult point in the evaluation of efficiency (Holger, 2000). The section “Selection of Inputs and Outputs” (Section 3.4) is entirely dedicated to this issue. Before going deeper in the analysis of the methodologies, a brief discussion about the concept of efficiency is presented.

3.2 The Meaning of Efficiency

The main attempt of DEA is assessing a measure of efficiency. When a decision making unit can be considered efficient? Before going deeper in the handling of the methodology, a short discussion of the concept of efficiency is recommended.

The efficiency of a firm, an industry or a project refers to the performance in the utilization of resources at its disposal. This measure is basically based on a method of comparing the observed performance of an entity with some specified performance.
Recently, the Data Envelopment Analysis method is becoming popular for accessing the relative efficiency of business entities, as, for example, the departments of hospitals, that can be considered the business units of a firm.
The efficiency of a decision making unit is a measure relative to all other DMUs with the simple registrations that all DMUs lay on or below the extreme frontier.
DEA analyses each DMU separately and calculates a maximum performance measure for each unit. DEA has become one of the most popular fields in operation research with applications involving a wide range of context (Verma, Kumavat, & Biswas, 2015).

According to the extended *Pareto-Koopmans* definition (Tone & Tsutsui, 2010), a DMU is considered fully efficient if and only none of its inputs or outputs can be improved without worsening some of its other inputs or outputs.
What is relevant to note is in the definition itself, that avoids the recourse to predetermined weights, which, in traditional methodologies (e.g. benchmarking analysis for example) are selected a priori and are supposed to reflect the relative importance of the different inputs or outputs.
To clarify, suppose that the objective is assessing the efficiency of an hospital, where the DMUs are represented by the all departments, such as surgery and paediatrics. If we want to consider two inputs, doctors and nurses, and two outputs, out-patients and in-patients, one way to simplify matters would be to weight the various inputs and outputs by pre-selected (fixed) weights. Of course it is a way to simplify the work, but it raises some other questions. Firstly, how the weights should be determined. Secondly, and even more important, it is not clear how much of the efficiency ratings are due to the weights and

how much inefficiency is associated with the observations. Thus many problems arise, so that a different approach is needed.

DEA, by contrast, uses variable weights, that are directly derived from the data with the result that the numerous a priori assumptions and computations involved in fixed weight choices are avoided. Secondly, the weights are chosen in a way that assigns a best set of weights to each department. This does not mean that the weights differ for each department in a way that maximize the individual efficiency, but it means that the resulting output-to-input ratio for each department, thus for each DMU, is maximized relative to all others when these weights are assigned to these inputs and outputs for each of them. This results in the fact that efficiency values are always at least as great as the ratio values obtained from the previous fixed value weights (W. Cooper, Seiford, & Zhu, 2013).

Moreover, the following conditions are the result of this best ratio approach:

1. All the data and all the weights are positive, or at least non-negative
2. The resulting ratio must lie between zero and one
3. The same weights are applied to all entities. Consequently, the entity evaluated cannot choose a better set of weights for its evaluation (relative to the other entities).

Finally, as we will see in the next section (Section 3.3), the application of DEA allows to avoid the need for explicitly specifying *a priori* the formal relations that are supposed to exist between inputs and outputs.

This basic kind of efficiency is referred to the concept of *technical efficiency*.

By adopting a more economic point of view, technical efficiency is the effectiveness by which a given set of inputs is used to produce an output. A firm, indeed, is said to be technically efficient if it is able to produce the maximum output from the minimum quantity of inputs, such as labour, capital, and technology.

Michael James Farrell, the father of DEA, defined technical efficiency as "*the combination of productive factors oriented by the function of production, which are used* *for the production of the maximum quantity of output without wasting them*" (Farrell, 1957).

The main aim of efficiency analysis is to estimate an *efficient frontier*, that can be considered as a kind of frontier that reveals which are the best practices adopted by the group of DMUs under evaluation.
The non-parametric approach of DEA has received a considerable amount of interest because it is based on few assumptions and, most important, it does not require the specification of a functional form for the frontier.
In DEA, the efficiency of a DMU is obtained by evaluating a ratio of weighted outputs to weighted inputs, subject to the constraint that any DMU can acquire weights that would make another DMU having a ratio greater than one. Thus 1 represents the maximum value of efficiency, as for example it is for the concept behind thermal efficiency in physic.
Charnes et al.(Charnes, Cooper, & Rhodes, 1978) extended Farrell's single output / input technical efficiency measure (Farrell, 1957) to multiple inputs and outputs and they defined this concept mathematically as follows:

$$\rho_o = \max_{u,v} \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

$$\text{s.t.} \quad \frac{\sum_{r=1}^{s} u_r \; y_{rj}}{\sum_{i=1}^{m} v_i \; x_{ij}} \leq 1, \; (j = 1, \ldots, n)$$

$$u_r, v_i \geq 0, \; (r = 1, \ldots, s; i = 1, \ldots . m)$$

Equation 1 – Farrell DEA Formula

where:

- ρ_o is the relative efficiency of the single DMU under evaluation
- j is the DMU index
- r and i are the indices for output and input, respectively

- n is the number of DMUs
- s in the number of outputs and m is the number of inputs
- $u(r)$ is the weight for output and $v(i)$ for input variables

If the relative efficiency is less than 1, the DMU is considered to be inefficient, while it is considered efficient when equal to 1 and thus will be part of the efficient frontier.
This formulation is a constant returns to scale form (CRS). There are also more complex models based on variable return to scale (VRS). This simply means that an increase in inputs does not result in a proportional change in the outputs.
In order to have a clearer idea of what the efficient frontier is, here a graphical representation is proposed (*Figure 10*). In particular, this example is retrieved from a case with two outputs and one input, whose ratio is represented in the two axis.
Supposed that the A, B, C, D, F and G represent the different DMUs of the entity under evaluation, such as the already mentioned hospital departments. Those departments that are under the efficient frontier are inefficient and part of the so called "production possibility set" region.
So, for example, the efficiency of unit D is measured by the ratio OD / OP. This ratio is referred to as a "radial measure" and can be interpreted as the ratio of two distance measures.
By a graphical point of view, the higher the distance between D and P, the higher will be the level of inefficiency of each department, thus the lower its efficiency.

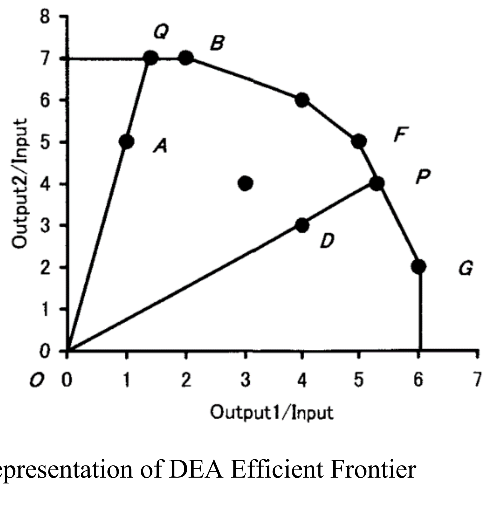

Figure 10 – A Graphical Representation of DEA Efficient Frontier

The above-mentioned case shows the meaning of *technical efficiency*. But there is also another case that we can show with this graph.

Consider the case of Q and B, where Q is a generic point in the frontier, while B is an efficient department. Even if a DMU is on its efficient frontier, it may not be economically efficient. This means that not all the points on the frontier have the same value. Hence, to be economically efficient, an economy must find that point on its frontier or that mix of products that has the highest value. This final condition of economically efficiency may be called *mix efficiency*. Thus, inefficiencies can be the result of a wrong input mix allocation.

3.3 Basic DEA Models

There are different types of basic DEA models: radial, additive and slack-based measure models. In this section we will provide an exhaustive description for each of them.

3.3.1 *Radial Models: CCR*

In the original DEA model proposed by Charnes et al. (Charnes et al., 1978), from whom the name is retrieved (CCR stands for Charnes, Cooper and Rhodes), a DMU's efficiency score is derived from the extent to which all of its inputs can be contracted and/or its outputs expanded, where this contraction or expansion occurs in a proportionate way.
As the figure below shows (*Figure 11*), the term "radial", as the examined input possibilities occur on the line extending radially from the origin of the input space (i.e. zero values for all inputs) to the DMU's original inputs (c.f. DMU A). In particular, the line between A and the target unit A' measures the possible improvement, so the level of inefficiency that the department has to cover in order to become efficient.

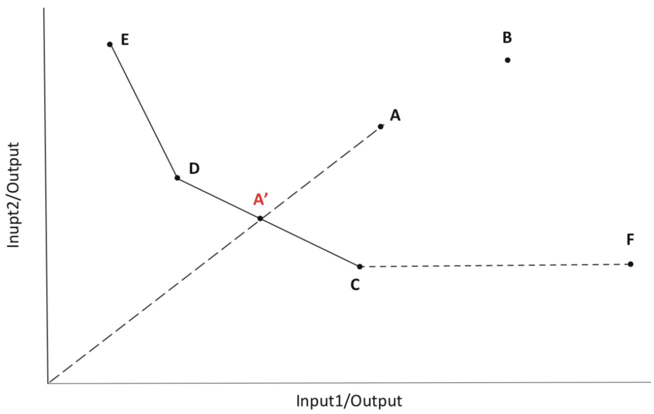

Figure 11 – A Graphical Representation of DEA Efficient Frontier with CCR Model

The main assumption behind the model, as mentioned before, is the constant return to scale (CSR), so that an increase in inputs results in a proportional change in the outputs.
Different formulations of CCR model have been developed. These are:

- Envelopment form of the input-oriented model
- Multiplier form of the input-oriented model
- Envelopment form of the output-oriented model

3.3.1.1 *Envelopment Form of the Input-Oriented Model*

For a model with *m* inputs variables, *s* output variables, and *n* DMUs, the *envelopment* form of the *input-oriented model* is given by (W. Cooper et al., 2013):

$$\begin{aligned} &\min_{\theta, \lambda} \theta \\ \text{subject to} \quad &\theta x_o - \boldsymbol{X}\lambda \geq 0 \\ &\boldsymbol{Y}\lambda \geq y_o \\ &\lambda \geq 0, \end{aligned}$$

Equation 2 – Envelopment Form of the Input-Oriented Model

where:

- x_o and y_o are the column vectors of inputs and outputs respectively for DMU_o
- X and Y are the matrices of input and output vectors respectively for all DMUs
- λ is the column vector of intensity variables denoting linear combinations of DMUs
- θ is the objective function

According to the studies of Rajiv Banker and his collaborators (Banker, Charnes, Cooper, Swarts, & Thomas, 1989), the main contributors of DEA, a general rule has to be defined. This is more a rule of "thumb" than a formal rule, which by its nature is a qualitative judgment.

Specifically, in order to have a meaningful result with a clear set of efficient and inefficient units, a minimum number of DMUs in relation to the number of variables has to be set, as the following formula shows:

$$n \geq \max\{m \times s, 3(m + s)\}$$

Equation 3 – Minimum Number of DMUs' Formula

where *m*, *s* and *n* are the number of inputs, outputs and DMUs respectively.

The first CCR model proposed, as the formula above shows (*Eq. 3*), aims to identify the largest proportion by which all inputs can be reduced, while, at the same time, producing, at least, the same level of the original outputs.

The linear programming optimization is then repeated for each one of the *n* DMUs. The optimal value of θ obtained, denoted by θ*, can be considered the efficiency score of each DMU. According to how the model is set, the efficiency score will range from 0 to 1, inclusive. Those units that are efficient will have a value equal to 1 and hence they will be part of the efficient frontier, while the remaining ones, that are inefficient, will be part of the possibility set region.

By definition, efficient units will not be able to further reduce inputs. What is relevant to note is that efficient units with a rating of 1 (or eventually 100% if expressed in percentage) are *relatively efficient* compared to the DMUs in the study but they do not have reached an *absolute efficiency*. They are efficient relatively to the set of departments under study, but this does not mean that they are efficient also in other cases. Coming back to the example of the hospital, the department of surgery can be efficient, and hence having a unitary score, when the analysis is made for hospital A, but it could be inefficient when compared to the departments of hospital B. So what is important here to highlight is the concept of relative efficiency, thus it depends on the sets of DMUs analysed.

According to the input-oriented model described, here the purpose is to further improve the DMU's production performance after the radial optimization by reducing the amount of inputs, thus increasing the efficiency. Similarly, even if this model focuses on reducing inputs, it may be possible to produce more outputs using the same amount of inputs. So the inputs are considered as fixed, and outputs variable. For example, in real practice, it is like training an operator working on an assembly line to make the process faster and hence improving the productivity of the system.

In any case these additional possible input reductions and output expansions are termed *slacks*, and can be optimized through a second stage to the DEA model. In the classic radial models, the slacks relate to the further increases in output or reduction in input that could be gained beyond the radial projection (i.e. equal increase in all outputs, or decrease in all inputs).

This second stage is represented by the following function:

$$\begin{aligned} \max_{\lambda, s^-, s^+} \quad & \omega = e_m s^- + e_s s^+ \\ \text{subject to} \quad & s^- = \theta^* x_o - \boldsymbol{X}\lambda \\ & s^+ = \boldsymbol{Y}\lambda - \boldsymbol{y_o} \\ & \lambda \geq 0, s^- \geq 0, s^+ \geq 0 \end{aligned}$$

Equation 4 – Second Stage DEA Radial Model with Slacks

where:

- e(m) is the row vector of *m*, inputs
- e(s) is row vector of *s*, outputs
- s- is the column vector of input slacks
- s+ is the column vector of output slacks
- θ* is the optimal input contraction obtained from the first stage (*Eq. 2*)

3.3.1.2 *Multiplier Form of the Input-Oriented Model*

The *envelopment* form of DEA already presented is not the unique one, since it is possible to formulate the same model in a different way. Another representation is the *multiplier* form, that is the equivalent model, expressed in different terms as following:

$$\begin{aligned} \max_{v, u} \quad & u y_o \\ \text{subject to} \quad & v x_o = 1 \\ & -v\boldsymbol{X} + u\boldsymbol{Y} \leq 0 \\ & u \geq 0, v \geq 0. \end{aligned}$$

Equation 5 – Multiplier Form of the Input-Oriented Model

where:

- *v* is the virtual (or marginal) weight for the input
- *u* is the virtual (or marginal) weight for the output

The model selects virtual (or marginal) weights for both inputs and outputs in a way to maximize the efficiency score of each DMU, named DMU(o), where efficiency is measured as the ratio of the virtual output (i.e. sum of outputs weighted by the virtual weights) to the virtual input. As in the previous model, also in this case the above function has to be run for each DMU.

Of course additional constraints have to be set: the weights have to be positive, hence non-negative and also feasible for the sample. This means that applying the same weights to any DMU in the sample will not produce an efficiency score greater than one.

What is interesting to highlight is that the weights, according to those constraints, can assume a null value. In such cases the interpretation of the results should explicitly consider the implications of the zero weights, as each DMU can look relatively more efficient by removing the inputs and/or outputs.

3.3.1.3 *Envelopment Form of the Output-Oriented Model*

Analogous to the input-oriented version, the output-oriented model seeks the maximum factor by which all outputs can be simultaneously expanded. Here the aim is to maximize the objective function in a way to find the output level that make efficiency larger. The formulation is the following:

$$\begin{array}{ll} \max\limits_{\phi,\lambda} & \phi \\ \text{subject to} & x_o - \boldsymbol{X}\lambda \geq 0 \\ & \boldsymbol{Y}\lambda \geq \phi y_o \\ & \lambda \geq 0 \end{array}$$

Equation 6 – Envelopment Form of the Output-Oriented Model

Here the main assumption is the constant return to scale (CRS). One property of radial CRS DEA model is that the efficiency scores determined for DMUs are the same in both input- and output-oriented models, i.e. $\theta^* = 1 / \varphi^*$.

3.3.2 *Radial Models: BCC*

BCC Model was developed by Banker, Charnes and Cooper (Banker, Charnes, & Cooper, 2008). This linear-programming model aims to measure the efficiency through inflows

(inputs) and outflows (outputs) relations as it was the CCR one. Here the main difference is that BCC model deals with variable returns to scale (VRS), whereas the CCR one deals with constant returns to scale (CRS). Hence production technology exhibits a VRS. Anyway, the results of the two models are quite similar: the resulting efficiency is always at least equal to the one given by the CCR model (W. Cooper et al., 2013).
The *envelopment* form of the *input-oriented* version of the model is given by Cooper (W. W. Cooper, Seiford, & Tone, 2007):

$$\begin{array}{ll} \min\limits_{\theta_B,\,\lambda} & \theta_B \\ \text{subject to} & \theta_B x_o - \boldsymbol{X}\lambda \geq 0 \\ & \boldsymbol{Y}\lambda \geq y_o \\ & e_n\lambda = 1 \\ & \lambda \geq 0. \end{array}$$

Equation 7 – Envelopment Form of the Input-Oriented in Vectors Form

The variables are the same, except for *e(n)* that represents the row vectors of *n*, the number of DMUs. At this stage a comparison between the envelopment form of input-oriented CCR model is recommended.
The two differ in the introduction of a new constraint in the VRS model, the third one, that sets the sum of the intensity variables equal to one. The main effect of this new constraint is to limit a DMU to being compared to other DMUs that are of roughly the same operational scale. This, indeed, allows the existence of variable return to scale. The CRS efficiency score will be less than or equal to the VRS score, and the ratio CRS / VRS scores gives a measure of the DMU scale efficiency. This relationship between CRS and VRS scores holds for all DEA models.
The VRS model is frequently applied since it is able to reveal additional useful insights. One of the advantages of DEA is that there is no need to know the functional form, which would include knowing the returns to scale characteristics.
In order to have a more practical view let's consider the following case: there is a larger unit that is less efficient than a smaller one, and, by deeply analysing the situation, there is the risk to overlook the real possibility that the large unit is less efficient due to the way

it operates and not due to decreasing returns or any scale effect. But this effect can be mitigated by applying both CRS and VRS, that would help identifying the inefficiency in the larger unit.

Because of the similarities with the CCR case, we avoid showing the multiplier form and the envelopment form of the output-oriented model. Instead, it is more relevant for the purpose of our analysis focusing on the situation where it is not clear or intuitive if emphasizing input reduction or output maximization. Maybe we can pursue both.
In order to address this specific case, we rely on the non-oriented form of the radial DEA models. The CRS version of the *envelopment* form of the *non-oriented radial model* was first developed by Fred Tam in 2004 (Paradi & Tam, 2012):

$$\begin{array}{ll} \max\limits_{g,\bar{\lambda}} & g \\ \text{subject to} & x_o - \boldsymbol{X}\bar{\lambda} \geq 0 \\ & \boldsymbol{Y}\bar{\lambda} \geq g y_o \\ & g \geq e_n \bar{\lambda} \\ & \bar{\lambda} \geq 0 \end{array}$$

Equation 8 – CRS Envelopment Form of the Non-Oriented Radial Model

where g = φ / θ and λ = λ = θ. The other variables are always the same as the one defined in the other models.
In this model both a radial contraction, θ, thus a reduction of input, and radial expansion, φ, hence an output improvement, are determined, subject to constraints that the target to which a DMU is being compared cannot use more inputs (θ <= 1) or produce less outputs (φ >= 1).
The efficiency score for the DMU is given by 1 / g* = θ* / φ*. For the CRS model, the efficiency score from the non-oriented radial model will be the same as those obtained from the input- and output-oriented models.

3.3.3 *Additive Model*

The methodology proposed by DEA is useful when modelling situations that involve multiple inputs and multiple outputs. One of the main issues has to do with the evaluation of trade-offs, for example between substituting one input for another. This evaluation is referred to as considering the mix or allocative efficiency of the DMUs.

While the *mix efficiency* was already defined in the dedicated section (Section 3.3), we need to figure out what the concept behind *allocative efficiency* is. By taking an economical point of view, the allocative efficiency occurs when there is an optimal distribution of goods and services, taking into account consumer's preferences.

More precisely, it happens when there is an output level so that the price equals the Marginal Cost (MC) of production. This is because the price that consumers are willing to pay is equivalent to the marginal utility that they get (Dan, 2013).

In situations with known prices for all inputs and outputs, the cost, revenue or profit can be optimized to decide upon the best input and/or output mixes.

However, in many situations, prices or values are not known or not fixed for all inputs and outputs. Radial DEA models generally avoid dealing with mix issues by looking at proportional changes to inputs and outputs in their first stage. Proportional changes keep the input and output mixes the same as those originally employed by the DMU (W. Cooper et al., 2013).

For these reasons the additive model has been introduced, since it addresses the input and output mixes of the DMUs. Its goal, indeed, is to determine the maximum extent to which slacks can be removed from the DMU under evaluation. Below the VRS envelopment form of the non-oriented model is provided:

$$
\begin{aligned}
\max_{\lambda, s^-, s^+} \quad & z = e_m s^- + e_s s^+ \\
\text{subject to} \quad & \boldsymbol{X}\lambda + s^- = x_o \\
& \boldsymbol{Y}\lambda - s^+ = y_o \\
& e_n \lambda = 1 \\
& \lambda \geq 0, s^- \geq 0, s^+ \geq 0
\end{aligned}
$$

Equation 9 – VRS Envelopment Form of the Non-Oriented Model

The characteristics of the additive model are very different from those of the radial DEA models. Its results are not easily expressed as standard efficiency scores. In this case, differently to the radial models, the optimal value for efficient units is zero, as efficient units will have no slacks, and there is no defined upper limit on the total slacks.

3.3.4 *Slack-Based Measure Model (SBM)*

In the CCR and BCC models there is no reference of the slacks in the optimal solution. But when discussing the total efficiency, it is important to consider not only the ratio efficiency but also the slacks, that, as previously discussed, relate to the further increases in output or reduction in input.

In 2001, Kaoru Tone (Tone, 2001) formulated the slack-based measure (SBM) as a development of the additive model that would generate a standard efficiency score and be unit invariant, while also allowing for input and/or output mix considerations.

Differently to the additive model of DEA, that directly deals with input excess and output shortfalls, this model has no scalar measure per se. Although it can discriminate between efficient and inefficient DMUs because of the existence of slacks, it has no means of measuring the depth of inefficiency, similar to θ* in the CCR model.

Having in mind these considerations, the envelopment form of the input-oriented CRS, SBM is given by:

$$
\begin{aligned}
\min_{\lambda, s^-, s^+} \quad & \rho = 1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{io} \\
\text{subject to} \quad & x_0 = \boldsymbol{X}\lambda + s^- \\
& y_0 = \boldsymbol{Y}\lambda - s^+ \\
& \lambda \geq 0, s^- \geq 0, s^+ \geq 0
\end{aligned}
$$

Equation 10 – Envelopment Form of the Input-Oriented CRS SBM Model

Because of the complexity of the model, and given the purpose of our work, we will consider only the relevant aspects of this formulation. First of all, it can be seen that the SBM model, as the additive one, maximizes the total input slacks, but the slacks are considered as a proportion of the initial input value, as opposed to being considered in absolute terms.

Comparing this formulation with the one of the envelopment form expressed by *Eq. 2*, it can be seen that the SBM is similar in form and function to a radial DEA model.
The difference is that the SBM model maximizes the average proportional input contraction across all the inputs, while, the input-oriented radial DEA model aims to maximize the proportional input reduction that is applied to all input variables. This means that, according to the SBM model, we implicitly assume that a 1% reduction in one input has the exact same value as 1% reduction in any other input, or as another example, the combination of a 0.4% reduction in a second input and a 0.6% reduction in a third input.

3.4 Modelling the Real-Life Situation

According to the main academic researchers in this field, there are at least three issues of paramount importance for methodological advances in DEA: data uncertainty in inputs and outputs, impact of external contextual variables on DEA-based efficiency, and the issue of correctly identifying and specifying the set of inputs and outputs in DEA. In particular our focus in this stage is mainly on the selection of the variables to be included in the model. Indeed, inputs and outputs must be able to properly model the real-life situation of each DMU. The main goal is collecting data and, thus, analysing the results that should be translated into actions to enhance performance. But, if the model represents only a relatively small part of the reality, the possible improvements will be weak. So the model must reflect the actual production process, and use variables, primary inputs and outputs, that reflect the environment managers deal with in their work to make the results meaningful and actionable.

This leads to the adoption of a more practical approach rather than a pure academic approach where the pure theory governs.

Of course, one of the main decisions that has to be taken when programming the DEA model is about selecting the proper input and output variables, having in mind that they should be able to represent the majority or, at least the most significant, portion of the reality of the DMUs. The following section is entirely dedicated to this topic, where tips and practical advices from real practitioners are included.

3.4.1 *Selection of Inputs and Outputs*

At first glance the choice of which inputs and outputs to include and the form of these measures seemed easy. But, upon examination, the problem resulted to be more complex. Suppose, for example, that we want to select as output something that is undesirable, for example bad loans, and as inputs the cost of education: in this case the output should be minimized while the input maximized. In this case a problem emerges. DEA, indeed, at its core, minimizes inputs while maximizing outputs to select the best score for the DMU. But, of course, we do not want to maximize bad loans or minimize educational costs that contributes to increased service levels.

Moreover, there are cases where some inputs can also be outputs, such as medical students providing hospital patient care and also receiving a medical education through their work in the hospital. So how is it possible to deal with those issues in a way to mitigate the effect? William Cooper, one of the founder of DEA, proposed some advices to properly approach this choice (W. Cooper et al., 2013). These are mainly listed below:

- Rather than deciding what is an input and what is an output, it is much better to examine each variable and decide if minimizing or maximizing it would result in a DMU appearing to be more efficient, productive or whatever the model is designed to show;
- If, for example, the inputs should be maximized and the outputs minimized, as the example above shows, a possible approach is to use the inverse (*1 / variable*) of the actual data.
- Sometimes could happen that a variable is considerable both an input and output. In this case a possible solution is to split the measure into two and create a positive and negative variable. For example, it is possible to divide the loans into good, that should be maximized as outputs, and bad, that should be minimized as input.
- In many cases two or more variables are highly correlated, such as salaries and hours worked. The manager may not accept that the analyst excludes one of these highly correlated variables as the manager may see the model as not a fair representation of the production process. In this case it is suggested to previously identify with proper methodologies (i.e. Pearson Correlation Coefficient) the level of correlation, and thus providing only one of the measures, possibly the most explicative and significant one.
- Variables in a ratio form or percentages are also troublesome as these variables will not scale the same way as scalars and the ratio removes the size component from the information available. The real concern is that mixing ratios and absolute input or output amounts can generate results that mathematically satisfy the model but are not meaningful in practice.

By taking care of financial industry, it is interesting to consider those cases where the input and output selection happens under expert information.

When determining the critical success factors of a public company, the raw financial numbers of a firm do not provide the perspective required to differentiate between healthy and unhealthy stocks for investment. In other words, the context provided by a comparison of a given firm to its industry and to the market as a whole is essential. Therefore, it is very weak, if not incorrect, evaluating a firm's business strength in isolation. Instead, a relative strength indicator is computed by comparing a given firm to many other firms which are in a similar business segment of the market, such as the industry which the firm belongs to. Especially in finance, there are many and many public (listed) firms that operate in a competitive environment and whose fundamental strength is observed by the external entity consisting of participants of a stock market. In case of informational efficiency, it is expected that internal managerial strength would be strongly associated with market gains for the company stock. This is, indeed, the basic behind the theory of *Efficient Market Hypothesis* (EMH), according to which all the information available to the public, including, for example, financial statements, are fully reflected in the firm's stock price (Fama, 1970).

Now, if internal fundamental performance of DMUs is scored and ranked by a DEA model, unless the inputs and outputs are appropriately chosen, the resulting DEA scores would not be consistent with the external reward process, in this case stock return, thus being in contrast to the concept behind Efficient Market Hypothesis. There is a clear tension between internal and external information.

In this sense, therefore, selection of inputs and outputs must be performed endogenous to the DEA model by incorporating the reward metric (i.e. stock returns in our example) as an external (response) variable. The choice of inputs / outputs based on an exogenous response variable was first articulated in the paper of Edirisinghe and Zhang, which laid the foundation of their model, the Generalized DEA (GDEA) approach. According to this model, the advice is to select a sufficiently smaller number of inputs and outputs so that the resulting DEA-based fundamental strength is strongly correlated with the external stock return process in a contemporaneous manner (Edirisinghe & Zhang, 2007).

3.5 The “Marketplace”

DEA has been largely recognized as an interesting new way of evaluating the efficiency of organizations. It has proven to be a powerful analytic methodology that could be adapted and developed to analyse organizational performance questions not adequately addressed with more traditional methods, such as a trivial linear regression. The purpose of this section is not to show all the possible models of DEA, since it would be a useful strategy, but we want to provide a rapid view of the evolution of this methodology and the *marketplace* behind it (e.g. the main areas in which the methodology is applied).

There is no master plan as to how DEA would evolve. The philosophy behind it, of which the already mentioned Cooper is one of the main contributor, is simply that DEA should be driven by the need to answer practical questions or problems not answered by existing methods. Consequently, many DEA developments and models where conceptualized with the aim to answer new questions or provide more complete and accurate views than existing DEA models. Some paths, for example, are working in the direction of developing new models in ways that would be more compatible with traditional statistical analysis, hence with the aim to create a higher compatibility with existing and new techniques.

Another direction was adapting DEA to respond to special situations, such as missing or imprecise data, or seeking insights into differences among the efficient DMUs (e.g. super efficiency). More precisely, according to the DMUs’ efficiency scores, DEA classifies the DMUs into two diverse efficient and inefficient groups. Unlike the inefficient DMUs, the efficient ones cannot be ranked based on their efficiencies because of having the same efficiency score of unity. It is not, however, reasonable to claim that the efficient DMUs have the same performance in actual practice. For this reason an appropriate ranking should be made with the purpose of distinguishing those DMUs that are classified as efficient, understanding which of them are *super-efficient* (S. Li, Jahanshahloo, & Khodabakhshi, 2007).

Since 1978, intense analytical power and energy have been devoted to DEA applications and methodology. The purpose of this section will attempt to identify the main applications of DEA from its origins.

DEA was initially developed with the main goal to analyse a US public education program, the *Follow Through* program[8], in order to determine the improvements over a pre-existing program. The unique challenge was that there were multiple outputs and inputs that needed to be considered in developing a fair evaluation.

When the results were firstly published it was clear that this new methodology had the potential to be used in a very large variety of situations, in particular in such cases where evaluating performance requires to consider multiple inputs and outputs. Indeed, most real assessments of performance require consideration of multiple inputs and outputs, since single measure does not fully capture the reality. This distinctive quality of DEA leads to the development of this approach to a wide and still expanding range of issues and organizations.

All applications utilize to varying degrees the basic and expanded range of models and theory described above. In the paper made by Liu et al., it has been identified over 20 real world applications domains led by banking, health care, agriculture and farming, transportation, education, power generation and distribution, and manufacturing (Liu, Lu, Lu, & Lin, 2013). The survey proposed in this paper covers DEA papers listed in the Web of Science database from 1978 through August 2010. The results show that, during the period, a total of around two-thirds of all DEA studies use real world data as the main subject of study. In reality, in the early days, there were more purely-methodological than application-embedded studies, while the fast growth of application-embedded studies started in in the mid-1990s, hence pushing the total amount of these studies to exceed that of purely-methodological ones.

According to this study the five major applications, namely those that represents the 41 per cent of all application-embedded papers, are listed below. Among all the applications, the highest growth momentum recently has been in energy and environment as well as finance. These are:

[8] **Follow Through** was the largest and most expensive experimental project in education funded by the U.S. federal government that has ever been conducted. Its function was to deliver educational, health, and social services to students in their early elementary years.

- *Banking*: the leading paper is the one proposed by Sherman and Gold (Sherman & Gold, 1985), that is the first work that applies DEA to study bank efficiency adopting the CCR model.

  This study was based on an exploration into whether DEA would generate insights that were valid and potentially helpful to the bank. The inputs and outputs used included ones that were readily available, and may or may not have included all those that were relevant for a complete usable analysis. The key result was a general understanding of efficient and inefficient branches as a good reflection of differences in the branches' performance.

  The conclusion for the researchers was that this supported the potential value of DEA in banking. Management agreed that the identification of inefficient and efficient DMUs in banking industry was a useful, but not sufficient, information for the decision-making process.

  Another popular insight is provided by Wanke et al., that studied the banking industry in Middle East and North Africa countries, well-known for regulatory and cultural heterogeneity, besides ownership, origin, and type diversity (Wanke, Abul Kalam Azad, Emrouznejad, & Antunes, 2019). In particular, they explored these issues by developing a Dynamic Network DEA model in order to handle the underlying relationships among major accounting and financial indicators. This methodology was significant in order to take care of the contextual variables related to bank ownership. This is interesting since also in our work we will have to rely on external variables related to the context in which the firms operate;

- *Health care*: except for few cases, most of the papers studied hospital performance, although nursing homes, primary care, and care programs are among many other subjects of study. For example, Nunamaker measured the routine nursing service efficiency for a group of Wisconsin hospitals (Nunamaker, 1983).

  Overall, as pointed out by Hollowgsworth, the techniques used in efficiency studies in the health care area are mainly based on DEA, but there is some usage of parametric stochastic frontier analysis, which is outside the scope of our analysis (Hollingsworth, 2008);

- *Agriculture and farm*: Fare et al. were the first study to apply the frontier concept to investigate agriculture economics. In that case the aim was to study the agricultural context in Philippine by analysing the production efficiency in order to understand how to better exploit the existing resources to maximize the output (Fare, Grabowski, & Grosskopf, 1985).
  More recently, Hansson explored how factors that have the potentials of driving and restraining forces on farm strategy affect farm performance, in terms of economic, technical and allocative input and output efficiency (Hansson, 2007). In this case the main strengths of the adoption of a DEA approach were firstly the fact that it allows multiple outputs, it let on the decomposition of both economic input and output efficiency and it does not require specification of functional form.

- *Transportation*: under the transportation category, the main paths consist of two independent streams of works: on one side there are studies based on analysing the performance of airlines, airports, or airport authorities, while on the other side there are paper that examined the efficiencies of ground transportation systems such as railway and bus. The leading article for air transportation was developed by Michael Schefczyk (Schefczyk, 1993). Hence, with the adoption of DEA it was possible to analyse the international airline strategy by taking care not only of the financial data but also the operational ones (i.e. number of available ton kilometres), because of the multiplicity of outputs and inputs that this technique allows.

- *Education*: education is the application that attracts the most attention in the early days of DEA development. As mentioned before, it was the main field of application. In particular, the main streams are focused on analysing the efficiency at education level in the case of higher and basic education. The recent trend of efficiency studies in the education category clearly focuses on the higher education sector as all articles close to the end of the main paths evaluate the performance of universities. It clearly appears that the main adopters are public entities and universities, whose aim is understanding if the amount of resources invested in education is well remunerated. Of course the number of variables that should be considered is very relevant.

As the cases above show, the potentials for the application of DEA are quite large. A notable point is that, according to many academics, DEA does not represent alone a tool for taking decisions. It is a useful support for measuring the efficiency of the system and thus understanding the best practices.

Anyway, because of its main strengths, our work rely on the application on this technique and the next sections are entirely dedicated to the application of DEA in the real case of the ICO. In particular, with reference to the dedicated section (Section 4.3) the application of the *two-stage approach* will be discussed, with the aim to identify the factors that affect the efficiency score of the ICO projects. The attempt of this chapter was to introduce the main concepts and the main technique behind DEA.

4
Research and Methodology

4.1 Research Introduction

The purpose of our pioneering research is providing new knowledge about the ICO world through a set of analysis whose aim is evaluating the efficiency of the ICO-based projects and the main variables which can impact on it.
In order to achieve this goal, we have set our analysis on a database, that was previously created by our research group, and then updated with new data and new variables.
The ICO phenomenon is quite recent, hence the availability of remarkable academic research is poor. Anyway, some interesting works have been proposed, catching our attention.
So far, the majority of quantitative analysis aimed to identify the critical factors that make an ICO project successful, hence when the target fund is reached. In particular, the main researchers tried to relate the success of ICOs with specified variables or characteristics of them.

4.1.1 *Evaluation of Success Factors*

In this section we have provided a synthetic overview of the most significant papers related to our work, hence providing a general understanding of the actual state-of-the-art in terms of statistical and data-based research.

In the *Journal of Economics and Business*, Adhami, Giudici and Martinazzi, starting from a sample of 253 ICO campaigns of 2017, demonstrated that the probability of success increases if the code source is available, if there is a presale before the ICO period and also if the contributors can access to a specific service. Instead, they did not find any correlation between the availability of a white paper or the inclusion of a bonus scheme in the sale with the success of the ICO process (Adhami et al., 2018).

Rasskazova, Koroleva and Rasskazov, in the paper “*Digital transformation: Statistical Evaluation of Success factors of an ICO-Campaign*”, by studying a sample of 672 projects, demonstrated how a higher price negatively influences the probability of success of an ICO campaign, and also how a shorter campaign increases the probability of achieving a positive outcome.
Beyond this, they evidenced that the probability of raising the required amount of money grows if there is not a presale stage before the ICO. This is a quite surprising result if compared with the work of Adhami et al., which stated the opposite. Conversely, they did not reveal that a high hard cap could frighten external investors from putting money in an ICO (Rasskazova, Koroleva, & Rasskazov, 2019).

Again, Fisch, in the *Journal of Business Venturing*, by collecting a sample of 423 projects, confirmed that technical white papers and high-quality source codes increase the possibility to raise an higher amount of funds (Fisch, 2019).

Wider considerations have been made by Burns and Moro: by studying a sample of 147 ICOs in 2017, they investigated the role of team quality, market sentiment and other ICO characteristics in the overall projects, considering not only the “issue period”, but also the next stages (Burns & Moro, 2018). In this way, they evaluated the crypto-projects on their short-term return on investment and first-day return, beyond obviously the total amount raised in the ICO. Also because of this wider set of outputs, the sample was quite small, considering that is not so easy to find all these data for each project.
Of their results, the most interesting ones are: the ICO token price is negatively related to the four-month ROI and first-day returns in the exchange, the use of Ethereum as blockchain platform is negatively correlated to first-day return. On the other hand, focusing on the quality and size of the team, they discovered that both the greater the leadership experience of the CEO (in terms of years) and the number of team members are positively correlated with the amount of capital raised in the ICO.

As we have stated in the literature review, the role of social media could be crucial to spread information and give awareness to possible crypto-investors. So far, one of the

most relevant is the work made by Chanson, Wortmann and Risius from the academic centres of Zurich, St. Gallen and Queensland respectively. They were intended to demonstrate the correlation between the activity on social media and on online discussion forums as Reddit or Bitcointalk and the success of the ICOs.
Among their hypothesis, the dependent variable selected was not only the funds raised, but also the underpricing: it is the difference between the first day trading closing price and the ICO token price divided all by the ICO token price. This underpricing bases on the fact that, typically, "*the price at which investors buy coins during the ICO is substantially lower than the price of the same coins when they are traded on cryptocurrency exchanges days or weeks later*" (Chanson et al., 2018).
Their results revealed that the more tweets a firm posts prior to its ICO, the more the firm will be mentioned on discussion forums, and, in turn, the higher discussion forum activity is related to higher ICO underpricing, driving up ICO performance.

To summarize, despite the data samples considered differ each other, what we have observed is that a greater probability of success of the ICO projects is affected by:

- the presence of at least a portion of the code source;
- a lower price of the token;
- a shorter ICO campaign;
- a larger size and larger experience of the team;
- a greater activity on social media and crypto-forum discussions.

The only discordant result was the one related to the presence of a *presale* stage before the start of the ICO. Adhami et al. found a positive correlation with the probability of success, while Rasskazova, Koroleva and Rasskazov a negative correlation.

4.2 Database Analysis and Data Source

The main asset of our thesis is the database that we have populated. It is not only the result of our work, but a strong collaboration with our colleagues that started to collect data since the very beginning of the ICO phenomenon in the wider range of the research group of Professor Giancarlo Giudici. The idea is having an updated source of information where all the participants to the research can improve the analysis by uploading new information, in order to better trace the ICO trends.

We have started to populate the database since the launch of the first project in the late 2014, even if majority of our data refers to the years 2017 until the mid of 2018 (May 2018). Indeed in 2014 and 2015 ICOs were virtually non-existent, whereas the phenomenon clearly exploded in 2017, with 216 offerings from January to August (Adhami et al., 2018).

As previously mentioned in Chapter 2 (*Initial Coin Offering*), one of the main issues of the research was populating the database. Of course, not because of the time spent for the data assortment, but due to the opacity and the scarcity of reliable sources where to extract the information required.

The phenomenon of the ICO, even if nowadays is largely recognized, is still in an immature phase, hence generating a strong information asymmetry. For example, if an investor in common securities wants to know the price of the Ferrari share, he/she can easily open a generic website, as Bloomberg or Yahoo Finance, and the price will be univocally declared. In this sense there is no room for ambiguity. In the ICO case it is not exactly the same. Different sources provide different information. Due to the lack of regulation and "standardization" there is any reference schema in terms of information disclosure. The greater difficulty was to deal with those asymmetries.

For the reason explained, we have decided to rely on different sources (i.e. sector-specific websites) in order to have a wider view for the specific case and thus making a comparison per each data. This made our work very complex and very time costly, but of course it increased the reliability of the database.

In accordance with the research group, we have adopted a structured approach with aim to maximize, as much as possible, the standardization of the data collection process.

First of all, we have conveyed to a general classification of the sources adopted, thus assigning, on the basis of our experience, a rating for each website (from 1 to 5). The score depends on the following factors:

- (A) *Availability of data*
- (B) *Number of ICOs data available*
- (C) *Availability of the whitepaper*
- (D) *Reliability of the data provided on the basis of a benchmark with different sources*. Sometimes it may happen that a website is reliable for a specific information (i.e. number of team members) but not for others, so this aims to be an overall consideration.

Of course, given the opacity of the information, the score appointed are valuated in relation to the entire set of sources. Other websites have been identified, but given their unreliability we have decided to neglect them.

Source	A	B	C	D	Total Score
IcoBench	4	4	3	5	4.00
IcoDrops	5	1	5	5	4.00
CoinMarketCap	4	2	4	5	3.75
IcoMarks	5	4	2	4	3.75
IcoRating	3	4	5	2	3.5
IcoBazar	4	1	3	5	3.25
FindICO	4	1	4	4	3.25
IcoHolder	2	5	1	4	3.00
TrackICO	2	2	3	3	2.50
IcoData	2	3	1	3	2.25

Table 3 – Sources of Data

As the table above shows (*Table 3*), our main representative websites were *IcoBench* and *IcoDrops*. Indeed, also according to BitCoinTalk these are the most reliable sources where to extract data about the ICOs (Bitcointalk, 2018).

In practical terms, we have populated the database by firstly looking at these two main sources, whose data tend to be quite aligned. If the data was available we have put it into the excel DB, otherwise we have continued to look at other sources by tidy following our list.

In the following section a more detailed discussion about our database is provided. We aim to present the variables that we have considered and their meaning. Not only the ones that we adopted for the Data Envelopment Analysis, but also all the other data which helped us in a broader study of the ICO world. Several have been collected, not only for our works but also for future studies, so that not all of them have been used in this thesis. We have decided to classify the variables selected in six main groups.
These are:

1) *Project*: these data refer to the general information of the ICO-based company and its team;
2) *Token characteristics*: it comprehends all the technical features strictly related to the token and the ICO offer;
3) *Social Media*: these are a set of data related to the trend of the ICOs in the *Twitter* platform;
4) *Funds allocation*: these are those variables whose aim is to trace the company's operating functions in which the funds raised have been allocated;
5) *Trading*: it consists of a set of data whose role is to keep track of the performance of the ICO and the underlying cryptocurrencies during the issue period.

Before going deeper in the review of each category, we should dedicate a paragraph to the social media topic. After a series of research, we have identified Twitter and Telegram as the most popular and adopted websites for the discussion of the ICO world.
According to literature reviews on this topic, Twitter and Telegram are the leading social media platforms for the promotion of the ICOs. The objective was to trace the level of interest, the investor engagement and the popularity of the ICO in proximity and during the issue period. In particular, we have defined a range for the data collection: from the

starting date to the ending date of the ICO, clearly and unequivocally defined for each process.

We have started to consider *Telegram*, and we have identified *Telegram Statistic* as a possible source of information where to extract data about the users' reactions and engagement. But, after some experimental tests, we have decided to stop the work because of the poorness of data for the ICOs made during the 2017. Probably this platform was newly adopted in that period, so that it was not significant for our analysis, since most of the projects are from 2017.

For this reason we have opted for the analysis of Twitter data, identifying *Twitonomy* as the representative statistic platforms. According to dedicated communities and academic discussions, it is one of the most reliable and popular analytical platform for those kind of data (Steen-Johnsen & Enjolras, 2015). The specific variables have been illustrated in the dedicated tables below (*Tables 4, 5, 6, 7, 8*).

Table 4 – Project Characteristics

Variable	Description
ICO Name	The name given to the ICO-based project
Token Ticker	The distinctive code of the ICO. It generally is made up of the first three consonants of the ICO name.
Core Team	The number of members taking part to the ICO project. It comprehends typically the founder, a series of Chief Officers and other managerial figures, mainly Marketing, Operation, Technology, etc.
Advisors	The number of external members who participated in the realization of the project. These are generally experts of Blockchain and Digital Technology who already faced similar projects.
Country	It refers to the main nationality of the Core Team, even if sometimes a dominant country cannot be attributed because of a decentralised governance mechanism through an online cooperation from multiple location. We tried also to collect data about the country jurisdiction with poor significative Â results mainly due to a lack of data.
Global Rank	It is a number referring to the ease of doing business for the specific country introduced in the line above. This ranking is provided by doingbusiness.org.
Product	It is a brief description of the product/service offered to the customers.
Industry Sector	It refers to the application field which the product is involved in (e.g. financial services, healthcare, gaming, etc).
Blockchain	It is the blockchain used to develop the project. In most cases it is ETH, sometimes WAVES, NEO, or others.
White paper	It is a dummy variable that assumes 1 if the white paper has been published, 0 otherwise.
Code Availability	It is a dummy variable that assumes 1 if it is provided a partial or complete set of programming codes of the project (on Github.com), 0 otherwise.
Italian Team	It is a dummy variable that assumes 1 if the team is Italian, 0 otherwise.
Italian Team Member	It is a dummy variable that assumes 1 if there is at least an Italian team member, 0 otherwise.
Italian Advisors	It is a dummy variable that assumes 1 if there is at least an Italian team member, 0 otherwise.

Table 5 – Token Characteristics

Variable	Description
Soft Cap	It is the minimum capital to be raised to have a successful ICO and continue the project after the investment round. It is generally expressed in USD, sometimes in EUR or cryptocurrencies as ETH.
Hard Cap	It is the maximum capital to be raised. When it is collected this amount of capital the ICO finishes. It can happen that the currency used is different from the Soft Cap.
Starting Date ICO	It is the initial date of the ICO offer.
Ending Date ICO	It is the closing date of the ICO offer. It can be before the expected date if it is collected the Hard Cap amount.
ICO Duration	It is simply the number of days between the two precedent data.
Token Supply	It is the number of tokens made available for the ICO. The measure is accounted in million. We split the token supply among: - Tokens Distributed Community: % of tokens allocated to the community - Tokens Distributed Management: % of tokens allocated to the team - Tokens Distributed Bounties: % of tokens allocated to people who help the projects in some way - Tokens Distributed Crowdsale: % of tokens available for external investors. Then we decided to collect also: - Tokens Distributed in ICO: sum of the previous four percentages - Tokens Distributed in ICO: number of tokens available for external investors (= % Tokens Distributed Crowdsale * Token supply).
Token Price	It is the price of a single token during the ICO, expressed in USD. Sometimes it is expressed in ETH or other currencies, either fiat or crypto, and it has been converted according to the exchange rate of that time.
Presale	It is a dummy variable that assumes 1 if the ICO had a presale, 0 otherwise.
Bonus	It refers to the presence or not of some kinds of bonuses. it can be “early stage” if at the beginning of the ICO the token price is lower, “major contribution” if the higher the number of tokens purchased, the lower the price, or it is empty if there are no bonuses.
Raised	It is the most important data of the ICO since it traces the capital raised during the ICO process.
Status	It is a dummy variable that assumes 1 if the ICO process is successful, 0 otherwise.
Token Role	It is a series of five binaries: - Token Currency - Token Service Payments & Access - Token Governance & Voting Rights - Token Profit Rights - Token Contribution Rights It is 1 if the token has that type of role, 0 otherwise.
Investment Round	It can be “first” (as for almost all the data it is the first ICO), “second” (if it already went through a first ICO), and so on.

Table 6 – Social Media

Variable	Description
Twitter Profile	It is the representative name of the ICO profile on Twitter (i.e. @AugurProject).
Mentions	This data traces as many times the ICO has been mentioned by other users of the platform by citing the specific profile with the @. We decided to neglect the traditional hashtag since it is not specific to the profile, but it could refers to something different. For example the hashtag *#sociall* it may refers not only to the ICO *sociall_io* but also to something else.
Likes	It counts the total number of likes of the posts (tweets) collected during the observation period previously defined.

Table 7 – Funds Allocation

Variable	Description
SW Development	% of the funds raised during the ICO which is allocated by the team to the research and development of the platform and the technology needed to improve the project.
Operations	% of the funds raised allocated to all the operating activities needed to run the project.
Marketing	Funds allocated to the marketing and advertising campaigns to make the project more popular and known among possible customers.
Reserves	% of funds raised kept for future activities.
Legal	% of funds allocated to the legal services, needed to comply with the regulations in the different markets.

Table 8 – Trading

Variable	Description
First day trading	It is a set of data referring to the trading phase after the end of the ICO: - First Day Trading Date: it is the first day in which the token is traded on an apposite crypto exchange. It generally happens the day or the Monday after the end of the ICO. - First Day Trading Open: it is the initial trading price of the token in its first day on the crypto exchange. - First Day Trading High: it is the highest value that the token achieves in its first day of trading. - First Day Trading Low: it is the lowest value that the token achieves in its first day of trading. - First Day Trading Close: it is the token price set t the end of the first day of trading. - First Day Trading Volume: it is the turnover of the first day of trading. The price used for this evaluation is the First Day Trading Close. - First Day Trading Volume Token: it is the number of tokens which have been traded in the first day. It is equal to the First Day Trading Volume divided by the First Day Trading Close.
Underpricing	It is the result of a fraction: at the numerator there is the difference between the First day trading close and the token price [USD]. At the denominator there is again the token price [USD].
Exchange Rate	It is a set of data concerning the exchange rate of the two biggest cryptocurrencies (Bitcoin and Ethereum) with the USD: - BTC CF: it is the average USD per BTC during the ICO period. - ETH CF: it is the average USD per ETH during the ICO period. - BTC CF End: it is the USD per BTC of the first day after the end of the ICO. - ETH CF End: it is the USD per ETH of the first day after the end of the ICO.
AVG Log Return	- 30DRET: it is the average log return of the underlying blockchain (if not "own" blockchain) return vs the USD in the 30 trading days preceding the ICO - 7DRET: it is the average log return of the underlying blockchain return vs the USD in the 7 trading days preceding the ICO. - 30DVOL: it is the volatility log return of the underlying blockchain return vs the USD in the 30 trading days preceding the ICO. - 7DVOL: it is the volatility log return of the underlying blockchain return vs the USD in the 7 trading days preceding the ICO.

4.3 Application of Data Envelopment Analysis

The objective of our work is understanding the level of efficiency of ICO-based projects and, hence, identifying which are those factors that influence it. The desirable output consists in assigning a efficiency score to each project on the basis of the data available in the sample considered.

As previously stated in chapter 3 (*Data Envelopment Analysis*), the main advantage of this non-parametric method compared to the parametric ones is that it supposes neither a predetermined functional relationship between inputs and outputs, nor a priori information about weights of inputs and outputs (Raheli, Rezaei, Jadidi, & Mobtaker, 2017).

Once the score is computed, the main purpose is identifying those factors that influence this value. There are many approaches used in the identification of these factors, in which the most commonly followed procedure in many approaches is the *two-step procedure* (i.e. two-stage approach). In the first step, the efficiency or inefficiency score is estimated. In the second step, the estimated score is taken as a dependent variable and is then regressed against a number of other explanatory variables that are assumed to affect efficiency (Chen, Liang, & Zhu, 2009).

In DEA, an inefficient unit can be made efficient either by decreasing the input levels while holding the outputs constant (input orientation), or symmetrically, by increasing the output levels while holding the inputs constant (output orientation). The choice between input and output orientation is a matter of concern and it depends on the characteristics of the set of DMUs under study. In this study, the input-oriented approach was assumed to be more suitable, because there is only one output, the efficiency score, while several inputs are used (Zhou, Ang, & Poh, 2008).

With reference to chapter 3 (*Data Envelopment Analysis*), we both applied the CCR and BCC model, based on the CRS (Constant Returns to Scale) and VRS (Variable Returns to Scale) assumption respectively. Given these premises, the main choice was deciding which inputs and outputs to consider. In particular, the selection of input is widely considered the most important and, perhaps, the most difficult point in the evaluation of efficiency.

Indeed, one of the aspect that mostly makes DEA different from other methods is the way in which input and output are converted when measuring efficiency. Its attempts, indeed, is to compare the overall input and output of various units with each other and not, as the most traditional methods, to discover a function of production that can combine input with output.

In order to apply this complex methodology we have relied on the adoption of the open source software R. In particular, the appropriate code for both the CRS and VRS model have been retrieved from the R platform. In addition, the paper "Implementing DEA Models in the R Program" resulted to be very useful (Francisco & Pessanha, 2013).

4.3.1 *Input Selection*

The selection of the inputs was made with the common idea to consider factors of different nature. In particular, the main areas on which we have focused were human resources and social media.

The choice of considering human capital as the main source of input was mainly guided by academic literature. It is largely recognized that human resources are, more and more, the main competitive asset of those companies that are intellectual based.

For example, if considering the case of crowdfunding, it was demonstrated that individual social capital has a significant positive effect on the probability to reach the target fund (Giudici, Guerini, & Rossi Lamastra, 2013).

Moreover, the presence of valuable team members is considered as critical success factor for the success of an ICO campaign. Indeed, the involvement of a qualified team is highly valued by investors. In particular, if the blockchain platform is being developed by means of outsourcing then there is a risk that in the case of a technical failure the team will not be able to eliminate it and the project will become vulnerable. Hence, the availability of own marketing specialists and financial experts adds points. Their knowledge of the business helps to efficiently cooperate with investors (Rasskazova et al., 2019).

Thus, according to the paper mentioned, human capital is one of the main responsible to efficiently transform inputs into outputs. For this reason we have selected as input factors the dimension of core team and the number of advisors. The core team is represented by founders, managers and employees that work in different areas, such as operations, business and software development, legal and marketing activities. The advisors are usually those professionals with great experience in the industry as managers, entrepreneurs, evangelists or academics. Their role is to support the decision making process of the companies and, hence, providing the guidelines for the achievement of successful outcomes (Burns & Moro, 2018).

The social media has been the second category of input that we have accounted. The main goal was understanding the exposure and the effort of ICO-based ventures on social platforms. Among the crypto-related sentiment, social media channels, rather than traditional news channels, are the main source of investor sentiment (Drobetz, Momtaz, & Schröder, 2019). Moreover, it has been demonstrated that social medias play a leading role in the legitimation of the ICO campaign (Chanson et al., 2018). Their role is crucial when deciding if investing or not in an ICO, hence it is considered as one of the main input for the company. The decision of which platform and which measure to consider and the methodology adopted was previously discussed in section 4.2 (*Database Analysis and Data Source*).

Anyway, to recap, we have collected the measures of the number of mentions and like on Twitter for each ICO. Once the data have been collected we have identified a strong correlation between the two, the reason why we have decided to opt only for the *Mentions*. By deeply analysing our data, as it is proved in section 4.5 (*Sample and Univariate Statistics*), due to the large variability of the duration of the campaigns, the number of mentions during the ICO period has been adjusted by dividing the value with the duration expressed in days. In this way a new indicator has been set: *Adjusted Mentions* (Mentions/Day).

4.3.2 *Output Selection*

Similarly to the other financial alternatives, as IPOs or crowdfunding campaigns, the main goal of an ICO is raising funds to finance a project, so that the selection of the output was initially identified in the *Amount Raised* expressed in US dollars and the *Status* (i.e. binary variable where Success = 1 and Failure = 0). The main issue with the *Status* variable has been the low variability, since most of the samples, about 90%, are successful. For this reason we have decided to consider as output factor only the amount raised, with appropriate modifications. Indeed, not all the values have been expressed in US dollars, so that a conversion has been made, by considering the average exchange rate during the ICO period.

Once the algorithm has been set on the open-software R, both the CCR and BCC model have been computed. In particular, the BCC-based scores have been used as dependent variable for our work, while the CCR-based ones have been rejected.
This decision was mainly driven by practical considerations: assuming a constant to scale return implies that an increase in inputs would result in a proportional increase in the outputs. But, for example, an increase in the team size does not necessarily result in a proportionate increase in the capital raised. For this reason, we have only opted for the BBC-based scores.

4.4 Hypothesis Development

Our work aims to change the perspective, by analysing not directly the success and amount raised of ICOs, but the efficiency of the crypto-projects.

As a matter of fact, the second part of our study follows the standard procedures used by the other researches previously mentioned, with the declaration of some hypothesis and the elaboration of them through quantitative analysis. The notable difference with them is our usage of the efficiency score as dependent variable, instead of the success/failure or the amount raised by the ICOs.

We have selected a set of variables from the initial database on which we have worked in the first months and we have tried to demonstrate their relationship with the dependent variable. In particular the analysis are based on a sample of 803 data, from the beginning of 2017 to May 2018.

4.4.1 *Characteristics of the Token Sale*

As previously stated, we have collected plenty of data about the characteristics of the ICOs to enrich our database, from the type of bonus adopted to the distribution of tokens, from the token role to the allocation of funds raised. Unfortunately, we did not find all the data for all the projects, above all as far as the token role and the allocation of funds raised are concerned. Some analysis, by the way, can be run with other data.

Concerning with the presale and the bonuses, some studies already tried to associate their presence with the probability of success of the campaign.

Among the different studies, we cite again Adhami, Giudici and Martinazzi: they demonstrated a positive significant relation between the presale presence and the success of the ICO, but not with the bonus, that comprehends both early bird and major contribution (Adhami et al., 2018).

Following the same procedure, we have considered a possible relation between the dummy variable for the availability of the presale (1 = presale available, 0 otherwise) and the efficiency score of the project.

H1.a *The presence of a presale before the beginning of the campaign increases the probability of a high efficiency.*

On the other hand, if considering the bonus, we have decided to opt for a dummy variable not related to all the kinds of bonus, but only the *early bird.* We did not take into account the bonus *major contribution* because of the scarcity of this data. Thus, our dummy variable is 1 if the ICO involves an early bird bonus, 0 otherwise.

H1.b *The presence of the early bird as bonus during the campaign increases the probability of a high efficiency.*

4.4.2 *The Funding Target and Token Offering*

The funding target, typically named hard cap, consists of the amount of money that the company is intended to raise when launching an ICO process. One of the goal of our analysis is understanding if the value of the hard cap influences the efficiency score of the project. Our assumption is that the higher is the hard cap, the higher is the ambition of the company, hence the funds size that it wants to achieve. But, being ambitious it is not enough: the venture should be compliant with its size. Thus, the process is standardized and structured based on the goal that it wants to be reached. If the target is too ambitious the risk is that the company is wasting resources, time and capital, to achieve something that is too far, hence making the process inefficient.

This has a practical implication, since the higher is the funding target, the higher will probably be the number of tokens offered to the public or the price of the token in order to achieve the goal.

By looking at the academic resources in the ICO field, these two relations have never been analysed. Indeed, we were inspired by the traditional IPO process. According to Martin Steinbach, IPO Leader at EY, basically the higher is the funding target that the company wants to get, the higher are the resources that it has to exploit, as, for example, the number of advisors and the financial institutions involved (Steinbach, Kelley, Choi, & Suzuki, 2018). This probably means putting more shares on the market or increasing the price in order to reach the "hard cap". The system is different but the meaning is the same: in this case the company will need to supply a large number of tokens or to increase the price of them. In particular, given the strong correlation between price and token supply, only the variable related to the USD price has been considered, given its higher significance on the sample collected. For the reasons explained, the following hypothesis has been formulated:

H2.a *The higher is the hard cap the lower is the efficiency score that the company is able to gain.*

H2.b *The higher is the price of the token the lower is the efficiency of the company*.

Finally, beyond these more standard hypothesis, given our set of data collected, we have made some studies with other variables, which popular papers so far did not take into account. Particularly, the data about the portion of tokens available for external investors (i.e. the crowd) caught our attention, being a possible driver of the efficiency score. Hence, we have introduced a new hypothesis. In our opinion, a variation in the percentage of tokens distributed to the crowdsale could be related with the investor sentiment and, in turn, to the efficiency of the ICOs themselves. Hence, the following assumption has been formulated:

H2.c *A higher percentage of tokens made available to external investors positively affects the efficiency of the projects.*

4.5 Sample and Univariate Statistics

The objective of this paragraph is to provide a general overview of the sample collected in our database, by analysing the main determinants of the ICOs.

4.5.1 *Industry and Technology*

By merging and cross-referencing the data, we have built a taxonomy, as it is shown in the table below (*Table 9*). In order to identify the dimensions, we have made a list of the industry categories already identified by the specialized websites (i.e. IcoBench, IcoDrops), using as labels the most popular ones. We were also inspired by a well-reputed work from University of Cagliari, but suitable modifications for our case have been made (Ibba, Pinna, Baralla, & Marchesi, 2018).

In total we have identified 21 dimensions, which represent the category of the industrial ICO sector. Afterwards, we have populated the taxonomy considering both the number of projects developed and the amount of funds raised in each specific sector, by showing the results in percentage for the two variables. In this way we were able to understand the ICO sector trends and the investors interests towards the projects.

As the table below shows (*Table 9*), the leading industries are *Financial, Trading and Investing* and *Blockchain Platform and Services*. They show greater results not only in terms of projects but also for the amount that they have been able to raise.

This means that the industry on which the investors are willing to provide their money represents a support factor. So it is possible to state that the more the industry is popular and well reputed, the more people are pushed to invest.

Moreover, an interesting result is shown by the huge amount collected for all the applications based on *Data Analytics, Artificial Intelligence and Machine Learning*. This could rise a consideration: given the innovative path of the ICOs, these investors are more likely to spend their capital in new technological solutions, that are, on average, more onerous in terms of capital requirement.

	Number of Projects	% of Projects per category	Total Funds Raised [Million USD]
Blockchain Platform & Services	135	17%	3709.7
Finance, Trading & Investing	190	24%	2515.6
Data, AI & Machine Learning	86	11%	1912.2
Payments, Wallets & Cryptocurrency	74	9%	1123.3
Commerce & Retail	43	5%	587,9
Network, Communication & Social Network	49	6%	562.3
Media, Entertainment & Advertising	43	5%	403.2
Security & Identity	33	4%	354.8
Gaming & VR	37	5%	306.6
Other	16	2%	205.1
Healthcare	16	2%	202.9
Energy & Utilities	13	2%	177.8
Industry & Logistics	10	1%	176.8
Betting & Gambling	15	2%	91.0
Transportation	9	1%	60.4
Funding & VC	8	1%	49.4
Tourism	8	1%	49.1
Education	5	1%	30.0
Mining	4	1%	27.8
Real Estate	8	1%	19.1
Insurance	1	0%	5.0

Table 9 – An Industrial Sector Taxonomy of ICOs

4.5.2 *Geographic Distribution and Funds Raised*

The geographic area has been then considered as a second category of classification. Exploring the ICOs we realized that they represent a global phenomenon. In particular, according to our database, about 80 nations have been identified. But not all of them have the same relevance. There are some countries where only one project can be accounted, while others are real ICO districts.

The table below (*Table 10*) shows the leading countries in terms of amount raised. Despite this reality, it must be said that these ten countries raised over the 74% of the total global amount raised. In particular, the leading countries are United States (18%), Russia (17.1%), Singapore (10.8%), Switzerland (10.1%) and United Kingdom (4.8%).

	AVG Funds Raised [Million USD]	Total Funds Raised [Million USD]	% Total Funds Raised
United States	16.73	2,258.90	18.00
Russia	26.19	2,147.40	17.10
Singapore	18.93	1,363.20	10.80
Switzerland	25.79	1,263.50	10.10
United Kingdom	11.39	603.80	4.80
Israel	41.48	373.30	3.00
Estonia	11.61	359.90	2.90
Decentralized	8.79	316.30	2.50
Gibraltar	18.59	316.10	2.50

Table 10 – Leading Countries in terms of Amount Raised

Interestingly, a relevant number of projects have been proposed from Singapore and Switzerland, countries that issued specific actions for fintech companies. This means that, even if an ICO is online-based and investors are international, the environment on which the company is headquartered could have its relevance.
There are also other cases where projects cannot be attributed to a dominant country of origin, whereas 36 projects (4,5% of the sample) adopted a “decentralized governance” mechanism; in other words, project promoters cooperate online from multiple locations throughout the world with no incorporations of the business, thus fully adopting the decentralization philosophy that is the basis of distributed ledger technologies.
Only in few cases the white papers specify the jurisdiction that regulates the token sale. In these instances, we often find Singapore, Gibraltar, Cayman Islands, Virgin Islands, Delaware, and Estonia as choices of jurisdiction.

What all these countries have in common is the absence of a regulatory framework. The fact that the majority of the ICOs were successful despite the absence of a regulatory authority of reference for the token sale suggests that contributors have been quite insensitive to regulatory issues and the lack of protective measures. Furthermore, most ICO promoters delegate the assessment of investment eligibility to the investors themselves. In other words, the responsibility of checking the eligibility of investing in the token offering according to their country of residence regulations relies solely on the potential investor.

In terms of amount raised, *Telegram Open Network*, TON, is the leading project, with a total amount of $1.7 billion collected in 2018. The entire amount was received from private investors who bought GRAM cryptocurrency tokens. TON is a blockchain platform of Telegram instant messaging system. The main concept of the messenger is the anonymity and secure communication of users. The project is mainly associated with the work of the Telegram messenger, in which it is planned to integrate the cryptocurrency GRAM.
In the sample, the total amount raised by the 803 ICOs considered accounts to $12.6 billion, with an average of $15 million.

4.5.3 *Human Capital*

As previously mentioned in the section 4.3 (*Application of DEA*), what really matters in an ICO-based project is the presence of valuable human resources. These can be classified in advisors and team members. By analysing our sample, the average number of team members is 9, while for the advisors the average is quite lower, only 4.
What it is interesting to note is that, while the number of team members is equally distributed among the industries, for the advisors there are some heterogeneities.
Indeed, for the logistic and industry sector the average number of advisors is 9, and for other industries the support resources are few, as 3 or 4.

4.5.4 *Duration*

It consists of the number of days in which the ICO has been open to investors.
These data changed a lot from ICO to ICO, according to the strategy adopted by the team. Very few (only 2) are the cases where the process lasted for more than a year. For example, Goal Bonanza, a football betting project, launched the offering in November 2017 and the entire ICO process was completed in December 2018.

In general, the duration of the ICO process largely differs. The variety of the duration is well explained by its standard deviation, which is 34.34, above all if compared with a mean that is just one day larger 35.93.

More specifically, according to our sample, 98 of the 803 ICOs evaluated lasted less than one week, of which 44 just one day. The majority of these ICOs which turned to be immediately successful were between the end of 2017 and the first months of 2018, when the hype for crypto was at its peak. Conversely, 31 ICO lasted more than 100 days, with only 4 more than 200 days.

As stated by *Medium.com,* the duration of the overall ICO projects raised in 2018 took an average of 48 days, while in 2017 it was of 29 days (W12.io, 2018). Our set of data, made of 488 ICOs in 2017, 303 in 2018 and 12 before 2017, does not follow this trend. Actually, the average duration is bigger in 2017 (37.83 days) than in 2018 (32.97).

4.5.5 *ICO Price and Funding Target*

The funding target is difficult to compute because most of the times the ICO price is defined in a cryptocurrency, but in our sample, we have projects that raised CHF (only two cases), EUR (17 cases), and USD (465 cases). Given the significant volatility of cryptocurrencies, the exchange rate in USD can change significantly in few days.

Therefore, we have measured the funding target using the average exchange rate computed during the ICO period. Usually a minimum, soft cap, and a maximum funding target, hard cap, are defined. Specifically, the range between soft and hard cap is quite wide and, indeed, we have observed that the funding target in many cases is rather uncertain, indicating that project promoters do not typically exhibit a detailed budget for future investments. Moreover, some projects did not intentionally disclose minimum and maximum funding caps for either the project or the single contributor to supposedly prevent large market participants from manipulating the market or controlling the supply. Indeed, a high hard cap can be harder to reach, but in case of positive investors' opinion, it can increment consistently the amount raised. We guess that most projects whose ICO lasted just a few days regret not to have set a higher maximum cap.

Of the 803 ICOs analysed, we found only 373 soft cap (46%). The average hard cap of our sample is approximately $36 million, with a median of $19.6 million, symptom of a

tendency to have smaller hard cap of the average, with a minority of ICOs with very high caps.
In particular, 36 ICOs have set a hard cap higher than $100 million dollars, but just 3 higher than $500 million (*Friendz*, *OneGram* and *Wysker*).

4.5.6 *Blockchain-based Network*

The most popular blockchain-based network chosen as the underlying technology for the projects is not Bitcoin (only 7 projects adopted it) but, instead, Ethereum (682 projects, about 85% of the sample). This choice may be explained by the fact that the latter was developed from the beginning with the purpose of managing "smart contracts," unlike Bitcoin (Ream, Chu, & Schatsky, 2016). In the rest of cases the promoters aimed at developing their own blockchain.
We traced this trend by introducing a dummy variable *ETH_Dummy*, where 1 means that the platform is Ethereum based and 0 otherwise (i.e. Bitcoin or own platform).

4.5.7 *Code Availability*

This variable traces the availability of at least a part of the code. It's a variable that help investors to evaluate the kindness of the project development even if, sometimes, is subjected to possible source of violation by hackers.
Most ventures divulge their code online so that the source code is observable. Code is usually published on the platform *GitHub*, an open-source community platform for programmers. According to Christian Fisch, the presence of a venture's source code could be a signal of its technological capabilities (Fisch, 2019).
Analysing our data, 570 out of 803 ICOs show at least part of their code. Of the 70 ICOs that didn't achieve the soft cap in our study, the code availability is perfectly balanced, with 35 ICOs with the code available as many as the ones which do not have. Hence, it can be supposed that, according to our study, it does not represent a strong added value for the efficiency of the project.

4.5.8 *Bonus*

The possibility to have a discounted price during the ICO can be a variable able to influence investors' choice. The two types of bonus we found are *early bird* and *major contributor*, as explained in chapter 2 (Section 2.4.4). Hence, every ICO project can have no bonuses, only early bird, only major contributor or both.

For the purpose of our linear regression analysis, we have decided to consider as variable the dummy "presence of the early bird or not", simply named *Early_Bird*. Then, if the early bird bonus is available the variables is equal to 1, while, when the ICO presents only the major contributor as bonus, or no bonus at all, our variable is 0. We have opted for this solution because the majority of ICOs presents at least one of the two types of bonus with a big majority of early bird. Our results tell us that 66% of the ICOs has the early bird as bonus.

The use of the presale represents a leading approach in our sample. Indeed, more than 60% of the ICOs decided to do a presale offering before the main ICO. In this case a small percentage of the total available tokens will go on sale and the idea is to give interested investors an opportunity to buy tokens before the official ICO date. It can either be to a group of selected, private investors (by invitation for example) or open to the general public through the token sale webpage. The biggest advantage for investors will often be the opportunity to buy tokens at a discount. This discount can be as much as 50%.

There are different reasons that push companies to do a presale (Fintech Fans, 2017):

1. It could be to test the waters before the main event. This would give management an indication of the level of interest in the project and whether or not they need to intensify their marketing and promotional efforts to reach the funding goal for the official ICO.
2. An ICO-presale can also be seen as sort of a beta launch. Because it is smaller and therefore more manageable and controllable, if something does go wrong, it is much easier to fix with fewer people affected. This way they can smooth out the kinks before the main event.

3. A recent trend in pre-sales, which seems to be working, is to get private VC investments at a bigger discount behind the project at an early stage.

4.5.9 *Tokens Supply and Tokens Distributed to Crowdsale*

Concerning with the number of tokens, every ICO team established a certain *token supply*, not necessarily all addressed to external investors.

There's a huge variety from ICO to ICO, depending also on different range prices per token adopted. Our data goes from thousand to billion dollars: the minimum supply was 1250 tokens (*Primalbase*) while the highest amount was 250 billion tokens (*Holo*). The 84% of projects were comprehended between one million and one billion tokens.

Another data that we have traced in our analysis is the percentage of tokens issued which are addressed to the external investors, the so called *crowdsale*. It indicates which portion of the total number of tokens the team project wants to give away. According to the token role, then, it can also mean to give away part of the ownership or profits stemming from the project.

The strategy of the team and the token utilities can influence this percentage: some ICOs decided to keep also a high percentage of tokens as reserve for future activities, while others gave away all the 100% of the tokens. Our average percentage of tokens to the crowdsale is 57%, with 60% as median. We met some ICOs which privileged the distribution to the community or bounties and gave to external investors just the 3% (e.g. *Dentacoin* and *Payall*), while 15 projects opted for all the 100%. 41 ICOs offered less than the 20% and 117 more than the 80% of total tokens.

In accordance with the actual literature review, until now, any relation between this data and the success or failure of the ICO have been founded.

	Mean	SD	Min.	Median	Max.
Amount Raised (Million USD)	15.65	64.06	0.0004	62.00	1,700.00
Advisors (people)	4.24	3.93	0.00	4.00	23.00
Core Team (people)	9.05	6.12	1.00	8.00	64.00
Duration (days)	35.94	34.36	1.00	31.00	396.00
Token Price (USD)	12.16	267.53	0.00	0.20	7,554.60
Hard Cap (Million USD)	35.72	85.21	0.0047	19.62	1,700.00
ETH (dummy)	0.85	-	0.00	1.00	1.00
Code Available (dummy)	0.71	-	0.00	1.00	1.00
Presale (dummy)	0.63	-	0.00	1.00	1.00
Early Bird (dummy)	0.66	-	0.00	1.00	1.00
% Tokens Distributed to Crowdsale	0.57	0.22	0.03	0.60	1.00
Token Supply (million token)	2,125.80	13,854.42	0.00001	173.84	250
Data Available	**803**				
Missing Data	**0**				

Table 11 – Variables' Statistics

4.6 Model Setting

Once the univariate analysis has been performed, we set the regression model using our variables of interest and the control ones. Before going deeper in the specification of the model, a recap of our journey should be described.

We initially started with the computation of efficiency scores by adopting the DEA methodology, as described in section 4.3 (*Application of DEA*).
Now the goal is linking the value obtained with the factors traced in our database. Hence, we have decided to set a regression model to understand the link between the dependent variable (i.e. efficiency score) and independent ones, also introducing appropriate control variables. These are described in the detail in the table 15.

4.6.1 *Dependent Variable*

The dependent variable of our work is the efficiency score retrieved from the application of the DEA methodology. The statistics related to this dependent variable are reported in the table (*Table 12*).

As shown by the descriptive statistical data, the variability of the dataset is not particularly large. It is interesting to notice that the overall sample shows a mean consistently higher than the median. Indeed, the median ranges in between of mean and mode, hence revealing a negative asymmetry. This is due to the negative *skewness* (-0.933) and *kurtosis* (-0.168). The values for asymmetry and kurtosis between -2 and +2 are considered acceptable in order to prove normal univariate distribution (George & Mallery, 2003). But it is not enough for our case.

Indeed, due to the adoption of a regression model and the fact that the variable ranges continuously in the range 0 -1, a mathematical transformation has been set. In particular, instead of considering the pure score we adjusted it according to the following formula:

$$\text{Log10}\ (\frac{p * \Delta}{1 - p\Delta})$$

The value of p indicates the single efficiency score for each ICO project, while the Δ has been introduced to avoid biases cases due to the range 0-1. The value of Δ is 0.99, and it was set as much closer to one in order to avoid distortions of the model.
In particular, the data with the value of 1 have been transformed in 0.9999999 to prevent the existence condition of the logarithmic function (all the values in our analysis have seven decimals). Anyway, a robustness analysis has been made, and the results have verified that the choice is well performing (Section 4.9.1). Given this transformation, the new regression is no longer the standard one but it is generally called *logit regression*: it is a traditional linear regression with a logit variable as dependent one.

Beyond this mathematical transformation due to the variable distribution, we want to provide a general analysis of the standard efficiency score (i.e. the data refers to the score without the transformation). The analysis reveals that the ICO projects are largely efficient, with an average value of 0.75 and a standard deviation of only 0.18.

	DEA Efficiency Score
Mean	0.75
Median	0.82
Mode	1.00
Std. Deviation	0.18
Variance	0.34
Skewness	Negative Asymmetry (- 0.933)
Kurtosis	Negative Asymmetry (- 0.168)
Range	0.73
Minimum	0.27
Maximum	1

Table 12 – Statistics of DEA Efficiency Score

As the following table shows (*Table 13*), by adopting this methodology we have identified 7 companies that are part of the efficient frontier, hence with a DEA score equal to 1.
In the first position we have the already mentioned *Telegram Open Network* (TON), thus a project successful not only in terms of amount raised but also in terms of efficiency. Of course this success was also encouraged and facilitated by the popularity that the company has since its foundation in 2013.

Another point that emerges from this analysis is the year in which these processes have been launched. Except for the TON case, all the projects that are part of the efficient frontier have been launched in the period 2017.

This can be the result of several reasons. For example we can state that investors were more prone to finance projects through an ICO process due to the novelty of this approach. But, if we consider the total raised in 2018, this is higher than the one in 2017, even with a smaller number of projects. Hence, we can state that it is more a company specific problem rather than a market turmoil.

	Funds Raised [Million USD]	**Country**	**Industry**	**Duration [Days]**	**ICO Year**
Telegram Open Network	1,700.00	Russia	Blockchain Platform & Services	16	2018
COMSA	320.00	Japan	Blockchain Platform & Services	21	2017
Speed Mining Service	257.00	Japan	Payments, Wallets & Cryptocurrency	97	2017
DMarket	232.00	Ukraine	Blockchain Platform & Services	5	2017
Sentiment	157.90	Switzerland	Finance, Trading & Investing	36	2017
Flypme	153.00	United Kingdom	Payments, Wallets & Cryptocurrency	24	2017
MCX	150.50	Thailand	Payments, Wallets & Cryptocurrency	89	2017

Table 13 – Leading Efficient Projects

In order to deeply analyse the results, we have tried to understand if there are some leading countries in terms of efficiency projects. In order to avoid biases cases, we have included in the sample of analysis only those countries with a relevant number of projects available (i.e. more than 10 projects). The table below shows the results (*Table 14*).

Country	Avg. Efficiency Score	Number of Projects
Ukraine	0.87	11
Russia	0.83	82
Germany	0.80	17
Decentralized	0.79	12
Estonia	0.78	31

Table 14 – Leading Efficient Countries

It is very interesting to note that the Russian Federation countries are the leading companies in terms of efficiency. The main question is why?
In order to answer to this question we found out a discussion about this topic on a reference website for blockchain-based services, *Bitcoin.com*: one of the main competitive factors that makes the Russian Federation countries leaders is the low cost of developing an ICO project. According to the study conducted by *OECD*, the development of an ICO project in Russia costs between $1,500 and $50,000. The researchers found that the average price tag for these orders, the blockchain and web development part, is almost $18,000, not counting marketing and legal expenses (OECD, 2019).

4.6.2 *Independent Variables*

Once the dependent variable is set, the objective is understanding which are those factors that are able to predict its trend. The choice of the independent variables was mainly driven by personal experience and the available literature on the topic.
We identified five independent variables, in accordance with the hypothesis introduced in section 4.4.

1. *Presale* and *Early_Bird*: these two variables are linked with the characteristics of the token offering. In particular, we want to test hypothesis H1.a and H1.b respectively. Given their binary distribution, any transformation has been made.

2. *LOG_HARDCAP:* this variable traces the maximum target fund that the company wants to achieve. Because of the asymmetric character of its distribution an appropriate function has been applied: by measuring the index of skewness and

kurtosis, a logarithmic transformation has been used. This factor aims to test the hypothesis *H2.a.*

3. *USD_Price*: this variable traces the price of the token expressed in US Dollar. As previously stated, we supposed that the price can be considered as a factor that tests the goal of the company in terms of capital funding. In this case any transformation has been applied given its standard distribution. The aim is testing the hypothesis H2.b.

4. *%Distributed_Crowdsale*: the variable traces the percentage of tokens that are distributed to the crowd. By analysing its trend, the distribution seems to be regular, hence free of mathematical transformations. It wants to test the hypothesis H2.c.

4.6.3 *Control Variables*

In addition to the main variables of the above-mentioned hypothesis, we have introduced a set of variables that are acknowledged, from existing studies, to have an impact on the investment decision. The selected metrics are control variables.

In order to consider different aspects related to the ICO process, we have classified the control variables into four main groups:

- Firm specific variables
- Industry specific variables
- Location specific variables
- Market-Trends specific variables

<u>Firm specific variable</u>

We have identified as firm variable the availability of the code and the duration of the ICO process. The variable *Code_AV* captures whether a venture had any source code available in GitHub website at the start of the ICO. The variable takes a value of 1 if the code is partly or fully available in a GitHub repository and 0 otherwise. This variable controls for the fact that ventures without any code on *GitHub* may be different from those that reveal their code on *GitHub*, since it shows a greater transparency and a prove of existence in front of the investors. This practice was strongly suggested by Christian Fisch, in its paper “Initial Coin Offerings (ICOs) to finance new ventures” (Fisch, 2019).

The second variable introduced is the duration. It counts the days in which the ICO process is open for possible investments by external contributors, similarly to the issue period for traditional bonds. The ICO period is set independently by every team project according to their expectations and forecasts of raising funds. By the way, a campaign closes earlier if the capital raised reaches the hard cap. It’s then normal to think that a shorter ICO could mean a greater raised capital. Hence, it was successfully demonstrated with a significance of 99%, p-value < 0.1 (Rasskazova et al., 2019).
Due to its asymmetry we have adopted the same practice of the hard cap factor, thus introducing a logarithmic transformation: *LOGDUR*.

Industry specific variables

As stated in the previous paragraphs, the industry on which the company is operating in strongly matters. *Finance, Trading and Investing* and *Blockchain Platform and Services* are the leading sectors, hence are those with higher potential to attract investors. On the other hand a higher exposure and popularity could also attract inexpert and unreliable small investors, hence negatively influencing the venture success. Maybe the company is able to collect money but not to sustain the venture in the long period. Also in this case the selection of this control variable was suggested by the Fisch’s work (Fisch, 2019).

Location specific variables

A venture's location is crucial for attracting finance, such as venture capital (Stuart & Sorenson, 2007) and even crowdfunding (Mollick, 2014), albeit to a lesser extent for the latter due to its online context (Agrawal, Catalini, & Goldfarb, 2015). Inspired by the current literature, we have decided to introduce a new variable in order to trace the specificity of each country in which the ICO-based projects are headquartered: the *country ranking*.

This variable was retrieved by the data of the World Bank database (DoingBusiness, 2018). We want to assess the general status of the economy and the easiness of doing business in each specific country.
Without going in detail to the specific description, economies are ranked on their ease of doing business, from 1 to 190. A high ease of doing business ranking means the regulatory environment is more conducive to the starting and operation of a local firm. The rankings are determined by sorting the aggregate scores on 10 topics, each consisting of several indicators, giving equal weight to each topic. The rankings for all economies are benchmarked to May 2018. The following paper provide additional information on the way in which this variable is computed: "*Ease of Doing Business Score and Ease of Doing Business Ranking*" (DoingBusiness, 2018).

Market Trends specific variable

When dealing with crypto-projects a focus on the underlying platform and its related factors should be provided. Some variables have been introduced in order to account different aspects related to the market trends.

ETH_Dummy: ventures can develop their own Distributed Ledger Technology (DLT) or build on existing ones. As of 2018, a multitude of DLT platforms developed their applications on Ethereum, NEO and Waves. Anyway, the most common standard to build on is Ethereum (Magas, 2018). As previously stated in Chapter 2 (Section 2.4.2 – *A Blockchain Underlying the System, Ethereum*), Ethereum-based tokens are also referred to as ERC-20 ("Ethereum Request for Comment") or ERC-223, which is the technical standard they implement. Ethereum also defines the rules that certain transactions need to follow in order to meet and enable greater interoperability between transaction parties in the Ethereum ecosystem. As such, building a token based on Ethereum may signal a higher future utility if investors assume that the Ethereum standard will successfully establish itself as the benchmark for ICOs. For this reason having a control on this aspect is significant. The variable *ETH_Dummy* captures whether an ICO is built on Ethereum (= 1) or not (= 0). Data are obtained primarily from ventures' white papers and are aided by information from venture websites and ICO-tracking sites.

ETH_USD: this variable accounts the exchange rate between Ethereum cryptocurrency and US dollar. Since our database is mainly populated by ETH-based projects (about 90%) having a control on this factor is fundamental. This cryptocurrency is frequently used, thus the amount raised in an ICO is heavily dependent on the value of ETH at the time of the ICO. These data have been retrieved from *CoinMarketCap* website.

Moreover, for a subsample of token offerings that adopted either the Bitcoin or the Ethereum platform, we control for both the return and the volatility of the cryptocurrencies themselves at 30 days and seven days before the ICO start date (*30D_return*, *30D_volatility*, *7D_return*, *7D_volatility*). Doing so captures any relationship between the market momentum of the cryptocurrencies and the probability of raising financing.

Dependent Variable	Description	Variable Name
DEA Efficiency Score (logit)	Score of efficiency retrieved from DEA, under the assumption of variable return to scale. The value of the ordinary variable ranges from 0 to 1.	*Logit_DEA*
Independent Variables	**Description**	
Presale (dummy)	Dummy variable assuming 1 in case of token presale, 0 otherwise.	*Presale*
Early Bird (dummy)	Dummy variable assuming 1 in case of early bird based bonus, 0 otherwise.	*Early_Bird*
% Tokens Distributed to Crowd sale	The percentage of tokens distributed to crowd sale	*%Distributed_Crowdsale*
Hard Cap (log.)	Maximum funding target set by the company	*LOG_HARDCAP*
USD Token Price	Price of the token expressed in US dollar	*USD_Price*
Control Variables	**Description**	
Global Rank	Value of the Easy of Doing Business Index ranging from 1 to 190	*Global_Rank*
Code Availability (dummy)	Dummy variable assuming 1 if the code is partly or fully available, 0 otherwise.	*Code_AV*
Duration (log.)	Number of days of the ICO issue period.	*LOGDUR*
Fintech (dummy)	Dummy variable assuming 1 if the ICO is related to the *Finance Trading and Investing* industry, 0 otherwise.	*Finance*
Blockchain Solutions (dummy)	Dummy variable assuming 1 if the ICO is related to the *Blockchain Platform and Service* industry, 0 otherwise.	*Block*
ETH-USD Exchange Rate	Average exchange rate for the ICO issue period between ETH and USD	*ETH_CF*
ETH Platform (dummy)	Dummy variable assuming 1 if the ICO is Ethereum based, 0 otherwise.	*ETH*
30D_Return	Average log return of the underlying blockchain return vs the USD in the 30 trading days preceding the ICO.	*DRET_30*
7D_Return	Average log return of the underlying blockchain return vs the USD in the 7 trading days preceding the ICO.	*DRET_7*
30D_Volatility	Volatility log return of the underlying blockchain return vs the USD in the 30 trading days preceding the ICO	*DVOL_30*
7D_Volatility	volatility log return of the underlying blockchain return vs the USD in the 7 trading days preceding the ICO.	*DVOL_7*

Table 15 – Description of the Variables Adopted in the Model

	Mean	SD	Min.	Median	Max.
Dependent Variable					
Logit_DEA	1.276	1.07	-1.01	1.45	4.60
Independent Variables					
Presale (dummy)	0.63	-	0.00	1.00	1.00
Early_Bird (dummy)	0.66	-	0.00	1.00	1.00
%Distributed_Crowdsale	0.57	0.22	0.03	0.60	1.00
LOG_HARDCAP (log.)	7.17	0.68	3.67	7.29	9.23
USD_Price	12.16	267.52	0.00	0.2	7,554.60
Control Variables					
Global_Rank	29.43	29.77	1	19.00	175
Code_AV (dummy)	0.71	-	0.00	1.00	1.00
LOGDUR (log.)	1.36	0.49	0.00	1.49	2.60
Finance (dummy)	0.33	-	0.00	0.00	1.00
Block (dummy)	0.17	-	0.00	0.00	1.00
ETH_CF	514.48	277.18	0.89	463.34	1,365.21
ETH (dummy)	0.85	-	0.00	1.00	1.00
DRET_30	0.08	0.63	-3.28	0.00	5.68
DRET_7	0.05	1.08	-9.38	0.00	11.64
DVOL_30	0.66	2.02	0.00	0.07	12.66
DVOL_7	0.69	2.30	0.01	0.06	15.86
Data Available	**803**				
Missing Data	**0**				

Table 16 – Statistics of the Variables Adopted in the Model

4.7 Results of the Model

In this part we show the results of our model. It consists of a set of analysis based on three main statistical applications: the T-test, the correlation matrix and the logit regression.

The Pearson's correlation matrix has been the first step of our analysis. The goal was understanding the relation between the dependent variable and its five predictors. This is represented in the table below (*Table 17*):

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Logit_DEA	1	-0.037	0.146 **	-0.128 **	0.175 **	-0.039
(2) Presale		1	0.222 **	0.148 **	-0.077 *	-0.045
(3) Early_Bird			1	0.031	0.044	0.027
(4) LOG_HARDCAP				1	-0.185 **	-0.015
(5) %Distributed_Crowdsale					1	-0.034
(6) USD_Price						1

** Correlation is significant at the 0.01 level (p-value < 0.01)
* Correlation is significant at the 0.05 level (p-value < 0.05)

Table 17 – Correlation Matrix

Then, a T-test has been set with the aim to validate the results of the correlation and regression models among all the variables, both in case of significant and non-significant cases (Bewick, Cheek, & Ball, 2003). The results are shown below (*Table 18*).

The application of this test has been preceded by the creation of a dummy variable, *eff_dummy*, in order to make a distinction between efficient and inefficient project. In particular, the variable assumes 1 if the project has an efficiency score higher or, at least, equal to 0.75 (we consider the standard value not the transformed one), 0 otherwise.
The table below (*Table 18*), shows how the sample is distributed among the two groups in the column "N". The distribution is quite homogeneous; hence it is in line with the requirements of the T-test adopted, described below.

By considering the average value of the efficiency score of our sample (0.75) and by having a general overview of the scatterplot between dependent and independent variable, an efficiency threshold has been set to 0.75.

This decision was the result of many tests that we made with the objective to obtain the same number of cases in the two populations (i.e. efficient and non-efficient projects). Indeed, one of the main assumption of the T-test is the equal numerousness of the sample in the populations. A second one is the assumption of equal variances in the two cases (Suppa, 2011). Since our data did not show the same variances, in order to overcome this hypothesis, a specific T-test has been applied: the *Welch T-test* (Albright, 2019).

Anyway, given the experimental nature of our test, further robustness checks will be provided in section 4.9.2 (*Welch's T-test for Efficiency Groups*).

Variables	Cut Point Efficiency 0.75	N	Mean	Significance Level T-Test for equality of means
Presale	1	495	0.63	0.918
	0	308	0.63	
Early_Bird	1	495	0.72	0.000
	0	308	0.57	
LOG_HARDCAP	1	495	7.12	0.003
	0	308	7.25	
%Distributed_Crowdsale	1	495	0.60	0.000
	0	308	0.52	
USD_Price	1	495	3.77	0.374
	0	308	25.64	

Table 18 – Welch's T-test Results

The creation of the logit regression models has been made with the following approach: In the first model (Model I) we initially consider all the predictors. Then, in the following ones (II and III) the predictors with no statistical significance, hence with a p-value higher than 0.05, have been excluded one by one.

Now a detailed description of the three models is provided:

Model I - All the predictors

The results of the fist model are very interesting. The p-values related to *LOG_HARDCAP*, *Early_Bird* and *%Distributed_Crowdsale* tell us that these three variables are very significant. In all the cases the level of significance is more than 99%. The result is also confirmed by the T-test, where the hypothesis of equal means can be significantly refutable for all the three variables.

In terms of correlation, *Early_Bird* and *%Distributed_Crowdsale* are both positively correlated while the *LOG_HARDCAP* has a negative relations with the dependent variable (i.e. *Logit_DEA*).

This means that the presence of an early-bird-based bonus positively affect the efficiency score, hence verifying hypothesis *H1.b*.

Moreover, also the hypothesis *H2.c* has been verified, since the higher is the percentage of tokens distributed to crowdsale the higher the level of efficiency of the ICO project.

On the other hand, the relation between hard cap and efficiency has been tested and it shows a negative relation, hence verifying the hypothesis H2.a.

Also the T-tests, as it is shown below (*Table 18*), confirm these three hypothesis. In particular, by dividing the sample in two groups, efficient and inefficient projects, the values of the mean differ. For example, the average percentage of tokens distributed to the crowdsale by efficient projects is more than 60% while for the inefficient ones is about 50%.

The value of pseudo-R^2 obtained by the logit regression is of comparable with the ones obtained by the works of Fish (Fisch, 2019) and Adhami et. al (Adhami et al., 2018). In our case the value is 27.3%.

Model II and III

The main aim of these two models was testing the absence of statistical significance of the variables *Presale* and *USD_ Price*.

In all the tests that we made, hence T-tests, correlation matrix and logit regression, the results are the same: the price of token expressed in US dollar and the presence of a presale offer do not significantly affect the efficiency of the ICO-based projects. For this reasons we are pushed to reject hypothesis H1.a and H2.b.

Variables	Model I			Model II			Model III		
	Coeff.	(SE)		Coeff.	(SE)		Coeff.	(SE)	
(Constant)	0.860	(0.400)	*	0.849	(0.399)	*	0.859	(0.399)	*
Presale	-0.109	(0.073)		-0.107	(0.073)				
Early_Bird	0.164	(0.072)	*	0.162	(0.072)	*	0.139	(0.070)	*
%Distributed_Crowdsale	0.329	(0.152)	*	0.331	(0.152)	*	0.341	(0.152)	*
LOG_HARDCAP	-0.112	(0.050)	*	-0.112	(0.050)	*	-0.118	(0.050)	*
USD_Price	-6.53E-5	(0.000)							
Code_AV	-0.174	(0.073)	*	-0.172	(0.073)	*	-0.164	(0.073)	*
Global_Rank	9.84E-5	(0.001)		8.95E-5	(0.001)		0.000	(0.001)	
Finance	0.112	(0.074)		0.113	(0.074)		0.111	(0.074)	
Block	0.121	(0.093)		0.122	(0.093)		0.129	(0.093)	
ETH_CF	0.000	(0.000)	*	0.000	(0.000)	*	0.000	(0.000)	*
ETH	-0.073	(0.103)		-0.073	(0.103)		-0.077	(0.103)	
DRET30	0.090	(0.091)		0.090	(0.090)		0.096	(0.090)	
DRET7	-0.020	(0.048)		-0.020	(0.048)		-0.023	(0.048)	
DVOL30	-0.061	(0.061)		-0.060	(0.061)		-0.061	(0.061)	
DVOL7	-0.007	(0.049)		-0.007	(0.049)		-0.006	(0.049)	
LOGDUR	0.947	(0.070)	**	0.950	(0.069)	**	0.949	(0.069)	**
R-squared	0.273			0.273			0.271		
Adj. R-squared	0.258			0.259			0.258		

** Significance at the 0.01 level (p-value < 0.01)
* Significance at the 0.05 level (p-value < 0.05)

Table 19 – Results of the Logit Regression Model

4.8 Further Analysis of the Results

The results of our models justify, at least partially, the hypothesis introduced in the section 4.4. Three of them resulted demonstrated, while the remaining two do not show significance.

The presence of the presale before the coin offering and the token price (expressed in US Dollar) did not find any correlation with the dependent variable, the DEA efficiency score, considering both the correlation matrix and the logit regression.

Looking to the previous academic papers, there is ambiguity in the role of presale: it is not clear if the effect on the success is positive or negative. What we state here is that the presence of presale does not significantly influence the efficiency of an ICO-based project.

Considering the token price, it was still demonstrated its negative role in the probability of an ICO-campaign success (Rasskazova et al., 2019). In our case we can only state that its role is not significant in the gain of a higher efficiency score.

On the other hand, it is more interesting having a focus on the three significant outcomes that we have achieved: the hard cap, the percentage of tokens given out to external investors and the presence of the early bird are all correlated with the DEA efficiency level, with a significance level up to 95% ($p\text{-value} < 0.05$).

In order to have a better explanation of this relations, further analysis have been made, by providing additional tests in section 4.9 (*Robustness Analysis*).

4.8.1 *Early Bird*

The first relevant outcome we got is the positive correlation between the presence of the early bird as bonus and the efficiency score of a project. By confirming the hypothesis *H1.b*, it can be assessed that the possibility to buy tokens at a lower price in the first phases of the ICO increases the probability of having a high efficiency. Adhami, Giudici and Martinazzi tried to prove a similar correlation between the presence of a general bonus (including the major contribution indeed) and the amount raised. Unfortunately, any significant correlations have been found out.

Differently, our work wants to evaluate the effect of a bonus in terms of efficiency and not in terms of success. The two aspects are very different, since a success factor does not necessarily implicate an efficiency gain.

The early bird effect gives dynamicity to the ICO, making investors more active, especially in the first days or weeks. It can help launching the public offering, attracting a greater potential number of customers. Supporting this belief, Alon Goren, CEO and founder of leading start-up communities, interviewed by the CNBC, said that "*nothing attracts a crowd more than a crowd*". He recommends focusing on raising 20-30% of the target in the first offering days. "*You don't want to be publicly sharing a campaign that has zero amount of money in it, you have to show there is some traction*." (Pofeldt, 2014).

Another interesting relation we have studied is between, again, the early bird and the duration of the ICO. It is clear that if an ICO lasts just a few days it's rare to find an early bird scheme due to the very short time. If the ICO lasts months, instead, it's important to no keep a linear offering for all the time, by introducing for instance an early bird, as it actually happened also for our set of data.

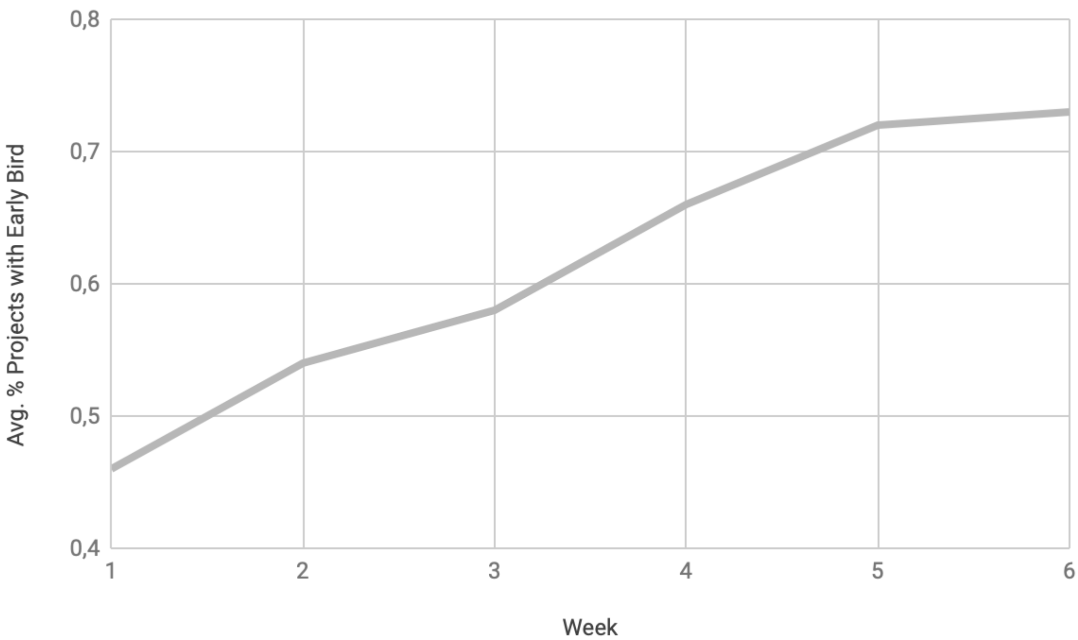

Figure 12 – Average Percentage of the Projects with Early Birds on a Duration Base Expressed in Week

Looking at the graph above, this trend is pretty clear. Less than half of the ICOs do not include an early bird scheme when the process lasts less than one week, while, on the contrary, this portion increases up to 73% for the longest ones (six weeks and more).

4.8.2 *Percentage of Tokens Distributed to Crowdsale*

Concerning with the "tokenomics" of the projects, we thought that the percentage of the tokens distributed to external investor could be a driver able to explain the efficiency of a project. The results test our theory and, then, the hypothesis *H2.c* can be confirmed. It means that a higher percentage available to the crowdsale positively contributes to increase the efficiency score.

This results pushed us to deeper analyse our data: we have found out that smaller companies tend to distribute a higher percentage of token to external investors.
In order to statistically verify this hypothesis, we have applied the Welch's T-test by introducing a new dummy variable called *size_dummy*.
This assumes the value of 1 if the sum of the core team and advisors is higher than 13, 0 otherwise. In particular, the sum of these two categories provide a partial but sufficient idea of the dimension of the company, since, as previously argued, human resources are the main assets.
The distinction between large and small-medium projects has been made by introducing a threshold in the number of people working as team member and advisors. Its value was mainly identified by considering the main statistics of the variable that counts the sum of core team and advisors and the related scatterplots. Indeed, by considering also the graphs we convey that fixing at 13 the threshold was a good choice. Anyway in the robustness analysis the value has been further verified (Section 4.9).
Moreover, we also studied the correlation between the variable that counts the *sum of core team and advisors* and *%Distributed_Crowdsale*: the relation is negative and significant (p-value 99%), hence the hypothesis is still verified.
By considering our sample, we have identified 391 small-medium and 412 large projects. The average percentage of tokens distributed to the crowdsale in the first group is 60.2%

while in the second ones is 54.2%. The table below shows the results of the T-test (Table 20). Of course it is possible to argue that the analysis is not extremely precise, but, in our opinion, it provides a general explanation of possible trends.

Variables	Cut Point Size 11	N	Mean	Significance Level T-Test for equality of means
%Distributed_Crowdsale	1	391	0.5418	0.000
	0	412	0.6018	

Table 20 – Welch's T-test Results with Cut Point of *Size_Dummy* at 13

4.8.3 *Hard Cap*

Concerning with the hard cap, we can confirm the hypothesis stated in the section 4.4: the greater the hard cap set, the less the probability to have an efficient project. As shown above (*Table 19*), the result is significant at 98%, with a p-value of just 0.019.
This negative relation between the maximum capital raised and the efficiency of a project is not a new theory. Also Rasskazova, Koroleva and Rasskazov studied it, but not finding any significant result (Rasskazova et al., 2019).
Our result can be explained by saying that, when the goals are too ambitious, maybe not coherently set with the size of the project, the company prepares itself for a capital collection not in line with their possibilities, resulting in an overall efficiency quite low. It would be interesting also to investigate if, in the steps beyond the ICO, this unsatisfying capital raised keep on being a problem for the organization of the problem or not. Unfortunately, the data about that are poor and solid analysis cannot be run.

By explaining the relations identified we have also decided to deeper investigate how the size counts (i.e. sum of core team and advisors). For this reason we have introduced a new variable, *Total_Size*, that accounts the sum of the members of the core team and the advisors. In particular, by analysing the correlation between *Total_Size* and *Logit_DEA* (Table 21), the result shows that the relation is negative and significant at 99% (p-value < 0.01): hence, the smaller the company is, the higher the efficiency score.

One can argue that this relation is obvious given the way in which the efficiency score is set. But, in our opinion, it is not. Indeed, not only the inputs, but also the output should be considered. Hence the projects with few members are able to collect more capital in proportion than the largest ones. Maybe because the largest projects are too ambitious and tend to overestimate their ability to collect money, hence resulting to be less efficient. We tried to find out some papers about these considerations in the fields of crowdfunding and IPO but any remarkable works have been identified. For this reason, we have conveyed that this is only a personal consideration.

Variables	(1)	(2)
(1) Logit_DEA	1	-0.345**
(2) Total_Size		1

** Correlation is significant at the 0.01 level (p-value < 0.01)
* Correlation is significant at the 0.05 level (p-value < 0.05)

Table 21 – Correlation between Project's size and Efficiency

4.9 Robustness Analysis

In this section we will describe some further analysis mainly done to confirm the results of the previous models. In particular, we want to understand the robustness of the transformation adopted for the dependent variable and the cut point for the T-tests implemented, by analysing the changes in the three statistical methods (i.e. correlation matrix, T-test and logit regression).

4.9.1 *Dependent Variable Transformation*

One of the main transformations that we have applied is related to the value of efficiency score retrieved from the DEA methodology. Due to the fact that the scores range in the continuous interval from 0 to 1 we have opted for a logarithmic conversion, hence running a logit regression and not the standard one.
What we have fixed by default is the value of delta at 0.99. In order to confirm and validate our choice, a robustness analysis has been run, aiming to change this parameter and, thus, observing if the results differ.

All the results of the test that we have performed are provided in the related part of the appendix.

Check 1

In this first test we want to check the robustness of our choice by setting the value of delta at 0.98.
As the table (Appendix, *Tables 1, 2*) shows, the data obtained varies minimally, as well as the significance. Our elaboration is then confirmed with a $\Delta = 0.98$.
In the correlation matrix, the only independent variables not significant are still the *Presale* and the *USD_Price*, while the *Early_Bird*, *LOG_HARDCAP* and %*Distributed_Crowdsale* have a significance up to 99%. In the logit regression, as well, the three models are the same, with equal results. Indeed, considering the R-square, the maximum variations account less than 5%.

Check 2

In the previous robustness analysis we have changed the delta value of just 1%. Thus, we have decided to run a second analysis by setting a $\Delta = 0.95$, farther than the first (Appendix, *Tables 3,4*).

Even in this case there are no variations worthy of being reported. The R-square ranges in an interval from the original 0.273 to 0.300. Hence, the variations are very limited.

These two further elaborations confirm what assessed concerning the matrix correlation and logit regression.

4.9.2 *Welch's T-test for Efficiency Groups*

When running a T-test, a cut point has been set, aiming to create two different groups starting from a general sample. In our case we have firstly decided to divide the projects in two main populations, efficient and inefficient, by setting the threshold at 0.75.

By changing the value of the cut point, the check has been made aiming to confirm what have been validated before.

Hence, we have run a robustness analysis with two cut points: 0.70 and 0.85.

Check 1

The T-test with 0.70 as threshold divides the two samples in 253 inefficient and 550 efficient projects. The results confirm how the *Presale* and the *USD_Price* are not enough significant. This means that the hypothesis of equal means is rejected only for the other three predictors, hence hard cap, percentage of tokens distributed to the crowdsale and early bird (Appendix, *Table 7*).

Check 2

As well, the T-test with 0.85 keeps on giving us the same results. In this case the inefficient projects are 489, while the remaining 314 are efficient. It is the only T-test with a pool of efficient ICOs lower than the pool of the inefficient. Nevertheless, the outcome does not change (Appendix, *Table 8*).

4.9.3 *Welch's T-test for Size Groups*

The third robustness analysis has been made in order to test the cut point assigned to the variable *size*, whose role is dividing the project into small-medium and large ones. This T-test has been done in relation to the analysis of the percentage of tokens distributed to the crowdsale discussed in section 4.8.2 (*Percentage of tokens distributed to crowdsale*). The cut point that we have used to divide between small-medium and large size projects was 13. Here we set the threshold at 11 first, and 14 later. The goal is trying to weight differently the two groups and see what happens.

<u>Check 1</u>

With a cut point of 11, we obtain two samples of 333 and 470 projects for small-medium and large companies respectively (Appendix, *Table 6*).

<u>Check 2</u>

Conversely, it we use 14 as cut points the samples are of 455 and 348.

In both cases, the results confirm what said previously, with significant difference between the two average values of %*Distributed_Crowdsale*. It adds solidity to our findings. In the appendix the related charts with all the data about the robustness analysis are presented (Appendix, *Table 5*).

Conclusions

Since the advent of the Internet in our lives, there has not been a disruptive technology able to reshape again the digital world, until the rise of the blockchain technology few years ago. Being a relatively young technology, the application fields are still not certain and well developed, but with time they will become clearer and clearer. What is clear, instead, is the paradigm of blockchain and its potentialities.

We live in a world where few big tech giants know what we eat, what we love, where we go, what we watch and when we sleep. So everything is *centralized*, all the data are collected in a central database. On the contrary, the blockchain paradigm is *decentralization*: it consists of an open architecture with a *peer to-peer* system that gives users the possibility to connect and make transactions instantly without the interference of costly intermediaries. The p*roof-of-work* validation model gives then security to the procedures by adding blocks to the existing chain.

The research made McKinsey (Section 1.4), argues that Financial Services is the industry sector in which the blockchain has the third best impact and the best feasibility of applying. Indeed, there are lots of innovative projects, from payments and lending systems to funds raising.

With more than $25 billion raised, the Initial Coin Offering has been one of the blockchain-based application with the highest hype in the last couple of years. Pushed by a really high interest in everything that is crypto (and especially by the bitcoin run), this new crowdfunding-alike alternative source of financing has found luck both among project developers and investors. The token-based offering, which gives contributors a personal set of services and the easiness to invest in it, have been well interpreted by crypto-investors, at least until 2018. Indeed, if the lack of specific regulations and bureaucratic procedures helped launching this alternative, they alarmed entities and authorities, which started taking action by limiting the freedom range of the ICOs. If to this we add a general loss of trust in the last year, the natural consequence was that ICOs approached a negative trend.

Declared a market dead by some, new evolved forms of ICOs took hold in the last months, by replacing the old structure with new state-of-the-art characteristics addressed to be pleased also by regulatory entities.
The *STO* (Security Token Offer), as the name suggests, entitles the token-owners of profit or reward rights. The *IEO* (Initial Exchange Offer), conversely, are directly listed on the cryptocurrency exchange, with companies and investors relying on them as underwriters. Anyway, there are still some doubts, as argued by Aaron Brown, a leading writer for Bloomberg Opinion, whose comment about the crypto-exchanges role in the IEOs is: "*It's not even clear to me that their promised due diligence is meaningful, even nominally. It seems to revolve more around ensuring the coins will trade than attesting to the underlying value of either the project or the coins, or the use for the funds raised, or the governance of the project*" (Kharif, 2019).

Considering the recent results, in May 2019, the ICO market registered a peak of $1.2 billion, the first result in ten digits after June 2018. The cryptocurrency market is up-trending with an increment of popularity of the IEOs over the ICOs (IcoBench, 2019b).
Except for the technical aspects, the projects and the way of doing of teams willing to raise capital through blockchain platforms remain very similar. The analysis conducted in this work, even if based only on ICO projects, can be considered valid even if taking into account IEOs or STOs.

<u>*Model Implications*</u>
The primary goal of our work is understanding which are the main factors that influence the efficiency of the ICO process. In order to assess this pioneering task, we have decided to adopt the DEA methodology, whose origins date back to the mid of twentieth century (Farrell, 1957). This decision was primarily driven by the advantage of its non-parametric nature, since there is no need to prescribe in advance weights for each input and output, as in the traditional approach, and, also, it does not require to set the functional forms that are needed in statistical methodologies.
One of the main issues was setting the inputs and output to introduce in our model. In particular, taking care of the current literature, the core team and advisor members

combined with the daily mentions reached on Twitter have been set as input factor of the ICO-based project. On the other hand, the amount raised expressed in US dollar has been introduced as the output of the project.

Once the model has been set, we have applied the *two-stage approach*, with the aim to link the efficiency score obtained from DEA with possible predictive factors.

For this reason, starting from the sample collected, the efficiency score retrieved from DEA has been set as dependent variable, while we have identified five predictors: two dummy variables that account to the presence of a presale and an early bird bonus scheme, the price of the token, the percentage of tokens distributed to crowdsale and the hard cap set by the project. In addition, eleven control variables have been introduced in the model, in order to check the consistency of our findings.

By adopting different statistical methodologies, of the five main hypothesis that we have supposed in advance, two have been rejected. Hence, we did not find any link between the presence of an anticipated sale of token (i.e. presale) and their price (USD token price) in relation to the level of efficiency.

On the other hand, three main insights have been found out. First of all a significant positive relation between the *early bird* bonus scheme and the efficiency has been revealed. Alon Goren, CEO and founder of leading start-up communities, interviewed by the CNBC, said that "*nothing attracts a crowd more than a crowd*". Indeed, the early bird effect gives dynamicity to the ICO, making investors more active, especially in the first days or weeks. It can help launching the public offering, attracting a greater potential number of customers. Moreover, we have also studied the relation between early bird and the duration of the ICO: the more the duration is extended over time, the more a bonus scheme as the early bird is proposed by the ICO projects.

In addition, we have demonstrated that a higher *percentage available to the crowdsale* positively contribute to increase the efficiency score. In order to have a better understanding of this result we have made further investigations. From them we have found out that smaller companies tend to distribute a higher percentage of tokens to external investors.

Then, another hypothesis has been verified: the greater the *hard cap* set, the less the probability to have an efficient project. We thought a lot about this finding. Our conclusion is that when the goals are too ambitious, maybe not coherently set with the size of the project, the company prepares itself for a capital collection not in line with their possibilities, resulting in an overall efficiency loss.
Also in this case, we have decided to make further investigations, who revealed that smaller companies, on average, tend to be more efficient.

Hence, to summarize, smaller projects with few but valuable team members are those with higher potentials to be efficient. Maybe, due to their small size, they are more cautious and realistic, and they are very prone to attract investors. Indeed, they tend to distribute a higher percentage to the crowdsale and they are more focus to achieve possible funding target, thus setting a hard cap compliant with their size.

Practical implications

In light of our results, we have decided to stress the insights of our research by contextualising and providing practical implications in the real life. For this reason, we have identified the main actors involved in this market. These are: entrepreneurs, investors and policy makers. For each of them a specific and peculiar advice is provided, with the aim to go beyond the academic work and provide personal considerations to improve the actual stage of the system.

Entrepreneurs: this category represents the wide arena of professionals, start-uppers or even academics that decide to fund their project, typically based on blockchain or financial solutions, by adopting the ICO approach. This practice is particularly exploited by new young ventures, typically start-ups.
According to our results, a good practice is being as much as possible open to the "crowd", by providing early bird incentives and distributing larger amounts of tokens. More than ever for small medium ventures, that cannot rely on the well-known popularity of projects as the Russian Telegram Open Network. What is fundamental is the role of token. Differently to traditional securities, a token is able to create incentives for multiple

stakeholders. In advertising, for example, a token could allow a start-up to reward all the different players (advertisers, publishers, or content producers) for their contributions to the ecosystem. According to Catalini, Founder of the MIT Crypto-economics Lab, there is a key difference between tokens and traditional equity. Equity gives to investors the right to the returns of a team of entrepreneurs on a very long-time horizon, no matter what new idea that team may come up with or how the idea may evolve further. On the other hand, tokens are about building shared, digital infrastructure for an ecosystem. They can be considered as a sort of public good (Catalini & Gans, 2018).
Moreover, the ICO process may appear as a relatively quick, uncomplicated way to secure access to funding with low barriers to entry. For example, it can take less than 100 lines of code to create a token on top of blockchain-based platform Ethereum. Hence, sometimes happens that given this "easiness", entrepreneurs roughly build up their business, setting ambitious goal that are not in line with their possibilities. For start-ups, an ICO might seem like a "golden ticket" to get a project off the ground (Catalini & Gans, 2018). On the other hand, being compliant with the complex requirements and regulations of traditional financial institutions may also have some advantages. Indeed it may encourage companies to better focus on their objectives and the strategy in which they are intended to achieve them.
Differently, Internet, and more specifically ICOs, are by nature open and weekly regulated. Hence, the willingness to raise money can obscure the real fundamental of the company. Not by chance, our research revealed a negative relation between the *hard cap* (i.e. funding target) and the efficiency of the project.
To sum up, the advice for funders and team members is: be consistent with your size and your possibilities. Maybe in the short period you will have some losses, but in the long time you will gain. Be open with the crowd with valuable and ambitious marketing initiatives. Give it a role. Make it part of your business. Investors are not only money provider, but also generator of ideas.

Investors: these are those who decide to invest in crypto-projects. Not all of them are professional investors, but of course the majority uses Internet as a valuable source where to understand how and in which company to invest. Hence the role of marketing and, in particular, of social media platforms is crucial. Not by chance we have included in our analysis the number of mentions daily reached on *Twitter*.

According to Maxwell Arnold, analyst at Global Blockchain Technologies Corp, there is a whole public relation and marketing industry around building meaningless hype for crypto projects that do not actually do anything. Hence, the objective of an investor should be based on the understanding of what blockchain technology does, how a given ICO or start-up is using it in a unique way, and why this will be translated into a ROI. Without doing this research, is like buying a “lottery ticket” (Sergeenkov, 2018).

This activity is costly and time consuming. The investors should be able to collect reliable data in order to mitigate the information asymmetry and thus, distinguish between “peaches” and “lemons”. Sometimes happen that smaller and less known firms are overlooked. But, according to our results, small-medium projects are the ones that are able to more efficiently transform inputs into valuable outputs. For this reason a good financer is the one who spend the right time to look for alternative and unique business models, maybe small, maybe with few resources but with a valuable potential to growth and to scale.

To conclude the advice is: try to look for something unique, not necessarily big with valuable human resources and positive feedbacks on media platforms. Do not follow the crowd but leverage on your experience to find out the new “hype”.

Policy makers: even if it is not the objective of our work, we have provided a synthetic overview about the actual role of policy makers and how this will change in the future. As largely recognized, the regulation is one of the main issues for ICOs, so a brief discussion is provided.

First of all, the introduction of smart contracts has been perceived by many as a possible source of disputes. This is a misconception: smart contracts rely on codes which perform transactions automatically, but they do not make sure that there are no litigations between the parties involved. The relation between smart contract and the country law is still affected by opacity and, hence, innovation is strongly claimed.

By observing our sample we noted that teams usually opt for a jurisdiction which guarantee them a quite broad space of action, without incurring in possible sanctions. The issue of jurisdiction emerged in many court cases, mainly due to the decentralized nature of the network (Ortolani, 2019). The real issue is understanding in which way, how and where the jurisdiction has the power to be adopted by policy makers, given the global presence of companies and investors. Indeed, tokens can be purchased by people from (almost) all around the world.

The authorities, as previously described in the section 2.9 (*Market Regulation*), made some steps forward to close this existing gap, but still not enough. Indeed, there have only been a few countries that have actually taken severe actions against misleading initiatives. There is still a lot of discussion required for remaining nations on what to do moving forward with ICOs. Some of them banned ICOs, as China, while in others these alternative forms of finance are very welcomed, as in Switzerland and Singapore.

By looking at the European case, while the European Bank does not have the power to ban Bitcoin or any other cryptocurrency, the EU stands strong in their idea that stricter regulation laws are necessary, as ICOs are considered highly-risky. On December 2017, the European Union, along with the UK Treasury, was reported to be making plans on cracking down on the big rising issues that ICOs would bring to the table: from criminal activities such as drug trafficking and money laundering, to tax evasion. This stance was in conjunction with the worry that investors and consumers had too much risk of loss to their investments, whether due to security failures or market manipulation (ESMA, 2019). In line with these guidelines, France opted for a complete check of all the white papers, creating a blacklist with risky and less virtuous projects, hence allowing investors to finance only good and reliable ventures.

Across the pond, due to the absence of ICO-specific regulations, the SEC decided to sort ICOs into two basic categories: security and not a security. Even applying the Howey Test, in order to determine if a transaction is considered an "investment contract" and is therefore subjected to securities law, a final and synthetic regulation has not been set. Indeed, while the Howey Test forms the foundation for the SEC's classification of ICOs, the authority reserves the right to make judgment calls about new ICOs on a case by case basis.

These shrinkages allowed STOs and IEOs to flourish: they give more transparency and credibility to the processes, with regulatory compliance and efficient marketing to the industry respectively (Sergeenkov, 2018).

Policy makers are fighting against the enemy of information asymmetry. The real issue is the presence of low-quality projects with opportunistic behaviors (Vereckey, 2018).

To pursue this objective, it is fundamental to contrast the fraudulent start-ups and give investors the possibility to check frequently the ongoing development of the projects and how funds are spent, as it usually happens in other businesses (Sergeenkov, 2018).

Limitations

The research conducted has some limitations and by acknowledging them, we have then provided hints for future studies and developments. The main limitation lies in the data used for the model. As previously stated, the ICO market is strongly affected by opacity and lack of transparency. Dealing with a strong information asymmetry was the main obstacle. There are lots of different websites that provide lots of different data.

For this reason a structured classification and procedure of the sources has been adopted, but, due to its experimental nature, its reliability is questionable. In this sense, a possible improvement is leveraging on the power of API and focusing on a wider set of remarkable sources, in order to mitigate the information asymmetry.

On the other hand, a contestable aspect of our work is the choice of inputs and outputs selected for the application of DEA. One can argue that our choice is limited to few variables. Of course data are always an issue. We have tried to make all the bests with the available resources. In the future, a more detailed analysis can be made by introducing new inputs, such as the costs related to marketing and operating activities or the number of investors involved. Moreover, instead of considering only data from Twitter, new social media as Reddit or Facebook can be included.

Another issue is the possible selection bias in final dataset used for the analysis. Since we have excluded many projects for missing or undisclosed data, about the half of the total sample, the model is exposed to a possible selection bias that could be solved by using an improved dataset. Hence, in the future, a more comprehensive and completed set of data can be included, leading to have more solid and reliable results.

The main peculiarity of this work, beyond the findings identified, is, especially, the novelty of the approach adopted. There are still many studies about the critical success factors of the ICO, whose aim is understanding which are those factor that predict possible outcomes. But our "innovation" has been the study of those factors that influence not the success but, instead, the efficiency of ICO-based projects. Maybe it is not perfect, but we have slightly contributed to investigate the recent phenomenon of the ICOs.

Thanks.

List of Figures

List of Tables

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APPENDIX

Table 1 – Correlation Matrix with Δ = **0.98 for *Logit_DEA***

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Logit_0.98	1	-0.035	0.150 **	-0.133 **	0.180 **	-0.040
(2) Presale		1	0.222 **	0.148 **	-0.077 *	-0.045
(3) Early_Bird			1	0.031	0.044	0.027
(4) LOG_HARDCAP				1	-0.185 **	-0.015
(5) %Distributed_Crowdsale					1	-0.034
(6) USD_Price						1

** Correlation is significant at the 0.01 level (p-value < 0.01)
* Correlation is significant at the 0.05 level (p-value < 0.05)

Table 2 – Logit Regression with Δ = **0.98 for *Logit_DEA***

Variables	Model I			Model II			Model III		
	Coeff.	(SE)		Coeff.	(SE)		Coeff.	(SE)	
(Constant)	0.826	(0.374)	*	0.815	(0.373)	*	0.824	(0.373)	*
Presale	-0.101	(0.068)		-0.099	(0.068)				
Early_Bird	0.158	(0.067)	*	0.156	(0.067)	*	0.135	(0.066)	*
%Distributed_Crowdsale	0.322	(0.142)	*	0.324	(0.142)	*	0.334	(0.142)	*
LOG_HARDCAP	-0.112	(0.047)	*	-0.112	(0.047)	*	-0.118	(0.047)	*
USD_Price	-6.56E-5	(0.000)							
Code_AV	-0.169	(0.068)	*	-0.166	(0.068)	*	-0.159	(0.068)	*
Global_Rank	9.24E-5	(0.001)		8.34E-5	(0.001)		0.000	(0.001)	
Finance	0.099	(0.069)		0.100	(0.069)		0.099	(0.069)	
Block	0.096	(0.087)		0.097	(0.087)		0.104	(0.087)	
ETH_CF	0.000	(0.000)	*	0.000	(0.000)	*	0.000	(0.000)	*
ETH	-0.063	(0.096)		-0.063	(0.096)		-0.067	(0.096)	
DRET30	0.087	(0.085)		0.087	(0.085)		0.093	(0.085)	
DRET7	-0.017	(0.045)		-0.017	(0.045)		-0.019	(0.045)	
DVOL30	-0.056	(0.057)		-0.056	(0.057)		-0.057	(0.057)	
DVOL7	-0.007	(0.046)		-0.007	(0.046)		-0.007	(0.046)	
LOGDUR	0.910	(0.065)	**	0.913	(0.065)	**	0.913	(0.065)	**
R-squared	0.284			0.284			0.282		
Adj. R-squared	0.270			0.271			0.270		

** Significance at the 0.01 level (p-value < 0.01)
* Significance at the 0.05 level (p-value < 0.05)

Table 3 – Correlation Matrix with Δ = **0.95 for *Logit_DEA***

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Logit_0.95	1	-0.031	0.154 **	-0.137 **	0.187 **	-0.042
(2) Presale		1	0.222 **	0.148 **	-0.077 *	-0.045
(3) Early_Bird			1	0.031	0.044	0.027
(4) LOG_HARDCAP				1	-0.185 **	-0.015
(5) %Distributed_Crowdsale					1	-0.034
(6) USD_Price						1

** Correlation is significant at the 0.01 level (p-value < 0.01)
* Correlation is significant at the 0.05 level (p-value < 0.05)

Table 4 – Logit Regression with Δ = **0.95 for *Logit_DEA***

Variables	Model I			Model II			Model III		
	Coeff.	(SE)		Coeff.	(SE)		Coeff.	(SE)	
(Constant)	0.686	(0.328)	*	0.675	(0.328)	*	0.682	(0.328)	*
Presale	-0.086	(0.060)		-0.084	(0.060)				
Early_Bird	0.143	(0.059)	*	0.141	(0.059)	*	0.123	(0.058)	*
%Distributed_Crowdsale	0.299	(0.125)	*	0.301	(0.125)	*	0.309	(0.125)	*
LOG_HARDCAP	-0.104	(0.041)	*	-0.104	(0.041)	*	-0.109	(0.041)	*
USD_Price	-6.21E-5	(0.000)							
Code_AV	-0.153	(0.060)	*	-0.150	(0.060)	*	-0.144	(0.060)	*
Global_Rank	9.43E-5	(0.001)		8.58E-5	(0.001)		0.000	(0.001)	
Finance	0.079	(0.060)		0.080	(0.060)		0.079	(0.060)	
Block	0.063	(0.076)		0.064	(0.076)		0.069	(0.076)	
ETH_CF	0.000	(0.000)	*	0.000	(0.000)	*	0.000	(0.000)	*
ETH	-0.049	(0.084)		-0.050	(0.084)		-0.053	(0.084)	
DRET30	0.079	(0.074)		0.079	(0.074)		0.084	(0.074)	
DRET7	-0.011	(0.040)		-0.011	(0.040)		-0.013	(0.040)	
DVOL30	-0.048	(0.050)		-0.048	(0.050)		-0.049	(0.050)	
DVOL7	-0.009	(0.040)		-0.009	(0.040)		-0.008	(0.040)	
LOGDUR	0.832	(0.057)	**	0.835	(0.057)	**	0.835	(0.057)	**
R-squared	0.300			0.300			0.298		
Adj. R-squared	0.286			0.287			0.286		

** Significance at the 0.01 level (p-value < 0.01)
* Significance at the 0.05 level (p-value < 0.05)

Table 5 – Welch's T-test with **cut point of size_dummy = 14**

Variables	Cut Point Size 14	N	Mean	Significance Level T-Test for equality of means
%Distributed_Crowdsale	1	348	0.5363	0.000
	0	455	0.6003	

Table 6 – Welch's T-test with **cut point of size_dummy = 11**

Variables	Cut Point Size 11	N	Mean	Significance Level T-Test for equality of means
%Distributed_Crowdsale	1	470	0.5501	0.001
	0	333	0.6044	

Table 7 – Welch's T-test with **cut point of eff_dummy = 0.7**

Variables	Cut Point Efficiency 0.70	N	Mean	Significance Level T-Test for equality of means
Presale	1	550	0.62	0.614
	0	253	0.64	
Early_Bird	1	550	0.72	0.000
	0	253	0.54	
LOG_HARDCAP	1	550	7.12	0.001
	0	253	7.27	
%Distributed_Crowdsale	1	550	0.60	0.000
	0	253	0.52	
USD_Price	1	550	3.47	0.357
	0	253	31.04	

Table 8 – Welch's T-test with **cut point of eff_dummy = 0.85**

Variables	Cut Point Efficiency 0.85	N	Mean	Significance Level T-Test for equality of means
Presale	1	314	0.62	0.756
	0	489	0.63	
Early_Bird	1	314	0.72	0.004
	0	489	0.62	
LOG_HARDCAP	1	314	7.08	0.009
	0	489	7.22	
%Distributed_Crowdsale	1	314	0.61	0.000
	0	489	0.55	
USD_Price	1	314	5.38	0.475
	0	489	16.52	