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Blockchain technology in the agrifood sector

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Summary

Introduction

This elaborate has been developed in order to contribute to the analysis and research about a potentially disruptive technology such as blockchain, which represents a quite popular topic of discussion during the last years. The focus however, will be on the industrial application that this tool can exploit, instead of the most common field of discussion regarding blockchain namely, the cryptocurrencies.

Indeed the core of this elaborate will deal with the blockchain application from a supply chain perspective, more specifically, in the Agrifood sector. Today's industrial systems are characterized by an always-increasing complexity of structure and management requirements. Supply chains are the perfect example of complex structures in which multiple independent entities, have to collaborate and coordinate themselves in order to reach a common goal: delivering the products to the end of the distributive chain. In recent years, food supply chains have expanded both in a geographical and organizational way, in order to ensure to final consumers an increasing variety of food. However, the expansion of supply chains have bring to various negative outputs such as lack of trust between distant business partners, low transparency of processes, information asymmetries and an overall difficulty in managing all the information exchanges required to coordinate such heterogeneous systems. All these aspects can lead to inefficiencies, deliveries delays, fraudulent or opportunistic behaviours and increased operational costs, all factors that negatively affect the distributed value of an industrial system.

Given this landscape, blockchain technology has been taken in consideration considering the possibilities that can bring in terms of distributed trust, digital transparency and decentralized management. This distributed ledger technology, in few words, is able to create a digital representation of actors, processes and transactions that compose a determined supply chain, in a tamper-proof and immutable way, thanks to its consensus mechanism based on hashing codes, permitting to obtain transparent and secure supply chains, creating distributed benefits to all the components of the system.

The objective of this thesis is to highlight and assess the impact that such an innovative technology can have, if applied properly to pre-existing supply chain's key activities, thanks to scientific literature review and practical examples. Drawing attention to the improvements of processes resulting from blockchain application, but also to the limitations and obstacles that inevitably such a modern and technologically complex paradigm can face in its initial stages of life.

The framework of the above-mentioned elaborate is composed by an initial chapter in which is reported a panoramic view of the actual global Food Industry situation, introducing important concepts such as supply chains stages, stakeholders, traceability and the related problems. The second chapter presents an introduction and overall description of blockchain technology, necessary in order to understand furthers analysis and concept elaborations present in the following chapters. The third chapter, based on the scientific literature, analyses the actual blockchain application in the food sector, considering also its integration with other supportive technologies, in order to create synergies needed to encompass all the aspects related the functioning of a global supply chain, revealing benefits and challenges concerning BC application in Food sector. The fourth chapter tries to classify and analyse blockchain technology application in food industry in order to pose questions useful to create a basis for the final company analysis but also for future researches, through the perspective of six different organizational theories.

The last two Chapters are focused on the final company analysis, more specifically, the fifth chapter contains the three research questions on which will be developed the research, then will be described the methodologies used in order to collect information for the analysis. In the sixth chapter are reported the answers to the research questions, basing them on the findings of the research.

CHAPTER 1: A panoramic of Actual Agrifood industry

1.1 Food's role in human life

Food has been constantly a basic aspect of human life, since the beginning of time feeding ourselves has been a tool not only for surviving and strengthen our body defences, but also a way to take part in collective situations, such as a restaurant, a family dinner or a daily lunch in a school canteen.
From this beginning it's clear that issues about Food have to be seen and analysed from a collective point of view, keeping in mind that the decisions taken nowadays in a macroeconomic dimension are reflected consistently to a large part of human population both in a positive and in a negative way.
In the last decades, have witnessed an exponential increase in inter-connectivity and reciprocal dependence between different actors across the Globe, thanks to the expansion of the Consumer Society during the XX Century, increased in the last years due to new possibilities permitted by technology innovation, food is not an exception of this trend. In the actual landscape, a normal consumer has the possibility to enjoy a huge variety of different foods compared to 30-40 years ago as a result of improvements in shipping and delivery, creating an intricate web of economic relations all around the world, in order to satisfy the increasing demand of food belonging to different Cultures.
Considering these premises, it's clear that the value delivered across the Agrifood supply chain comprehend a vast group of actors, that are going to be described in the next paragraphs in order to have a clear image of the elements involved.

1.2 SupplyChain

Although Food Supply Chain can vary in a consistent way depending on the type of provision that we take in consideration and on the stages necessaries to obtain the final product(Caro et al., 2018a), here is presented briefly the average framework of a food Supply Chain.

1) provision: raw materials suppliers, such as seeds and nutrients, but also pesticides, chemicals, and fertilizers.

2) production: growth of food and cultivation. producers have to follow international and local restriction and policies in order provide a final product in line with the quality standards required by Policies and the Market.

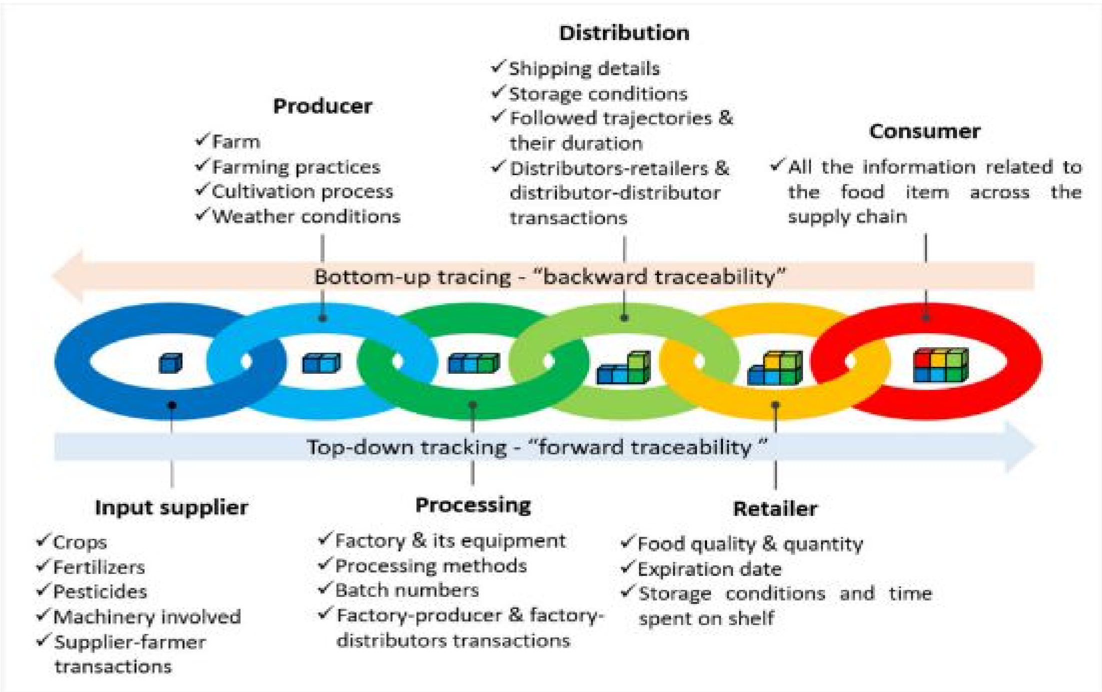
3) process: once the harvest is completed, the food need to washed and prepared, the methodologies and phases of this segment are subject to the sector and typology of food(ex. the process of production of meat is much longer and complex compared to fruit)

4) distribution: this is usually the longest stage along the supply chain, and also the most critic in terms of environmental impact because it consist in the shipping of food from the LAVORATION site to retailers, and it can consist in thousands mile journeys.

5) retail: this segment is composed by local and mass retailers designed to provide to final costumers the products required ;

6) consumer: last element in the chain, represent people who buy food for personal use.

Image 1: Food's Supply chain framework Source: (Tagarakis et al., 2021)



1.2.1 Different transformation processes

In food industry approximately every product is processed in some way, the entity of transformation from raw materials to final product varies depending on the specific sector and the type of food interested. A classification made by the University of Sao Paulo in 2016 (NOVA classification), divides in four different categories all types of food, based on the grade of processing (Monteiro et al., 2019):

Group 1: *unprocessed food*, transformed by industrial process only to remove non edible or undesired parts, also includes procedures such as drying, crushing, grinding, fractioning, roasting, boiling. These industrial interventions don't add fats, oils or salt, they are only adopted in order to stretch out the life of product such as vegetables, legumes, milk and fruits.

Group 2: *processed culinary food*, these type of products come by industrial processes applied to group 1 food or directly from nature (salt, sugar, fats), the processing can include pressing, centrifuging, refining, extracting with the aim to extend their shelf life.

Group 3: processed food, manufacturing products obtained by mixing group 1 food with salt, sugar or other elements belonging to group 2, adopting maintaining procedures like canning and bottling, and, in the case of breads and cheeses, using non-alcoholic fermentation. These transforming methods are planned not only for extending the marketable life of products but also to make them more pleasant by altering their sensory characteristics.

Group 4: ultra-processed food, resulting from the combination of industrial use ingredients subject to industrial transformation. Usually the starting point is the extraction of substances such as oils, fats and sugars from whole food such as soya, wheat, corn and livestock's remains. Successively other substances are added to the previous, often resorting to processes such as extrusion, moulding and pre-frying, often are added also elements like flavour enhancers, colours, emulsifiers, emulsifying salts, sweeteners in order to transform the resulting product more appealing and savoury to end consumers. In this category we can find savoury packaged snacks, chocolate, candies (confectionery), ice cream, mass-produced packaged breads and buns, and mechanically separated meat. These type of products are specifically designed for having an high-profit margin compared to foods belonging to the other three groups, indeed they often rely on a longer shelf life, enhanced flavour, transnational branding and a cheaper production. This consideration can be a seen as an health threat because ultra-processed food are known to be responsible of many food related diseases compared to unprocessed or minimally processed foods, not to mention the fact that because of the various steps in the making process of these foods the traceability can be more challenging.

1.2.2 Value chain differences related to national income

Because food is an essential good for every human being, it's easy to imagine how vast and complex can the global food Supply and Value chains are, because in every corner of the world, people need to consume it; infact food systems and agricultural technics are variegated, from mass production and vast-scale distribution to more rural and small-scale supply chains, for exemple farming practises in low and lower-middle income nations face a prevalence of small firms indeed, around three quarters of farms are characterised by agricultural land lower than five hectares (FAO. 2014).

In recent years we are witnessing a transformation in food production and retail approach, there is a bigger trust in global scale supply chains, usually ending up in Supermarkets as retailers.

The trend that food system is following is based on a capital concentration in fewer hands, vertical integration is a concept key in this situation because of a growing unification between primary production, processing and distribution, the automation of large-scale processing and higher capital and knowledge intensities. (FAO 2017)

In poorer nations, such innovations in food value chain raise barriers for local producers to compete in local, national and global markets; in fact a large number of small-medium growers strive to take part in such networks, due to lack of possibilities to fund themselves, transportation issues and keeping up with new quality standards (FAO

2017). Through an enhanced coordination and reinforcement of connection among the different actors (agriculturists, markets and consumers) of the value chain there will be the potentiality to generate greater income growth and job opportunities.

1.3 Traceability

The concept of food traceability is relatively a modern need due to the constitution of a global framework related to food production, since the geographical origin of food and its consumption have been disjointed, moreover specialization of producing process, take advantage of industrial and scientific methods not easy to evaluate from average consumers (Coff & Christian, n.d.).

Reading and analysing the literature about traceability, I've encountered many definitions related to this topic, the most relevant and summarizing one is proposed by (Olsen and Borit, 2013), that define traceability as: "The ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications".

Keeping track of all the movement that a specific food has to make before reaching supermarkets shelfs can be very hard and it has to consider many aspects , the most relevant are the following (Andrew & Kennedy, n.d.):

Food Safety: traceability is needed especially when a food problem emerge and can potentially constitute a health issue for a multitude of people, professionals that work in this field should assess regulatory recordkeeping requirements, in order to make sure that processes and shipping are conducted in a transparent and precise way; with the aim of protecting public Health, and eventually identify affected products.

Logistic: a central aspect of backtracking a specific good is to focusing on its geographical and physical flow.

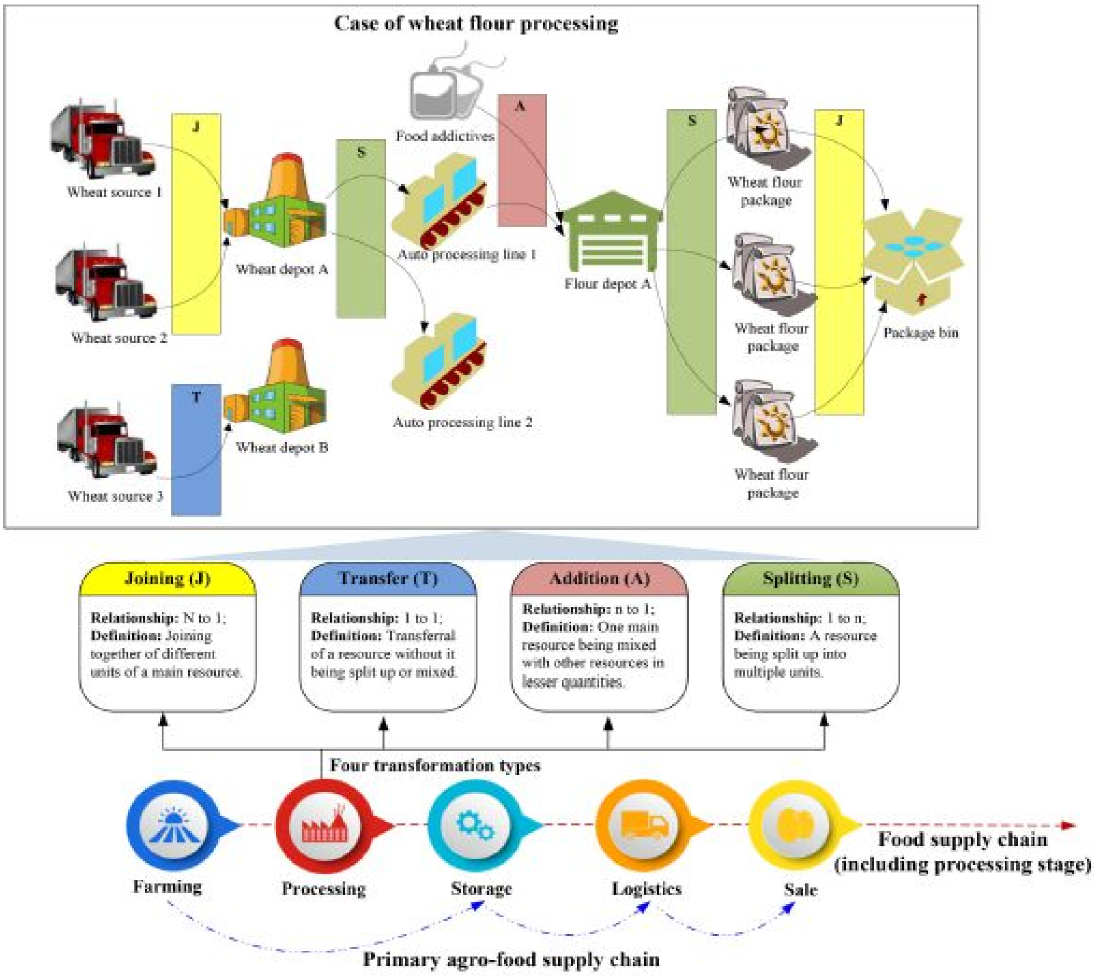
IT: as aforementioned, traceability is based on physical flow of food, but these movements need to be registered, so far recordkeeping in this industry has been paper based, also if , as I will analyse in next chapters, digitalization is the trend for the future.

Accounting: keeping track on the money flow related to the purchase/sell of products is a useful way to control the equivalent part in physical world

1.3.1 Processed food's problems

As reported in paragraph 1.1.1 some types of food require much more processing stages along the supply chain compared to primary agro-food, as a consequence traceability become more complicated. Manufacturing processes such as storage and carrying of processed food such as liquids, powders and crystals can challenge traceability investigations. Often, in these situations various batches can be contained in the same warehouse, waiting to be mixed with raw materials following chemical and physical transformations, before becoming production lots intended to be transported to the next point (Comba et al., 2013). As the example of animal slaughtering's process, in which approximately 1200 pounds of raw material generate 700 pounds of carcass originating 400 pounds of marketable product, with the potentiality of mixing meats from different sources (Shackell 2008). In average 10% of liver samples do not coincide with the corresponding animal (Heaton et al. 2005), posing real obstacles in traceability. Using another example, we can highlight traceability challenges of processed food in fig. 2 in which wheat flour processing is illustrated, it contains four types of transformations. Resource joining is the mixture of different inputs, resource transfer regards the transportation of resources from one point to another, resource addiction consists in adding a main resource with another of smaller amount and finally resource splitting is a procedure to divide resources from one depot of wheat to many lines.
It's clear at this point that processed foods pose obstacles in tracking the path of product in the supply chain, because of the variety of raw materials, batch mixing, and resource Transformation compared to primary agrifood sector.(Qian et al., 2022)

Image 2: Resource transformations in food processing stage.



Source: (Qian et al., 2022)

1.4 Stakeholders in Traceability

There can be different types of food traceability services (FTS), characterized by variable levels of audit relation and involvement based on who are the interested receivers of these information (Bendaoud, Lecomte, & Yannou, 2012). As (Islam S., Cullen J.) have identified, there are five main categories of direct FTS's stakeholders, that are reported below:

1.4.1 Public, standard-setting, NGO certification institutions

Public, standard-setting, NGO certification institutions have a crucial role in safeguarding the security of buyers, animals and terrains that substantially are those who benefits from FTSs actions. In US, for example, the FDA (Food and Drug Administration) analyse possible connections between food itinerary and possible foodborne illnesses that may be linked to it (Smith et al., 2005). Another case can be identified in the monitoring of fishing activities by national authorities in the European Union activities (Donnelly & Olsen, 2012). Also technical experts activities can help standard-setting bodies in shaping future rules, as the example of EU-financed Trace project, responsible of outlining the framework of ISO 12875 and ISO 12877 (Olsen, 2018). Lastly, independent certification organizations, establish relations with supply chain's actors in order to generate principles and rules useful to preserve food's standards (Norton et al., 2014).

1.4.2 Business partners

Suppliers are often required to have suitable Food Traceability Services by many possible business partners such as, exporters, GDOs and retail stores in order to eventually recall suspected products in the fastest and economically convenient way. As the case of US retailing company Walmart, that demand its furnishers to track back delivered food with the help of radio-frequency technology (RFID) (Smith et al., 2005). This type of information are useful to assist retailers in discount planning, stock rotation, keeping record of sales and eventually alert consumers who have bought possible contaminated food (Golan et al., 2004).

1.4.3 Public interest

Food traceability services help to empower trust and brand loyalty toward end consumers, that often are inclined to pay an extra price in foods with a guaranteed traceability system, as the case of Canada, where costumers are inclined toward purchasing more expensive traceable meat (Zhang, Bai, & Wahl, 2012), or in Japan, where picking date, process of production and certificates are in the interest of consumers regarding fresh products (Jin & Zhou, 2014).

1.4.4 Food business operator

Traceability systems help food business operators to enhance their supply chain consistency and coordination through the improvement of connection and communication along the different steps of food cycle of life (Golan et al., 2004). Indeed FTSs assist industry actors in connecting specific products to their relative data, helping them to monitor food movement and improve speediness in eventual recalls (Jedermann, Nicometo, Uysal, & Lang, 2014). As a consequence of ever improving traceability systems, companies started to provide a growing quantity of information as a strategy to differentiate from competitors, to attract consumers, creating in this way a synergy from which both parts can take advantage.

1.4.5 Scientific community

Increasing information and monitoring capabilities about food make the scientific community more ready to recognise the origins of foodborne illnesses (Regattieri et al., 2007), clearly that is a powerful tool to improve attention toward public health, making people more aware on consumption habits and helps to prevent future possible food hazard incidences. This type of data can also help business operators to shape their business in order to fit public demand.

1.5 Governing vs Governance

In order to help consumers to pursue an informed food choice and guarantee an ethic in traceability we have to highlight the two principal dimensions of authority in the society: public and private. The two notions apparently have to deal with both spheres of society, because ensuring an ethical traceability of food and its supply chain is part of the Common Good concept; on the other hand food choices are based arbitrarily on private decisions, based on Market's offer; so in this landscape, producers, retailers and consumers also play a crucial role from a political and ethical perspective (Coff & Christian, n.d.). The notion of Governing by public authorities has been always based on a command and control approach empowered by laws, however during last decades this aspect has changed favouring an hybrid form of governance involving a wide range of actors from the private sector as well as from government (Pierre, 2000). The empty space left by Government interventions, has been filled by a private, corporate-based and Market-like form of governance, for example ratings and quality standards setting, assurance schemes, contractual relationship between producers and retailers etc… (Reardon and Farina, 2001). Of course the State cannot abandon its supervisory and normative public responsibilities in favour of a full market-based approach, in order to safeguard public health and avoid opportunistic behaviours on corporate and private side; this dichotomy led the agrifood industry in a complex and contradictory value distribution issue.

In this dynamic landscape, we are observing the emergence of two processes, the socialization of food related to consumer side and the liberalization of food behalf of governments. The first concept suggest that nowadays food, in relation of the increasing consumer perception toward food quality and safety, has become a social and ethical topic of the actual population; in fact for a consistent part of western population, the attention put on food consume is no more limited to biological and health factors, but it has became a social and behavioural indicator.

Furthermore, governments have recognised the enhancing politicization of food consume, letting the whole sector to shape on more competitive and market-shaped logic, in order to make citizenship benefit of more consumption rights. (Busch, 2007).

1.5.1 Retailers lead the Market

The fact that agrifood industry in last decades has been influenced by market and private logics, combined with the necessary nature of this specific food have helped this sector

to become huge globally, in fact is the largest manufacturing sector in the European Union, constituted by a complex web of integrated inter-national contractual relations. Vertical integration and a growing elaborated supply chain approach that rely more and more on a transnational dimension, have replaced the long-established expansive and shattered food sector dominated by national norms. (Marsden Terry, n.d.).
In the last 30 years agrifood industry has evolved into a corporate retailer-led system, changes in the social perception of food has advantaged corporate retailers compared to the traditional fragmented production. As a consequence consumer behaviour toward food has changed, indeed domestic revenues now are spent in few number of large supermarkets, that are able to offer a vast quantity of goods and services, that usually seek to strengthen consumer fidelity with loyalty cards, a useful way also to track consumer's behaviours and preferences. (Guy, 2007).
This trend is a complex issue if we are talking about food security, indeed tracking back the journey of food along privately handled, fast moving and global-scale supply chains has become the focus point regarding public security (Marsden Terry, n.d.).

1.6 Problems and controversies

Of course the new shape that food industry has reached in last decades brings with it specific risks regarding food quality and the possibilities of tracing the food, as a consequence of increased geographical distances for shipping, increased pace and difficulties to obtain information from a privately managed system.
As effect of the retailer-led dimension of Agri-food industry for example, Buttel (2006) has highlighted four main consequences related to this trend, as we will analyse below:
Progresses in processing, transportation and distribution led to a expanding separation amidst raw material production or livestock, places where the food is processed and retail sites.
The creation of mega-farms, and the convergence of small pre-existing realities into singular big business, brings competitive advantage over smaller and fragmented family-

owned farms, by acquiring, converging and merging the bounded resources like land, water, market share etc…, creating an unfair competition.

Amplified and intense production mixed with the dependency on external inputs (pesticides, composts, OGM), can mine the long-term security of all the supply chain.

Investments and disinvestments made by wholesale actors in Agrifood industry provoke movements of people, that depend on this specific sector, causing possible instabilities in migrations.

1.6.1 Fast and right dilemma

When a foodborne illness explode, investigators have to face a controversial aspect, namely the “fast and right” dilemma, in other words they have to balance two important aspects related to food industry; on one side they have the legitimate and moral duty to intervene as fast as possible to withdraw the suspected food from supermarket shelters to prevent more public health problems. On the other side, they have to weight also the economical outcome that can occur due to a too hurriedly and inopportune food’s removal, causing important damages to firm’s and employees’ level. This is a very sensitive issue, indeed the consequences of an unsuccessful investigation campaign can compromise the reputation of forthcoming possible inspections, from institutional, business and consumer’s point of view.

This “fast and right” approach is clearly a double-edged-sword for agencies investigating foodborne illnesses, considering that they have to act timely and in the fastest way possible in order to preserve public security, while considering the necessity to be right and balanced, exposing in this way, possible contaminated food for a longer period.

Is clear at this point, that cooperation among government and industry is necessary for quickly and precise trace-back, also if recurring Agencies limitations to publish certain information due to governmental regulations have mined trust and coordination between regulatory authorities and firms, with the final result of a lack of protection toward final consumers.

1.6.2 Traceability's Lacks

It's estimated that roughly a half of the trace-back attempts fail to find the cause of an outbreak, that can be an outcome of two main factors, as we mentioned above, a regulatory one and a epidemiological one, lack in recordkeeping is commonly one of the principal obstacles to an effective investigative action.
This can be caused by the nature of documents (purchase orders, production information, sell orders…), indeed they fail to provide useful details except of economical one; moreover these document are continuously scanned, copied and sent leading to difficulties to track properly a specific product along the supply chain. Not to mention that these documents can contain missing or indecipherable information, for example the same product can be named differently along different stages of its supply chain, that can be a clear obstacle in conducting a proper and timely trace-back.
Also the nature of food itself can determine a specific hurdle for identify the race of a product. Let's think about fresh food, characterized by short permanence in shelfs, usually this type of products are sold in bulk, with poor information regarding provenience and other specific details, in addiction, if a foodborne illness is suspected is difficult to trace the incriminated lot because it can be already finished at the time of the investigation. Packaged food on the other side it's easier to trace, but presents other challenges, considering that producers might keep food records for three or four months, while the marketable life of a product can be over an year, can generate difficulties in conducting a proper trace-back due to lack of information. This type of food are usually the combination of many different ingredients, when an outbreak occurs related to a determined product, investigators must consider all the components of it, and eventually block the distribution of other product that may contain the common incriminated ingredient, slowing down the investigation procedure.

Chapter 2: Blockchain backgrounds

2.1 Centralized and decentralized ledger technologies

Blockchain can be defined as the evolution of the Centralized ledger, a tool used by public and private organizations to keep records of transactions carried out during the economic life of a determined activity. Centralized ledgers are based on a One-to-Many logic, a framework in which a centralized entity holds the power, the propriety and sets the regulations about the management and compilations of datas and accounting, in this situation the central institution that govern the centralized ledger is the only warrantor of transaction's security, modification and uploading of the ledger and trust by all the actors involved. Also with the arrival of digitalization the basements of this model have never changed, it has been revised and shaped on new possibilities allowed by technology, but the central authority mechanism hasn't changed for a long time in many sectors. (M. Rauchs, A. Glidden, B. Gordon, G. Pieters, M. Recanatini, F. Rostand, K. Vagneur, B. Zhang, (2018), "Distributed Ledger Tecnology System, A Conceptual Framework, Cambridge Centre For Alternative Finance.) . A step forward compared to Centralized Ledgers, are the Decentralized Ledgers, always relying on a One-to-Many logic, they are represented by many "satellites", organized in a Many-To-One framework toward a central authority, that are in a One-to-many relation with users. Substantially this is not a real innovation compared to Centralized Ledgers, because of the constant centrality of a single entity, but represent a way in which users place trust on nearer intermediate entities.

2.2 Blockchain: Historical background

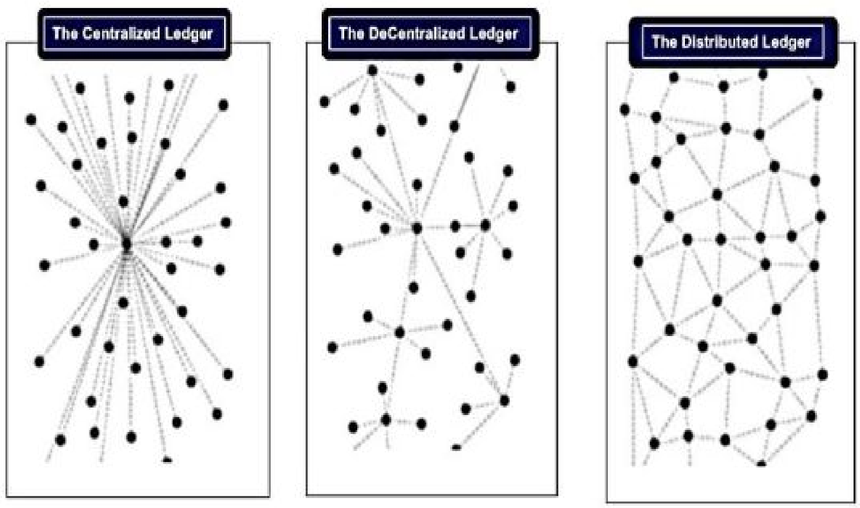
The Knowledge of Blockchain starts in 2008, with the introduction of the first cryptocurrency that relied on this new technology paradigm, known as Bitcoin. The first time that the world was introduced to this new concept was after the publication, made by an individual or a group of people still unkown under the pseudonym of Satoshi

Nakamoto, of an article called "Bitcoin: a Peer-To-Peer Electronic Cash System" in which the author defined the Bitcoin system as “a purely peer-to-peer version of digital currency that
allows online payments to be made directly from one user to another without having to go through a financial institution.” (Nakamoto, n.d.)
Initially this new disruptive technology had caught the attention of computer science and cryptography experts, that started to deeply analyse it, before the definitive and thriving notoriety among a broader crowd. We can describe Blockchain’s notoriety rise referring to Everett Rogers' theory of the innovation adoption curve (S-curve), that states that the weight and subsequent adoption toward a new disruptive technology, is distinguished by an initial period of slow adoption and then exponentially grows to a wider audience.

2.2.1 Blockchain a distributed ledgers technology

Blockchain technology relies on a new paradigm compared to the previous one, the Distributed Ledgers Technology (DLT), a database in which central authority is removed, based on a peer-to-peer logic in which every component (node) retain the shared archive of information identical for every node. This new framework revolutionize completely the concept of storing data, because the authority is no more in the hands of one Central ledger but pass through a shared consensus among the nodes of the chain, that through a set of rules manages the governance of the system. (A. Sunyaev, (2020), “Distributed Ledger Technology. In Internet Computing”, Cham & Springer.) All the DLTs possess a distributed ledger, in which multiple nodes can access and modify information, but there are different types of DLTs that present differences in the modalities that permit the consensus mechanism that will be analysed later on. One important thing to mention is that, apart from the specific type of DLT considered, once the consensus is reached, every node is instantly uploaded in an immutable way, creating in this way a web of relationship between all the users and all the information present on the chain. As a consequence, Blockchain permits reliable, immutable and openly consultable information that move along the system, making fraud actions very complicated due to the fact that to attack or damage only one node, there's the need to alter every component of the chain in the same time. **(**M.L. Perugini, (2018), "Distributed Ledger Technologies e Sistemi di Blockchain, Digital Currency, Smart Contracts e Altre Applicazioni, Cendon Book.)

Image 3: Different structures of DLT



Source: (www.bockchain4innovation.it)

2.3 Public vs Private Blockchain

Regarding the consensus protocol, cryptography, validation and control system, blockchain technology is divided in two main types, the first with a public dimension (Unpermissioned ledgers) and the second one private (Permissioned ledgers).

2.3.1 Unpermissioned Ledgers

The essential aspect of an unpermissioned ledger is that everyone can potentially become a node of the chain, and as consequence, verify, examine and validate every transaction made on it; everyone can do mining activity and participating in this way to the consensus mechanism in a voluntary way. Public blockchains are characterized by a low transaction processing rate due to the fact that the consensus mechanism require all the nodes to approve a determined transaction. Data on a public blockchain is secure as it is not possible to modify or alter data once they are validated, public blockchains guarantee an high level of security thanks to a complex consensus mechanism that force miners to highly rely on computational power which is necessary to maintain a distributed ledger at a large scale. (Heires K, 2016). .The system is decentralized and does not have any entity which supervises or controls the network, this can bring to the possibility of risky information privacy, if anyone in the system uploads sensitive information into the system there is no way to change them [23]. To achieve the consensus, each node in a network must solve a resource-intensive and complex problem (proof of work), that guarantee to the single node a level of influence, proportional to the computational resources that it's able to provide, incentivizing through rewards every transaction that is approved. Any modification have to be recorded adding the information to the genesis block in order to ensure integrity (Mik E, 2014) , therefore, unpermissioned ledgers don't have to rely on node's reliability, because everyone is encouraged to act in order to achieve the best outcome for the system, moreover transparency is guaranteed by the public visibility of every transaction.

2.3.2 Permissioned Ledgers

A more conservative type of blockchain is the private blockchain, characterized by a single entity, or a defined number of nodes, that manage the system, this brings to an higher transaction rate compared the public counterpart, resulting in a shorter time to receive the consensus. This type of blockchain is also characterized by an high degree of privacy due to the fact that sensitive information are visible only to the central entity (E.B. Hamida et al.). In fact usually the owners of systems like these are banks or big firms, able to ensure trust and integrity to the users. However, the small number of nodes that constitute a private blockchain, can cause an easier manipulation and potential hack attacks from external bad actors in comparison to unpermissioned ledgers.

2.3.3 Consortium Blockchain

Consortium blockchains represent an hybrid model between the single-entity centred and high trusted private ledgers, and the decentralized, low-privacy public counterparts (Turk and Klinc, 2017). Usually this kind of systems are build through the participation of different organizations in the blockchain, in which each organization represent one or more nodes of the system, able to record and validate transactions according to the common, pre-established rules. Consortium blockchain take advantage of the best features of public and private blockchains, indeed they are characterized by decentralization and transparency typical of unpermissioned ledgers, combined with the high efficiency process typical of permissioned ones, we can define this type of blockchain as partially decentralized (Buterin, n.d.). Moreover, for its intrinsic B2B nature, consortium blockchain can furnish additional services, including member's auditing, certifications and authorizations, all features that can facilitate collaborations between different entities. (Yang et al., 2020)

2.4 Blockchain's component

For a clearer reading to those who are completely unaware of what blockchain technology is, here is reported a short glossary of the key common components that together constitute the basement of this digital paradigm.

Nodes: computers connected to the blockchain system that using computational power can validate transactions and download data from a determined platform.

Transactions: transactions are data, in other words they contain assets that are traded and require to be validated and approved by the nodes.

Block: A collection of transactions on a blockchain network, gathered together in order to be hashed and added to the blockchain.

Ledger: public and distributed registers in which are registered all the details of every single transaction in a transparent, immutable and sequential way, inside of a ledger are contained all the blocks disposed in sequence, following a cryptographic rule.

Hash: it represent a digital function that takes an input and transform it into an output containing an alphanumerical string called “hash value” or “digital fingerprint”. Every block in a blockchain incorporates the digital fingerprint that validates the previous transaction followed by its own fingerprint, creating a “chain” relation between the sequential blocks.

2.5 Consensus mechanisms

One of the core properties of blockchain technology (public blockchains) is the absence of a central entity that controls the system, in this landscape it become crucial the presence of a distributed consensus mechanism for to guaranteeing the safety and sustainability of the network. In order to make it possible, there’s the need to establish a consensus protocol that defines the regulations that users have to accept in order to became part of the system (Seang & Torre, 2018). Nowadays, multiple types of consensus mechanism has been adopted, I will present below the two main types of protocols adopted: Proof-of-Work (PoW) and Proof-of_Stake (PoS).

2.5.1 Proof of Work

As mentioned in paragraph 2.1, the first introduction of the blockchain technology was made in 2008 by Satoshi Nakamoto, which introduced in his whitepaper the Proof-of-Work consensus protocol as the basis for the functioning of the network. It is based essentially on two fundaments, cryptography and computational power that it’s fundamental for generate consensus and validate the transaction made on the system. Further these two concept it necessary to introduce various notion in order to conceptualize the PoW functioning, such as: the reward entitled to “miners” that are essentially the nodes of the system, the quantity of reward, the length of the “Blocks” which contain transaction's information and the money supply limit. For conducting the "mining" validation process, miners has to make sure that the sender of a transaction possesses enough budget to operate and avoid double-spending attempts, for doing so they have to enter in competition with other mines in solving a cryptographic problem that will reward the miner with a reward established by the system and with fees related to the transaction. Once the solution is reached, the miner generates a block X containing the hash of the previous block, the timestamp and transactions, then the new block has to be attached to the previous blocks of the chain, waiting for other nodes to confirm the Block X, an essential process in order to legitimate transaction X. In PoW computational power is a vital part for "winning" the validation because it needs a huge quantity of energy and powerful computers in order to compete in the system, so more power a node possess for creating guesses, the higher the possibilities to resolve the problem. For having an idea of the energy's request due to Bitcoin, let's consider that in 2014 the energy used by the system was the same of the entire Ireland (O'Dwyer and Malone, 2014). Further, PoW protocol present a structural weakness, called the 51% attack which consist in the possibility that a miner or a group of them, take control of more than a half of nodes permitting them to freely create and self-validate a chain of blocks that may contain non-allowed transactions, that will be successively validated by honest miners.(Seang & Torre, 2018)

2.5.2 Proof of Stake

Different from Pow protocol, in blockchains that use Proof of Stake not everyone can come to be a miner, indeed only entities who possess a stake in the system can aspire to be a decision making node, in this case called "minter". In this consensus model computational power for resolving mathematical problems is not a requirement, instead the recompense is only composed by transaction's fees like a normal intermediary, there are not fixed rewards given by the system. The quantity of transactions contained in each block determine the total amount of transaction fees entitled to the minter who validate them, this process is designed to prevent the creation of empty or poor blocks. In PoS blockchains there is not a competition like scheme to become a miner like in PoW, instead there is selection made by the system on who should become a validator.

Usually the more stake a minter owns, the greater are the chance to be chosen, also if there are tools designed to balance this process in order to not create a disproportionate value distribution, favouring already rich minters (King and Nadal, 2012). Another issue that a consensus protocol such as PoS has to face is the so called nothing-at-stake, a scenario in which a minter can validate more than one block at the same time, possibly creating unfair behaviour and attempts to monopolize the system, to avoid this, a set of penalizations are designed for those who validate multiple blocks.

2.6 Blockchain's generations

So far it has been highlighted features belonging to the initial stages of blockchain disruptive technology, but since its first introduction in 2008 the fields of applications this digital innovation have spread along different sectors and in different ways, not limiting its enormous potentialities to a secure and efficient storage and processing of information. From the literature review it has been possible divide three different stages of blockchain life, that are, Blockchain 1.0 for digital currency (cryptocurrency), Blockchain 2.0 for digital finance, and Blockchain 3.0 for digital society (Xu et al. 2019). which are characterized by different possibilities of application in the everyday life of users.

2.6.1 Blockchain 1.0

We can position the notion of Blockchain 1.0 with the introduction of Bitcoin back in 2008, which reshaped the notion of a digital currency the so called cryptocurrency, that questioned the conventional currency's control intermediated by central Banks under the authority of governments (Dong 2018). Basically these types of systems are based on three principal tiers. The first one is the specific technology itself, the blockchain, that permits transparency and accuracy in managing transactions through decentralized nodes that reciprocally monitor and validate operations in the systems without the supervision of a central entity. The second one is composed by the protocol, that with a series of regulations assure that the properties of the blockchain are respected without any possibility of fails. Lastly, the ultimate tier is represented by the currency, for exemple Bitcoin, traded and exchanged in transactions and also used to reward miners or minters.(Swan, n.d.)

2.6.2 Blockchain 2.0

As Bitcoin founder stated back in 2010 “the design supports a tremendous variety of possible transaction types that I designed years ago. Escrow transactions, bonded contracts, third-party arbitration, multiparty signature, etc. If Bitcoin catches on in a big way, these are things we’ll want to explore in the future, but they all had to be designed at the beginning to make sure they would be possible later.(Nakamoto Satoshi, n.d.) Essentially the evolution of the first generation of blockchain consists in the decentralization of markets, based on the trading of several assets over the cryptocurrencies, including new notions such as , smart contracts, smart property, Dapps (decentralized applications), DAOs (decentralized autonomous organizations), and DACs (decentralized autonomous corporations). Essentially the real innovation of Blockchain 2.0 in confront to the first generation is the possibility of managing private and public documents like contracts, properties, financial transactions such as registrations of vehicles, derivatives, certificates, land titles, loans, bets and so on. Also identity documents like identity cards or passports can be insert in the blockchain, that for the intrinsic properties of its technology it’s able to guarantee security, precision and transparency. Cryptographic codes can be attached to physical (car’s rent, access to a hotel room etc..) and intangible assets (trademarks, patents, etc) in order to ensure the uniqueness of property, avoiding frauds and possible mistakes, as it wil be analysed in the next chapters the innovations of blockchain 2.0 paved the way to to track manufacturing goods along their supply chain in an innovative and precise way that wasn’t possible before.(Cheng et al., 2021)

2.6.3 Blockchain 3.0

The last generation of blockchain can be defined by the "digitalization of society" expression, which means that this new paradigm aims to spread the blockchain technology in new fields, not limited only in cryptocurrency, financial and business practises, such as health, food, identity, education and other components of human's social life (Swan 2015). In this scenario, Internet of Things (IoT) can be a disruptive element if applied in synergy with blockchain, to pursue advanced task that were hard to conduct in old business models. In other words, the adoption of blockchain 3.0 will allow the business operation's optimization across different industries, the possibilities of application of this distributed ledger are potentially limitless. For example, in healthcare industry, this technology can change in a disruptive way the management and storage of patient records and optimize the connections between different healthcare systems. Another case can be the development of new transportation and delivery services, improving traceability and accountability for goods as well as improving voting activity inside a specific organization, guaranteeing security, transparency and accessibility thanks to DLT characteristics (Efanov & Roschin, 2018).

Above were reported just few cases in which DLTs could be used outside cryptocurrency or financial systems, focusing on finding new ways to thrive new services and industries that don't belong strictly to the world of economics. Of course Blockchain technology is in a developing stage, especially regarding the 3.0 version, we are now witnessing a gradual adoption of this new paradigm across different private entities but the path is still long and full of new possibilities and difficulties. Indeed experts are still trying to find new solutions for the high energy consumption especially regarding PoW DLTs, thinking about new consensus mechanism in order to obtain a better scalability and efficiency.

2.7 Smart Contracts

One of the most disruptive possibilities, after its introduction with cryptocurrency, that blockchain technology permits to do is the concept of smart contracts, a new way to stipulate digital contracts between two parties, availing of decentralized, tamper proof consensus and automatic execution when the terms of agreements are met. The most important aspect to focus on is the fact that the presence of a centralized consensus brings to an high market power by the providing party. Not to mention the fact that usually in traditional agreements, there is a variable amount of human intervention, that for its intrinsic nature is less precise and uncertain compared to the functioning of an algorithm. So in this landscape smart contracts can be a turning point regarding contractual procedures such as property, money exchange and stocks in an algorithmically automated and conflict-free way (Christidis K & Devetsikiotis M, n.d.), another consequence of the absence of an intermediate trusted party, that implement and execute the contract, is the reduction of transaction fees compared to the classical stipulation process. There are many definition on this issue in the literature such as "autonomous machines", "contracts between parties stored on a blockchain" or "any computation that takes place on a blockchain". According to (Stark Josh, n.d.), smart contracts can be classified in two macro-divisions, smart contracts code and smart legal contracts, the first category can be described as "code that is stored, verified and executed on a blockchain", that in other words mean that the possibilities of execution of the agreements rely upon the programming language employed and the potential of the specific blockchain platform. Smart legal contracts instead, are designed to complement, or replace, existing legal contracts on a blockchain system, it means that the the possibilities of execution are bounded to legal, political and business institutions, so they are composed simultaneously by legal principles and smart contract codes. For example, let's imagine a typical situation in which a supplier and a buyer want to stipulate an agreement through a smart legal contract, the modalities of payment can be written in code and placed on the blockchain, while an indemnity clause can be attached on buyers demand, that would be enforced only if necessary by a court.(Alharby & Moorsel, 2017)

2.7.1 Smart Contract platforms

As mentioned above smart contracts vary depending on which blockchain platform we decide to use, here are reported three different platforms as an exemple of how smart contract can be applied in different ways:

NXT, a public blockchain platform that contains pre-setted, boilerplate smart contracts, so the possibilities of developing a digital agreement are bounded to the framework of platform's templates not allowing modifications due to lacks in scripting language.

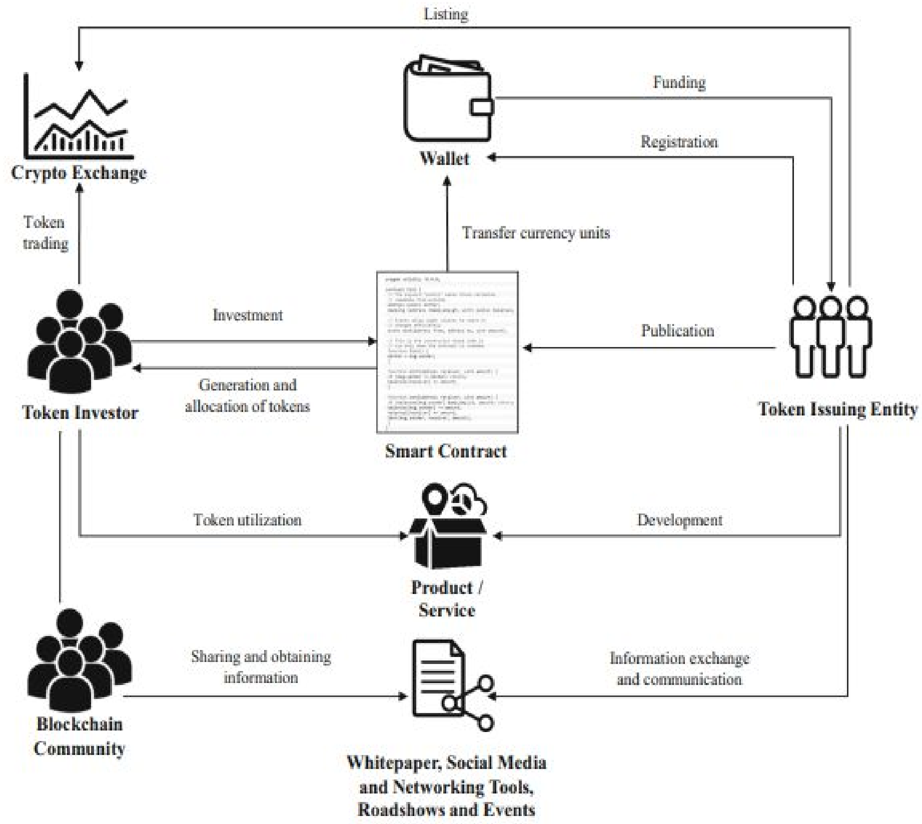
Bitcoin (Nakamoto, n.d.), the well-known first application of blockchain permits exchanges and trades of cryptocurrencies based on a stack-based scripting language, so the possibilities of writing complex codes in such a system are very constrained.(Lewis A, n.d.)For instance if a user want to set a code that repeat itself in a loop logic cannot set it in the Bitcoin system, indeed the only manner to do it, is to repeat the code every time needed, that's clearly brings to slowness and inefficiencies. (Buterin, n.d.)

Ethereum is another public blockchain system, it represent the most used platform to generate smart contracts, it permits a wide range of customization thanks to its exhaustive scripting language (Turing-complete), unlike Bitcoin system, Ethereum allows operations such as loops or withdrawals, financial contracts and even systems to designed to place bets. The platform is provided with tool called Ethereum Virtual Machine (EVM), where the stack based bytecode can be administered using complex scripting languages (e.g Python, Java, Serpent), bringing to vast possibilities of coding.(Alharby & Moorsel, 2017)

2.7.2 A Tokenised Economy

Another result of blockchain technology are the blockchain Tokens, that are assets such as currencies, securities, properties, loyalty points, and gift certificates, among others (Buterin, 2014), created on top of a blockchain using a smart contract (Massey,Dalal, & Dakshinamoorthy, 2017). We can define Tokens, as coded information stored in a decentralized ledger representing of some form of right, like the property of an asset, payments rights or the access in a determined service. The possibility of "Tokenizing" assets, products and services has led to the possibility of utilizing tokens as a form of financing for new-borne blockchain projects, is called Initial Public Offering (ICO). This process of selling tokens is similar to the fund-raising typical of crowdfunding campaign, such as Kickstarter, but with difference that blockchain tokens are tradable also after the purchase, in order to raise funds to a wider public. There few steps required to begin an ICO, the first one is the creation of a white paper in which are reported the project and the roles of the token in the project (Coinbase, 2016; Massey et al., 2017). Then in the white paper project managers have to evaluate in a balanced way the price of the token, reserving a portion of them as a recompense for developers and as a reserve for future fund raising, before selling the remaining part for the initial fund collection. Usually there are three main types of investors taking part in an ICO related to different purposes, early adopters are the firt group, that is composed by investors that buy in initial stages a discounted token that he/she will utilize later on, then there are the long-term investors who deeply consider that the project will be consistent in the long run. Lastly there are the speculators, that seek only to make profit from an higher selling price, in every project there is a percentage of investors belonging to each one of the three groups.(Chen, 2018)

Image 4: Tokenized system



Source: (Kranz et al., 2019)

2.7.3 Categories of Tokens

The ductility and different applications that blockchain technology combined with the codification of smart contract have permitted the creation of various type of crypto-tokens. The SEC (SECURITY Exchange Commission) for the moment distinguish them in only two categories, utility tokens and security tokens, in the literature there are still debates on token classification and how to catalogue them, indeed four main types of this particular tool have emerged (Pompella & Matousek, n.d.).

Payment Tokens: this category probably represent the most popular type of blockchain token, because of the intrinsic correlation with Bitcoin platform, the main characteristic of payment tokens is the capability of replacing traditional currencies or other liquid financial instrument. The functioning of payment tokens is similar to traditional currencies, indeed money supply, velocity represent and also the political landscape are a key factor in price trend. For long-term investors, this blockchain-based paradigm can represent also a value reserve, treating tokens as “digital gold” because of its limited emission.

Platform Tokens: Many blockchain systems include in their framework “internal” tokens as a tool to buy products and services offered in that specific blockchain platform (Cong et al. 2018, 2019), of course, the success of a specific platform token is bounded to the ability of the corresponding platform to fit the user’s expectations in term of solidity, efficiency and privacy performances. All these variables combined with the relative demand determine the final value of the crypto-token. We can see Platform tokens as a reduced version of Payment tokens, so limited to a specific system.

Product Tokens: this category may represent the less used blockchain tokens, the possess of one of them incorporates the right to ransom from the platform a a pre-determined quantity of product or service. This practise is typical of crowdfunding initiatives at their early stages, indeed they can represent a faithful “thermometer” for measuring the future demand in the market for a specific product or service. The price of the token should represent totally the price of the product/service offered or in alternative a determined ration between them. Dealing with this type of token can create some confusion because of the nuanced difference between product tokens and platform ones, given that beyond representing a “voucher” for ransoming products and services, they also represent an internal payment tool. Usually Platform Token and Product Tokens are described in a broader way as Utility Token.

Security Tokens: for defining what is a security token we can conform to what the Swiss independent financial-markets regulator, FINMA, published on 16 February 2018 “assets, such as a debt or equity claim on the issuer. In terms of their economic function, therefore, these tokens are analogous to equities, bonds or derivatives.” Security tokens permits the owner of them to obtain various rights toward the future cash flows resulting from a business activity and it may include voting rights, some sort of reward, or staking governance (Pompella & Matousek, n.d.). The price valuation for this kind of digital tool is usually defined by the discount of future cash flows to the moment of acquisition added to eventual specific features and conditions present in the smart contract. The main concern about security tokens is the legal regulation of them, given that they substantially represent a security instrument, in the majority position is neutrality, in fact there are not specific laws and regulations concerning digital tokens or DLT more generally, but the topic will be probably re-discuss in the near future.(Xu et al., n.d.)

2.8 Final considerations

Given this introduction on blockchain system and after having described briefly all the key component and their roles, it's time to sum up in a clear and effective way all the principal characteristics of blockchain technology, especially referring to its most disruptive version, the Public Blockchain.

Transparency: In public blockchains every block containing transaction has to be verified and validated from the network of nodes, then it's positioned on the distributed ledger remaining consultable to all the nodes in every moment, there is the complete absence of preferential positions among the users.

Reliability: trustworthiness is one of the intrinsic values of blockchain technology as consequence of its specific decentralized logic and thus almost impossible to centralize the control. Every validated transaction, is instantly registered in all the distributed nodes of the system at the same time, in this way if a node is subject to an attack seeking to damage the Ledger, information safety is guaranteed by the presence of the original transaction in all the other nodes of the system. Given this feature, the wider is the number of nodes belonging to the same network, the harder is possibility of altering and damaging the system.

Cost Reduction: another feature of blockchain framework is the disintermediation, that combined with transparency and reliability means that an intermediate third party is no more required to supervise the operation carried out by the users. This fact clearly brings to an operative cost reduction.

Solidity: from an informatics point of view the robustness of a blockchain system is guaranteed by the hash mining properties, giving a different couple of codes for every validated block, in this way every single block is distinguishes by the others and is possible to verify the accuracy of the block sequence, making impossible tampering actions.

Irreversibility: all the information are bounded to the precise instant in which they are registered on the chain, deleting, as well as altering them is impossible, every transaction is irrevocable and definitive.

Digitalization: thanks to its intrinsic nature blockchain technology possess a wide range of application in the digital word, it’s a completely game-changing tool as data and information transmission.

CHAPTER 3: BC applied in Agrifood Supply Chain

So far, it has been analysed the Agrifood supply chain system in the first chapter, and the blockchain technology in the second one, in this chapter the focus will be on the possible implementations and renovations that the combination between the disruptive blockchain paradigm and the Agrifood system can generate.

3.1 Digital Supply Network

During the last 20 years the technology improvements that have characterized the economic and industrial landscape had brought to an important shift, from the classical "Linear supply chain" to the "Digital Supply Network" (DSN), based on dynamic and market-ready connections. This transition has changed substantially the way in which firms and organizations exchange and share information, leading to innovative and complex network of integrated and interconnected operational relations. (Raab et al, Report Capgemini Consulting, 2011).

Despite the recent improvement in the management between good sold and actors of supply chain haven't eliminated complexities and possible related obstacles; indeed an accurate data collection and the relative safe storage in order to ensure a stable and consistent information flow able to reach all the supply chain's components is still an hard task to complete. Digital technologies have helped and simplified the information sharing, and allowed to achieve some important supply chain's issues, their implementation is still achieving; related to this, the main challenge for firms is to comprehend deeply the possible disruptive innovation that a specific new technology can bring to the market competition, choosing to adopt it despite of other technological options. The choice of the technology can have an huge impact on the business activity of a firm, it can potentially determine a sudden rise of economic activity or its decline. (A. Ganeriwalla, M. Casey et al., 2018).

DSN have achieved numerous improvement in managing supply chains across the Globe thanks to the new digital possibilities, but the challenges for supplying networks are still copious, paper-based process are very common even now, and the decision making process among the supply chain actors is becoming continuously more complicated because of many separated Information Systems, which hardly communicate with each other, bringing to an isolation of single business units.

3.2 Blockchain can be a solution?

Agrifood industry, like every other industrial sector, have to face problems of coordination and administration of data inside complex ecosystems, indeed many challenges that characterize the Supply Chain Management can't be faced with the actual technologies. Especially referring to cooperation solutions between the parts involved represent the key turning point for sharing information in more integrated and interconnected system, in which firms work together in order to optimise the flow administration of industrial processes, marking a breaking point with traditional linear structures. With these premises, it appears clear that Blockchain technology, due to its intrinsic characteristics can play a crucial part in changing the DSN. (Kane, et al)

From an operational perspective, blockchain doesn't represent a more efficient solution compared to centralized ledgers used for data storage, in some cases, blockchain can also be seen as a disadvantage from a power consuming perspective and for an actual lack of knowledge from possible user's side. However the implementation of such a technology can bring various advantages, blockchain technology is a tool that permits to reach consensus in the execution of a shared activity, conducted between different parts that don't necessarily have trust in each other, but they share a common final goal. Trust is the central concept that so far have legitimated the presence of an intermediate third party designated to insure trust and the responsibility to validate transactions, these central authorities can be substituted by the intervention of blockchain platforms. This technology can be defined as "Trustless", thank to its decentralized and distributed framework and its tamper-proof consensus mechanism, it permits to users of a determined platform to work in a trustworthy environment, without the need of any middleman, trust became a prerequisite of the system itself.

These characteristics fit perfectly in the Agrifood supply chain perspective, in which multiple actors that have a common goal (proposing a proper food offer for the final

consumer), but at the same time they are separated, that can cause lacks in reciprocal trust, can benefit in a substantial way from blockchain implementation.
Concerning data sharing inside a transaction, it's important to highlight that an exhaustive dialogue between the two contracting parts, can diminish the cost transaction related to it. This cost reduction can redistribute the economic resources, directing them to develop more specialized, market-oriented business models, in order to deliver to the final costumer adequate goods and services. Blockchain permits to establish trust in all that types of B2B relations in which a third party is not required, in such a scenario the two sides, because of the absence of trust, resort to costly negotiations. Indeed when two firms share reciprocally information, intellectual properties or data, trust among parties is dictated by contractual conditions, designed to guarantee fair behaviours and avoid frauds, of course designing the perfect contractual conditions for both parts is quite impossible due to information asymmetry and lack of visibility on the other part's activities. Nowadays, the long and complex production systems, cause an obstacle to monitor in an accurate way all the processes and data flows that take part in the integrated system, blockchain can play an intermediary role, providing an infrastructure in which is possible to create trust and permitting trades to happen. (Ganeriwalla et al., n.d.)

According to (Leng et al., 2018), the applications of blockchain technology in the Agrifood supply chain system can have important positive outcomes, which can be sum up in three main parts, namely:

3.2.1 Adjustable matching between supply and demand:

In a fully decentralized ledger every user (node) can potentially set in the system all their commercial conditions, transmitting them along the entire system. Given that, every supplier who represent a node in the system can easily meet the appropriate "client" among the nodes represented by possible acquirers. As soon as demand and supply are matched between two nodes, the transaction is registered in the ledger in an immutable and transparent way, in a manner that avoid completely every possibility of failure, thus preventing every dispute that can happen in future stages due to contractual misconceptions.

Another consequence of this adaptability in trades, is the fact that also small-volume food producers can participate in a more elastic and favourable-conditions way in the market, lessening the asymmetric contractual power of bigger actors. From a demand-node perspective, the possibility to fix determined standard and thresholds in order to accept the supply goods from another node, permits to choose in a selective way the best option.

3.2.2 Decentralized collective maintenance:

Centralized ledger have represented the only framework to administrate information and transaction flows so far, limiting the users of a determined system to the dependence of the centralized entity, exposing them to possible unfair and opportunistic behaviours derived from the central entity. The absence of such central administration enable every user to possess the same information of the other nodes, and at the same time to participate to the mainteinance of the whole system. Blockchain beyond guaranteeing a secure, tamper-proof and trustable consensus mechanism can also offer a wide range of agrifood supply available in a public and decentralized service platform.

3.2.3 Smart Contracts:

Smart contracts can record the functioning logic and contractual clauses in the form of codes, which can potentially fit with every programmable condition. Whenever demand and supply of resources, inside a blockchain platform, are aligned, smart contracts automatically execute the contractual agreement in a tamper-proof, encrypted way, without the need of a third party participation.

Regarding platforms involved in public services, smart contracts can be a solution able to ensure authenticity and robustness in transactions, as well as a tool to prove in a transparent and permanent way the chronology of transactions that take place, that is a powerful way to improve the public reliability of a determined service.

3.3 Blockchain combined with other technologies

As analysed in the previous chapter, blockchain technology, because of its intrinsic framework, can solve the third party issue, while it cannot contribute for what concern trust between the two contracting parties. Indeed, also if blockchain permits the administration of data in a tamper-proof, and trustable way, the authenticity of the records coded is in the hand of who codes them for the first time; these challenge can be faced by integrating blockchain systems with emerging technologies belonging to the Fourth Industrial Revolution. The role of these technologies in the Supply Chain Management, can be seen as the substitution of human role, considering technologies such as Artificial Intelligence and Internet of Things, as more trustworthy than human intervention in order to constitute a more precise and fraud-proof supply chain. The crucial point to focus on, is the creation of completely digitalized supply chains, in which physical objects can interact reciprocally thanks to the combinations of various tool in order to reach an efficiency that wasn't possible so far. Blockchain can be seen a key factor in such a process of trustworthiness delivery regarding Agrifood supply chain, but not as a stand-alone actor, indeed it will be analysed the potential value delivery caused by the combination of blockchain system and the various possibilities offered by the fourth industrial revolution (Niforos M., n.d.).

In the next section there will be presented the principal disruptive technological innovations that can create synergies combined with Blockchain:

3.3.1 Artificial Intelligence and Machine Learning

Artificial Intelligence (AI), is a technology able to emulate and replicate human behaviours and perceptions, in order to execute actions following an human logic without the physical intervention of any person. The principal steps of AI functioning are: learning (collecting information and elaborating them through algorithms), reasoning (get conclusions from initial information) and self-correction.

Machine Learning (ML) is a form of Artificial Intelligence designed to enhance the precision of the artificial thinking process, it consists in the elaboration of inputs through statistical tools in order to forecast possible results in the minimum range of alternatives. AI has already covered important role inside supply chain at a global scale, it is useful to optimize various logistic operations, for instance, it can avail of historic data of Supply Chain to predict the time of delivery of a specific Food product, considering also various variables such as weather, traffic or other circumstantial events. Regarding food products that are easily damageable due to humidity or temperature issue, they can be monitored during their travels along the supply chain and eventually some modifications to the packaging and transportation mode can be applied, using AI and ML, basing the decision on damage claims and other liabilities based on SC actions.(Kshetri, 2019)
It’s simple to imagine that an integration of AI with the Blockchain technology can have important outcome in terms of traceability, safety and transparency of Agrifood Supply Chain, for example physical sensors can be used to keep track of transportation conditions, recording the information into the blockchain, ensuring final costumers and retailers, that regulatory-approved guidelines are respected. Basically, Artificial Intelligence combined with Blockchain creates a specular copy of real object into a digital version, a “crypto object” containing specific details about physical and chemical characteristics as well as additional information such as location, creating a unique “fingerprint”. (Kshetri, 2021)

3.3.2 Remote sensing and satellite imagery

Using satellite imagine for recording data and enhancing the trust threshold, it’s a practise that is emerging during last years, the combination of such a tool with blockchain technology can be an traceability boost for the Agrifood Supply Chain. In other words, using smart contracts, there is the possibility to create interactions between business entities of a determined Supply Chain and owners of satellites or remote sensing devices, that can acquire the images from their devices, and then sell them through predetermined contractual bonds.

As an example, the well known retail company Walmart, in 2019 filed a patent called "Cloning Drones Using Blockchain" published by the United States Patent and Trademark Office (USPTO). The publication contained a detailed framework in which blockchain technology is depicted as a communication channel between drones, making possible an information flow between these devices designed to assist during the supply chain operations (Foxley W., 2019) . Walmart published another patent application back in 2017, in which suggested the use of drones for good delivery (Higgins S., 2017).

3.3.2.1 A practical example: Bext360

So far we have highlighted two technologies that combined with blockchain are able to contribute for a more trustable and transparent Agrifood supply chain, namely Artificial Intelligence and Satellite Imagery, below it's reported a company that combines these three elements together for the tracking of Coffee beans.

Bext360 is a start-up based in Denver, Colorado specialized in the tracking of coffee thanks to a combination satellite images, blockchain, and AI. The whole process starts in Uganda, where coffee beans are analysed and catalogued following strict quality rules, the tools used to assess the characteristics of coffee cherries are technology machine vision, AI, IoT, and blockchain. 3D scans are able to detect the best coffee beans for the market, adapting the price of each bean to its characteristics, the bigger and more mature they are, the higher the selling price. The lots of Coffee beans, are successively linked to crypto-tokens, representing their value, that increase proportionally to their advance along the supply chain. The farmers are paid as soon as their goods are analysed by Bext360 machineries, successively after the necessary food processes, thanks to a specific application programming interface, wholesalers and retailers can integrate their websites and marketing interfaces with specific information about the coffee sold thanks to Bext360. In the process also satellite images are used to ensure that the crop follow security and safety standards before coffee bean are sold to food processors. All these information taken along the supply chain are recorded in a transparent and irreversible way on the Bext360 blockchain ledger that, with the support of AI and remote sensing devices, deliver to final consumers a trustable panoramic of sustainable and fair practices.(Kim Vu, 2018)

3.3.3 Internet of Things

The internet of Things is a concept introduced for the first time by the the co-funder of Auto-ID Center in 1999, the concept represent an evolution of the Internet, in which physical object can communicate and exchange information with each other, thanks to the integration with electronics, softwares and sensors, diminishing in this way the need of mediation. As stated the technological research and consulting firm Gartner, IoT can be divided in three different layers: the edge, the platform and the user.

The first one is the physical position where the data flow starts, typically an object, here data can be formatted in order to be processed in a more efficient way. Then the information flow is transmitted to a cloud storage site, namely the platform, in which algorithms examine the data received, according to the results the platform choose to take some actions or not, eventually accumulating them for the future. The latter is the user of the specific device.

The data flow can be approached in three ways. The first one permits the consumer through an application programming interface query data, interfacing with the platform accordingly to the software's design specifics, the second one is a more automatized process, it consist in autonomous actions or warning to the users, whenever a specific combination of events happens. The third one is a mix of the first and the second ways.(Laskowski N., 2016)

As concerns Food traceability and monitoring systems the opportunities made possible by the integration of IoT instruments in the Food Supply chain are vast and continuously in development. Indeed in 2019 Juniper Research conducted a study in which they forecasted $31 billions of savings from food fraudulence by 2024 on a global scale.

The "virtualization" of supply chain made possible by IoT can revolutionize the traditional way to monitor and trace-back food products, from the seed stage to retailer's shelf, technologies such as sensors and Radio Frequency Identification play an important role in shaping the future management of SC. Specific features of food and the relative transportation such as humidity, chemical and physical details can be recorded, analysed and sent to specific business area of the SC in a completely automated way.

For instance, a combination between a consortium blockchain called Hyperledger Fabric, IoT technology and radio frequency identificators has been used by Golden State Foods, a huge producer of hamburger able to furnish more than 400.00 units per hour, to follow the movements and temperature good sold and broadcast the information to all the players of the system. Whenever an irregularity is detected, the system immediately warns the interested part, avoiding the insertion in the market of possible foodborne diseases, another feature is the inventory optimization permitted by the system, able to detect the quantity of meat contained in the designed places, giving restaurateur the possibility to organize in the most time-efficient way the flow of material. Smart contracts play a crucial role in communicating with IoT devices, for example executing automatically the terms of a contract whenever the shipment is completed or in the insurance field, the smart contract, with the help of IoT devices can verify if the insurable event, like a fire inside storing facilities, truly happened.(Kshetri, 2021)

3.3.3.1 A practical example: AgriBlockIoT

Caro et al.(Caro et al., 2018b) propose an integrated solution of a blockchain platform named AgriBlockIoT in the agriculture supply chain, designed to offer transparency, auditability and reliability of data storing, availing of blockchain infrastructure and IoT. The system is designed on three different layers, in which blockchain technology represent one of them, taking advantage of the possibilities related to modern devices (gateways, mini-PC, etc), that can be used as nodes of the bockchain system, empowering decentralization, robustness and trust in the functioning of the whole system. The three layers proposed are:

API: Application Programming Interface designed to exploit blockchain capabilities and adapting them to other applications, permitting malleable integrations with already existing software systems (ERP, CRM, etc.).

Controller: an element designed to transmute records of data into useful and understandable information for the first layer.

Blockchain: this technology represent the basement of all the AgriBlockIoT, the system thanks to smart contracts exploit the capabilities of blockchain, shaping them in order to serve the system in the best way. Selecting the proper type of blockchain selected is fundamental for the final results that an enterprise seek to achieve, indeed AgriBlockIoT has been tested with two distinctive Blockchain systems, Ethereum and Hyperledger Sawtooth, the results were diverging, in fact the first system observed better outputs in in terms of latency, CPU and network usage.

Of course in order to implement properly the whole AgriBlockIoT system, Caro et. Al(Caro et al., 2018b) conducted a bottom-up research in order to highlight all the requirements necessary to provide a detailed history of the food ready to be sold in the market, from harvest to the retailer shelf. The only previous requirement before analysing the following conditions is that every actor that take part in the supply chain have to be registered as a user in the blockchain system, in other words they have to possess the requirements to register every operation taking part during the process. Here are reported the resulting requirements of the research:

Raw Materials Purchasing: farmers and suppliers record in the blockchain the informations and details about acquisitions and sales of raw materials, listing them following technical characteristics and quantities. Producers can use also smart-tags such as QR codes to keep track of the records in more automatized way.

Planting: at this point producers have to insert planting process details in the blockchain. For example the quantity of seeds used to grow a determined crop can be monitored by physical sensors, that immediately send the information to the chain, eventually smart contracts can creating additional records whenever an irregularity is observed.

Growing: thanks to physical sensors, data can be recorded with a constant frequency, in an automatized way, keeping track of all the growing steps that a determined food have to follow in order to be proper for the sell, also in this case irregularities can be reported in the chain.

Farming: farmers have to upload in the system data regarding the multiple steps that each crop has to follow before the harvest, such as irrigation, fertilizing etc. Physical and chemical sensors combined with smart contracts can follow the process in an automatized way, signalling and recording eventual irregularities during the process.

Harvesting: information about the harvesting process, like the date of collection, have to be stored in the blockchain, like the previous steps, sensors and smart contract can analyse if the crop is in line with the standards required by legal requirements.

Delivery to processor: rights of ownership are transferred from farmers to the processors, the operation is made entirely on the blockchain system in a transparent and irreversible way. Details about quantity and date of shipping are recorded on blockchain in order to avoid possible incongruities.

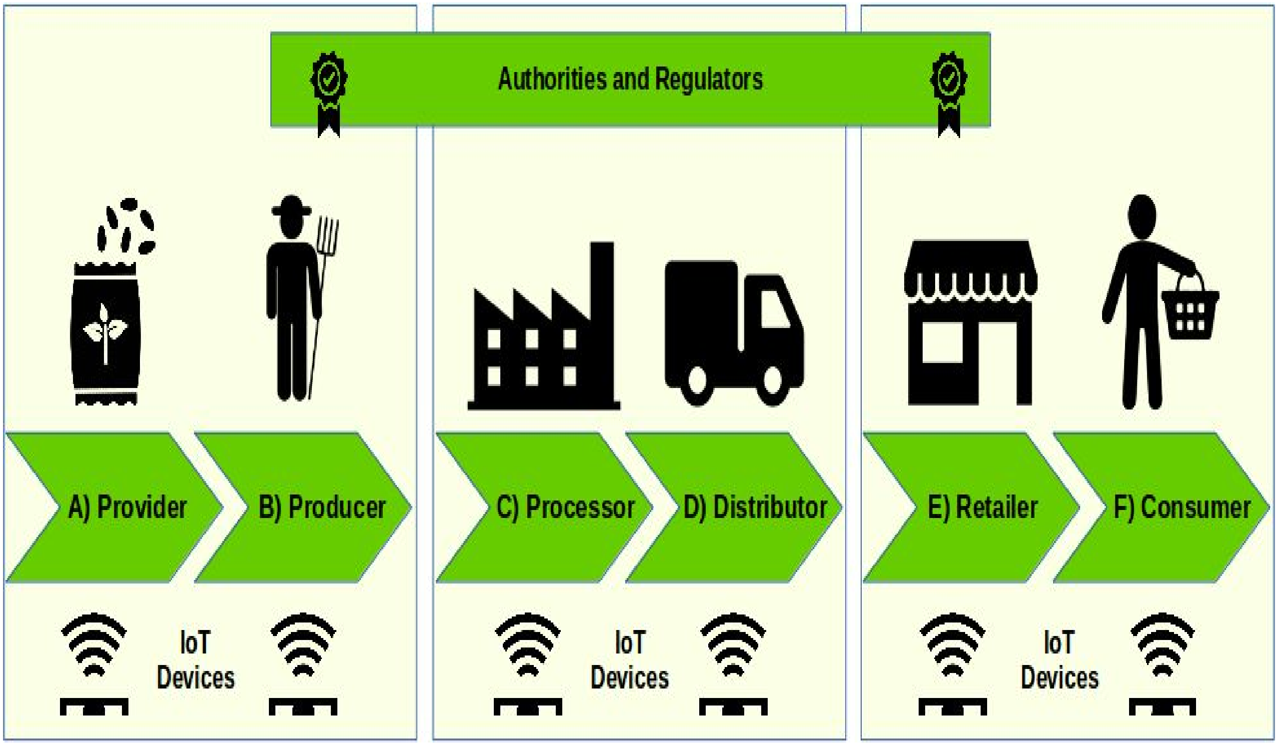
Processing: the operations at this stage can vary consistently depending on the type of food that is being processed (washing, cutting, packaging, etc.), considering for example the packaging process, sensors can record in the blockchain the quantity of product received, the related necessary quantity of packaging and ultimately eventual losses of materials during the operational stage. Obviously also at this stage sensors can automatically detect irregularities such as an excess in the use of packaged material.

Delivery to retailers: rights of ownership are transferred from processors to distributors, the operation is made entirely on the blockchain system in a transparent and irreversible way. Sensors can eventually detect incongruences in the amount of process food delivered and signal it to the competent area.

Retailing: retailers record in the system information about the inputs delivered from processors, while with physical sensors they can monitor the current state of sales and store them in the blockchain system eventually signalling irregularities to the system.

Consuming: the final step consists both in the storage of information about good sold by the retailers and from a consumer side, giving final users of Agrifood supply chain the possibility to monitor in a trustable way the complete journey of the specific product that he/she wants to buy, this can be made possible through the utilization of tools such as smart tags and QR codes, combined with specific Apps.

Image 5: AgriBlockIoT



Source: (Caro et al., 2018b)

3.3.4 Optical scanning technologies

Thanks to new possibilities offered by modern technologies, it is now possible to attach to physical objects QR (Quick Response) codes, bi-dimensional tags that can be scanned by machines equipped with optical scanning technologies, giving the possibility to obtain codified information about the specific product tagged. In the fiels of Agrifood supply chain traceability, QR technology combined with blockchain , can play an important role in tracking the journey of goods, not only to the ones who specifically work in this field

but also for final consumers, which can monitor the information attached to products only with the use of a smartphone.
A practical example: Chainvine and Danone's farm-to-fork

3.3.4.1 Chainvine

In the wine sector, especially regarding old and fine wines, is often hard to verify the fairness of the information provided, because of the specific properties of producing the alcoholic beverage, that can require many years of processes and conservations. Buyers of such products are often exposed to fraudulent behaviours, because of the average lack of knowledge and necessary information provided by producers, indeed in the majority of times the only details available on labels are scarce and incomplete. Globally it's estimated that roughly the 20% of the wine sold follows a fraudulent logic, estimating a total amount of US$1 billion of counterfeit profits annually (Mathieson MA, 2017). Another example is Chinese wine market, in which it has been highlighted that more than an half of the bottles priced more than US$35 contain fake information, resulting in more than 30,000 counterfeit bottles vended every hour in China (Ambler P., 2017).
Chainvine is a UK based firm, focused in supplying digital solutions and services in order to achieving more exhaustive traceability in wine sector, with the help of blockchain, QR code technology and IoT. The traceability process starts a tagging process of QR codes on every single bottle of wine by wine makers, containing information about the making process that instantly are recorded on Chainvine's blockchain. The enterprise in order to guarantee the respect of international laws, signed a collaboration with the a law firm (Lewis Silkin), specialized in import and export trades (Treiblmaier H., 2019). Every time that a bottles move forward inside the supply chain the event is recorded in the blockchain layer, thus creating an immutable and tamper-proof chronicle, that is continuously verifiable by customs agents and government officials thank to QR code consultation. Naturally, during all the journey, from vineyard to retail stores, physical sensors continuously monitor the position and the physical state of bottles (temperature and humidity) and with the help of IoT instruments, insert the informations in the blockchain, guaranteeing that all the indispensable conditions are

met. Eventually there is the possibility to note a bottle as “drunk” in order to avoid an unfair reutilization of that label. Using Chainvine solution not only represent a valid solution to the wine counterfeiting problem, but also reduces the need of recurring to paperwork and other sort of traditional documents designed for trades, always ensuring fairness and compliance with law.(Chainvine, 2019)

3.4 IBM’s blockchain-based Food Trust

One of the most important initiatives regarding a decentralized, blockchain based, traceability solution for Food and beverage supply chain is represented by IBM’s Food Trust solution. This platform was founded in 2017, IBM was supported by ten foundation program members including big firms such as Nestlè, Walmart and Carrefour(IBM, 2018)
.
The platform is based on a Software as a Service logic, grounded on the blockchain Linux Hyperledger Fabric system, a paradigm that permits open and decentralized governance for empowering food traceability systems for every enterprise who decide to join the platform (Hackett R., n.d.). Food Trust was officially inserted in the Market in 2018, open to every size of Company, the range of prices for the subscription varies from US$ 100 to US$ 10,000 (Allison I., 2018), once the operation is completed the organization will designate a specific supporting team with the task of recording and integrating all the pertinent information. IBM’s blockchain rely on “IBM cloud”, that guarantee adherence to the standards needed in the Agrifood tracking system at a global scale, always ensuring interoperability between the IBM’s system and the subscribed firms (Costa C., 2020).

IBM’s solution rely on a private and permissioned blockchain platform, a structure that fits properly for enterprise systems, in order to guarantee scalability, elaboration’s speed and privacy, making data visible only for authorized users of a specific network, always relying on the tamper-proof and irreversible features of blockchain technology.(Costa C., 2020).

Food Trust gives costumers the opportunity to benefit from four integrated modules, supporting them in facing the increasing complexity to ensure a faithful and secure Food traceability system, creating value for the entire network of subscribed enterprises (IBM., 2018):

Data entry & access: IBM's system permits to users such as retailers, processors and distributors, to record the Digital Supply Chain's business operations, such as transactions and certifications; regarding inventories, registers of orders, suppliers information etc..

Tracking: this module permits to monitor the path of products from farm to fork, keeping track in real time of the exact position of goods, with the aim to create trust and security for final consumers. In order to guarantee the functioning of Food Trust system, all the data about the specific goods have to be recorded in the Network by the participants, once the operation is done, the authorized user can track the product by typing a unic code called GTIN25, the purchase order or the product's name.

Fresh insight: this module permits users to benefit from an analytical system able to optimize the Digital Supply Chain processes such as the production process, packaging and purchase orders, the disposable information are constantly updating, also thanks to various extensions which can supply a great quantity of data, especially from IoT devices.

Certifications: thanks to this last module, firms have the possibility to dispose of a solution that permits to manage the activity of "Certification" and "Identification" of products, with a particular focus on the ones that need to be attached to an "ID card". The Certificates can help firms to ensure that a specific production system is properly supervised, if a supplier is legally in compliance with conducting the business activity and with sector's standards. Thanks to the "Certificate Manager" tool, the system is able to identify and archive all the Certifications needed, creating an "Added Value" for the product itself and for the producing entity.

3.5 Benefits of Blockchain applied to Agrifood SC

So far it has been described the benefits that blockchain applied to Agrifood supply chain can have in the present and in future years, exposing also some use cases in which the disruptive technology has been integrated successfully in food traceability programs. Of course, the potential is still very large for future development of this collaboration between blockchain and Agrifood system, indeed it is at an early stage so far, but the main benefits are already visible, but like every other technological innovation, also this one has to face various challenges and possible obstacles. Let's analyse them.

3.5.1 Enhancing food safety

Blockchain can have a thriving role in contributing to a realization and reinforcement of food safety programs at a global scale, especially in developing countries, in which foodborne diseases are more probable to happen. As the case of China, in which roughly 300,000 babies contracted a foodborne disease due to consumption of contaminated milk contained in an infant beverage, back in 2008 (Huang Y., 2014). This is only one example of food consumption's complications in China, indeed Chinese Government has focused its attention to food safety programs, collaborating with IBM in its Food Trust project, supported by Walmart, with the aim of increasing trust and transparency and ease of traceability for what regard's the retailer's food products present in the Market (Economist, 2017).

3.5.2 Brand awareness and reputation

Often consumers are doubtful regarding what food producers a reseller declare on their good sold, concerning what is contained inside of them and their provenience, blockchain technology can play an important role in order to reduce the doubts regarding food traceability and quality disclosures. If a company is able to integrate blockchain into Agrifood SC in a proper way, the result can only be positive, both from a reputational and practical point of view, regarding company reputation among consumers and food illnesses' reduction. An additional value delivered to final consumers, in order to increase integrity and trust, can be achieved thanks to the synergy resulting from the combination of blockchain technology with alternative technologies such as IoT and Quick Response (QR) codes; thanks to these new solutions, unfair and fraudulent actions are impracticable or remarkably high-priced.

From a practical point of view, taking as an example QR technology, it could be feasible to insert in the market counterfeit goods and pass them off as original ones. In order to do that, fraudsters can purchase authentic goods attached with the unique QR code, detaching and positioning the original code to a fake product. The operation is simple from a theoretical point of view, but typically whenever a costumer buys a specific QR-attached product, he/she can scan the code to check some relevant information, "burning" the code itself, making impossible to recycle the same code for another product (Alba D., 2018). This situation lead to a very expensive way for counterfeiting products, making the process disadvantaging.

3.5.3 Transparent and homogeneus value delivery

If we consider the global food supply chain, we will discover that a vast amount of every day products that we consume came from developing countries. As an example, regarding tropical food products coming from second and third word, coffee production represent almost an half of total exportations directed to developed economies such as Europe and US, with a thriving increase of roughly 550% during the last 60 years (Kshetri, 2021).

Considering the example analysed in paragraph 3.2.2, the blockchain based traceability solution Bext360, can be considered a good sample for highlighting the capability that blockchain technology can have in shaping a more fair and homogeneous value delivery at an aggregated level, across a specific industry. Indeed, increased visibility for small producers, can result from a transparent and complete traceability system, leading to an increased visibility of every single component of the supply chain. For instance, Bext360 requires that every single site designated to analyse and assess coffee beans characteristics in order to be sold has to be possessed by local businessman or local cooperatives (Clancy H., 2017). In this way local producers can acquire more information about market's trend and preferences, orienting their production in order to better match the preferred flavour for final consumers, in order to obtain the maximum profit from their sells.

3.5.4 Efficiency gain

Thanks to blockchain paradigm, concerning food traceability, enhanced efficiency and speediness of intervention is reachable, Walmart intervention in China regarding infected food can be a proper example in terms of effectiveness and promptness in term of suspected food withdrawals from the market. Thanks to the precise traceability process permitted by blockchain use, a company is no more forced to remove a complete product line whenever a food diseases is identified, instead the company can identify the specific suspected lot and withdraw it from the production line in order to be analysed. This simple change can lead to important cost savings for the future of a specific company, such operations are also made faster by the digitalization of the whole supply chain, thanks to digital-supported food's specifics such as batch number, shipping time, geo-localization, temperature and humidity of storage, all stored in a permanent and secure way on the blockchain ledger. All these new peculiarities permit to automatically detect a suspected lot and proceed with the recall in a span of time of few minutes, an incredible result compared to the old and traditional blockchain-free traceability process, in which many days were necessary to pass before an accurate identification of poisoned food (Yiannas F., 2017).

3.5.5 Transparency and Accountability in SC

Thanks to the huge quantity of information stored in the blockchain, derived from the various type of IoT sensors and other supporting technology tools, the actions and processes made by the various actors in the supply chain (growers, producers, processors and retailers), exposing them to possible responsibilities whenever a food

fraud emerges. In this way, it can be resolved also the power asymmetry problem consisting in big and international retail companies taking advantage of smaller suppliers, that often were subject to unfair behaviours, thanks to blockchain every single component of the system is accountable for its own actions, thank to tamper-proof and permanent record keepings.
In terms of Trasparency instead, the always increasing needs of final consumers in terms of disclosures about the food features that they purchase, thanks to technologies such as QR codes, every single consumer can check in a completely free and prompt way the origins and processes that characterize a determined product. Nowadays, big retailers companies such as Walmart, Nestlè and Carrefour are implementing blockchain traceability solutions, not only for a more transparent information delivery, but also because complete disclosures have become a competitive advantage in the actual Market, composed by always more demanding clients.

3.6 Challenges of Blockchain applied to Agrifood SC

So far it has been analysed and highlighted the synergies and development that an combination of blockchain technology and food supply chain have brought so far and what can possibly result in the next future. But obviously these innovative solution can face various problems and obstacles during its implementation at a global scale, indeed in the next section it will be described the possible concerns that characterize the realization of a fully blockchain-based and decentralized food supply chain.

3.6.1 Developing countries' skill deficiency and learning capacity

Being a fully digitalized, power-consuming tool, blockchain implementation represent an important task in terms of skills, knowledge and learning capacity required, especially regarding food traceability at a trans-national level. This can be an important problem if we consider developing countries situation, in which is common to observe a lack in competency, technological architectures and specialized abilities and governmental bodies. As an example, Walmart intervention in Chinese food market, in order to prevent the country's food diseases issue, needed a great involvement in terms of instruction about the proper use of blockchain technology, representing a great cost in terms of money and time, this aspect can be a discouraging factor regarding such multinational interventions in poorer countries.

At this point it's proper to say that blockchain technology is mainly formulated for multinational companies that possess the resources and capabilities to exploit the full potential of such a system, it's illogical to think that poorer countries can autonomously manage in the best way blockchain systems combined with the use of modern and sophisticated supporting technology analysed in previous paragraphs. Given that, it's clear that the willingness of big companies and first-world governments are essential in order to implement blockchain in food SC at a international level, including in the beneficiaries group, also the actors belonging to the initial part of the supply chain.

3.6.2 Small-scale business volume

For the reasons cited above, blockchain implementation in small businesses and developing economies needs the proper background of technological support and consistent economic resources. One of the factor leading to poor food's information, if we consider poor production territories such as China or Africa, we can easily deduct that often, on the harvesting site, isn't available a proper Internet Connection, a focal requisite in order to run any supply chain traceability based on a digitalized logic.

The cost obstacle not only regards poor economies and developing countries, but also low cost retail food present in shelves of every retailer or food products with a limited trade volume. The main issue in these cases is that the high cost of running properly a blockchain based traceability system might not be compensated if applied to low cost food, or in the case of limited business volumes, the producing company cannot exploit economies of scale in order to earn additional profits from the implementation of such a technology(Wood A., 2018).

So far we have highlighted problems related more to a social and economical sphere of blockchain application in Food SC, but there are also concerns about technical aspects of it, let’s spot them:

3.6.3 Scalability and storage capability

The bigger is the quantity of validating nodes inside a determined blockchain layer, the better it is in order to insure a safe storage systems for the information management and data handling (Koteska et al., n.d.) . An high number of nodes is necessary also to ensure a sufficient decentralization of the whole system, but this aspect is not exempted by controversies, because according to various researches, the number of nodes is inversely proportional to some important characteristics of blockchain: processing rate of transactions, transmission latency and the size of data (Koteska et al., n.d.). Indeed with the amplification of nodes and transaction’s number, the quantity of information increase and consequently the storing process become slower (Zheng et al., 2017). In an agrifood supply chain management system, there is a continuous addition of transaction’s data requiring a bigger capacity for the validating node and consequently bigger capability for the node itself, all these aspect can lead to an extended time of latency and synchronization for newcomers (Reyna et al., 2018).

3.6.4 Privacy concerns

As it has been analysed in Chapter 2, blockchain technology, especially regarding public decentralized ones, permits to every authorized user to examine every transaction taking part in a determined system, this aspect represent a great innovation in terms of trust and transparency, but it can represent a double-edge-sword considering privacy related issues (Reyna et al., 2018) . The privacy aspect can became a problem whenever there is competitiveness among different users of a determined system, let’s think for example about two suppliers of the same product, that may prefer to hide determined sensitive information that could create a competitive advantage for the rival counterpart (Forbrig et al., n.d.).

Many complicated attempt of additional encryption of sensitive information has been applied during the last years, but so far no one of them was able to secrete simultaneously the sender, the receiver and the amount (Zhao et al., 2019).
One thing is sure, the privacy issue represent a great concern in designing these type of platforms, the creators indeed has to carefully balance the transparency of information in order to avoid opportunistic behaviours but at the same time guaranteeing the openness and fairness of transaction, that characterize the main innovation of blockchain technology (Zhao et al., 2019).

3.6.5 Legal concerns

Another important concern is the international dimension that characterize today's food supply chains, that comprehend in their framework multiple countries and of course, different legislations. Summed to this geographical aspect, it has to be considered also the decentralized authority and absence of disclosure's limitations that can be a conflictual aspect regarding determined normative regimes (Atlam et al., 2018). In this landscape, it became clear that in the near future there is the need of formulation new rules and regulations regarding food and beverage system at a global level, in order to harmonize and favour the collaboration between different legislations with the aim of improving the value delivered to final consumers across the world (Crosby Nachiappan Pradan Pattanayak Sanjeev Verma & Kalyanaraman, 2016).

3.6.6 High cost and energy demand

Numerous studies has highlighted a proportional correlation between the dimension and complexity of a specific blockchain platform and the required computational power in order to create and add new blocks to the chain. At the same time, in order to increase the computational power needed, the system need a greater quantity of energy to be employed, especially regarding proof-of-work (PoW) consensus framework, in which the modalities of energy utilization can be divided in two modalities (Zheng et al., 2017):

- Mining process: the consensus mechanism requires the solving of an high energy consuming mathematical problem, the higher is the computational power of a specific node, the shorter will be the time needed to solve the "puzzle"
- Peer-to-peer contacts: communications between users of the same blockchain system have to pass through edge devices to ensure a networked framework inside of the system, requiring additional energy (Fernández-Caramés & Fraga-Lamas, 2018).

3.7 Reassuming considerations

As we have seen in this Chapter the impact of blockchain in food supply chain management and the related traceability can have significant positive repercussion and distribute an additional value to various actors across the entire system. Of course, representing an important change in the shape of complex and global-based production systems, this innovation brings with itself also a great number of questions and possible obstacles, comprehending many factors such as ethic, politics, transnational trading legislations and consumer's health factors.

One of the biggest problems so far is the asymmetry of adoption possibilities of developing countries, which are characterized by poor resources in terms of money, employee's knowledge and technological devices, in order to autonomously develop and implement a proper blockchain based supply chain system; so far the only possibility for these economies is to rely on multinational companies who are willing to put resources in term of money and time, in order to implement traceability systems able to prevent food illnesses and improve the welfare of a determined country. Of course this situation could possibly lead to opportunistic and unfair behaviours by powerful actors.

CHAPTER 4: Emerging Issues

4.1 INTRODUCTION

In this Chapter the application of blockchain technology will be classified and analysed following various organizational theories, in order to be able to pose significant questions for investigating the actual stage of blockchain application and its potentialities for the future in supply chain management. The questions that will emerge from this literature review will be a starting point for the research questions of the next chapter's company analysis, consisting in analysing a sample of start-ups using Cruchbase, in order to assess the actual and future utilization of blockchain technology from emerging companies.

Organizational theories are considered an useful tool especially regarding young field of knowledge such as blockchain use in agrifood system, because a proper application of such theories can support researchers in highlighting the potential positive intervention of innovative solutions that may be characterized by a lower presence of researches conducted so far. Organizational theories can be described as the "frame of reference which helps us to make sense out of the events which we observe. It facilitates the process of bringing together and linking events which seem to be randomized and without relationship into a meaningful relationship and order" (McCABE, 1958). So the principal aim of this chapter consists in "connecting the dots" emerged from the previous chapters and ordering them in order to be able to pose a theoretical set of questions applicable for conducting an empirical answer process in the last part of this elaborate.

The organizational theories chosen to assess and analyse the structure of supply chain management combined with blockchain technology are encompass different field of research namely management area, and socio-economical topics. Indeed the wide value distribution that this topic can potentially have because of its intrinsic nature (food is one of the most important pillars of human life) and its innovative dimension (blockchain technology can be a competitive advantage for those who are able to exploit its potential). The organizational theories chosen to carry out the research regarding the blockchain involvement in the supply chain system are namely 6: agency theory (AT), information processing theory (IPT), institutional theory (IT), network theory (NT), resource-based view (RBV) and transaction cost economics (TCE).

4.2 Agency Theory

The first organizational theory that is going to be depicted in order to assess the potentiality of blockchain technology in Agrifood Supply chain landscape, is the Agency Theory. This concept is based on the assumption that often, especially in medium-large companies, the interests of the owners can be differ from the ones of the owners of the same company, namely the well known principal-agent conflicts. This separation of views can create furthers business complications and slowdowns, caused both by opportunistic and egoistic behaviours from the managerial side and from the attempts from the company's side to avoid or mitigate such attempts (Jensen & Meckling, 1976).
One of the principal reasons in which this conflictual phenomenon happens, is due to information asymmetry between the managerial and owner parties, that can lead to misconceptions and deceptive communications, aimed to give an erroneous view of business and financial activities, in order to erode profits for personal interests. Blockchain technology can help in a consistent way thank to its various characteristics analysed during this elaborate, that seem to perfectly fit in order to reduce information asymmetry and ensure transparency between the two parts. In the next section there will be highlighted all the blockchain technology features that can possibly help to avoid Agency Theory problems:

SMART CONTRACTS: the main modality in which a principal-agent controversy can arise is thanks to inter personal relationship aimed to cause an asymmetric flow of information. Smart contracts represent an helpful tool for diminishing the potential origins of misleading inter-personal communication/ behaviours thank to their automated and digital way of functioning. Some useful features such as voting and auctioning, for example a smart contract can behave like a third party entrusted to guarantee against tampering attempts and transparency during voting and auctioning

actions (G. Drakopoulos, 2019) . Smart contracts in this case can help the company to achieve collective goals preventing the actions of adverse individuals and saving the money destinated to an eventual middle-man (v. Hassija, 2019).
Another characteristic of blockchain-based smart contracts is the immutable track that they leave on the ledger, that can emerge as an useful features when comes to investigate for eventual past unfair or illegal behaviours, that can eventually be prevented after the implementation of ad-hoc services able to detect immediately such situations such as the double-spending attempts (D. Kaid, 2018).

DISTRIBUTED STORAGE: one of the most disruptive features of blockchain technology is the diffused storage mechanism inside its structure, able to guarantee a reduced information asymmetry inside of a specific firm and also between all the actors belonging to the same supply chain (Schmidt & Wagner, 2019a). Blockchain specific storage mechanism is able to spread in a homogeneous way all the information along the supply chains, preventing from biased communication/information to lead to improper outputs from one or more peer of the system. As an example, a precise, transparent and real-time demand of goods could prevent recurring problems such as the Forrester effect, reducing the risk of asymmetries regarding the supply-demand issue (G.A. Akyuz, 2020).
In order to avoid and eventually detect and punish unfair behaviours, governmental regulations can be inserted inside the blockchain, forcing the peers of that specific network to follow the conditions imposed in a public and secure way, this could ensure companies to be part of a fair systems in which the possibility of opportunistic behaviours is weakened by legal and reputational constraints (Kshetri, 2021).

CONSENSUS MECHANISM: the mechanism of consensus required by every type of blockchain system, in order to approve every single addiction to the ledger, can be an important tool inside the principal-agent relationship. As suggested by (Shala et al., 2019), consensus mechanism can be exploited with the utilization of a “trust evaluation system”, able to keeping track of the quality of information given by peers of the network, assigning a score called “ bonus point alliance” in order to assess the best possible business collaborators with a neutral basis for comparison, avoiding the situation in which individual managers favour determined business collaborators for individual interest.

For example, in an Agrifood system, a manager of a retail company could favour determined supplier in return for extra-company compensations, with a trust evaluation system, the best suppliers for the Company business life can be highlighted by the blockchain.

CRYPTOGRAPHY: the hashing mechanism at the base of blockchain information encryption, is a perfect deterrent for opportunistic attempts, leading to a public and shared environment inside a delimited system in which only authorized actors can interact with each other in a transparent and visible way (T.K. Agrawal, 2020). Reputation became a focal point inside a blockchain network, because every component before being able to take every sort of action has to be verified by the other users, who reciprocally have to validate every action in the system. If a misleading action is taken by one or more actors, the fact will be visible to all the other users, ruining in this way the reputation of the specific entity, penalizing its future role in the system. Taking as an example Agrifood system, a supplier who give wrong information about a specific furniture can be immediately detected and not be taken in consideration for future calls. In addition, thanks to cryptography, users of a specific platform can share important and sensitive data without the risk of leakage of possible harmful information

TOKENS: tokens can assume the role of perishable digital goods representing a certain quantity, in the case of Agrifood system we are talking about the ownership of food or beverage right, owned by a determined actor of the system. In this manner, also thanks to the support of specific Technological devices, the utilization of the tokenized good can be traced, ensuring that the commercial activities regarding that specific good are fair.

Furthermore, tokens can operate as a guarantee of provenance and quality, 48 taking as an example Colorado based company Bext360, which thanks to optical scanning technology and blockchain, attach to every single coffee bean a unique token, representing physical and geographical characteristics, in order to offer to the buyers transparent and clear power of decision regarding supply options.

4.3 Information Theory

The second organizational theory taken in consideration to describe blockchain potentialities in Agrifood industry is the Information Theory, this ideology is based on the assumption that, , the provision, elaboration and utilization of proper information is vital for diminishing the “Margin of error” regarding economical choices. Another statement of this theory is that already grounded and well known themes are characterized by a lower possibility of gathering new information, due to already existing studies and analysis. That fits perfectly with blockchain technology, because of its relatively recent introduction in the digital world, especially regarding topics related to Agrifood Supply chain, permitting to gather continuously new information (Tushman & Nadler, 1978). Talking about food supply chain, information theory can help companies to understand why a proper stream of information about the provenance, methodologies of transformation and retail system, could be a competitive advantage in order to decreasing uncertainty on the final consumer side, creating an added value from an economical and reputational point of view (Galbraith, 1974). In this context blockchain technology can ensure to final consumers a robust instrument in order to supply proper information about the food journey before arriving to retailer’s shelf. Especially in this era in which consumers have become increasingly more demanding about food’s knowledge and provenance, also due to the various scandals that have affected the recent industrial food production as the case of Chinese infant formula. This information theory analysis will be mainly consumer-oriented, because this category represent the main subject of the value delivery due to a proper or in alternative incomplete information transmission; the food supply chain will be analysed from four different vital perspectives in order to reducing consumer risk talking about food choices: Origin of products, Authenticity, Safekeeping and coherence of information.

Origin of products: one of the main concerns talking about food choice orientation, is the geographical provenance of food, an aspect that direct in a significant way the purchasing choices, also due to rooted preconceptions about countries (Hall et al., 2015). Is well known for example that Italian consumers prefer to purchase products belonging to their country of origin instead of foreign ones, blockchain based traceability in this case can help them to have a stronger confidence in what is disclosed on product's tags. The permanent transcription that characterize data inserted into a blockchain ledger, favour the authenticity of the information disclosed, thanks to encrypted language, that eventually permits a fast and precise ex-post control whenever an untrusted and doubtful disclosure about food characteristics is suspected, discouraging possible illicit attempts.
Concerning the financial benefits that a proper information system can deliver both from a seller and a purchaser side, it's clear that a proper information system can be beneficial for every component of the supply chain. Retail Companies indeed can ask for an higher price whenever an high quality product is offered following a precise and easy tracking of a determined food product. Regarding final consumers, the possibility of purchasing well-traced goods can avoid the risk to buy products whose provenance is doubtful, eventually changing their food choices toward more trustable products that they may have ignored so far and vice versa.

Authenticity: always regarding the willingness to buy high-quality food products, food market is seeing an increasing demand for authenticity assurance, a wide argument that brings with itself also various concerns about the truthfulness of the information disclosed. During last years, companies have tried to mark their products with quality certification recognised by independent agencies, also due to the increasingly precise counterfeiting techniques that affect several sectors included Agrifood one. Blockchain platforms like IBM Food Trust (IBM, 2018) ,as we have seen in chapter 3, bases one of their four integrated modules exclusively on certification management. Blockchain platform management also permits to create internal protocols, designed to ensure quality and integrity during the supply chain process of food sold, the respect of the protocol is ensured by the consensus mechanism that permits to every designated node of the system to approve or deny every transaction(Tucker C. Catalini C., 2018).

Safekeeping: the actual agrifood supply chain is characterized by an increasingly worldwide dimension, that sees food products to take part in long journeys across the globe, often changing the mean of transportation (Trucks, ships, airplanes), and at the same time be subject to various transformation processes. This compounded and international supply chain needs a strengthened monitoring system in order to ensure to costumers and actors of the systems that during the various stages needed before the final sell, all the quality and safety condition are respected. Like we have seen in chapter 3, supportive technologies such as chemical, optical and physical sensors assume a vital importance in order to keep track of variables such as temperature and humidity threshold during the long shipment that food have to do. The combination of technological devices with blockchain technology, can create a digital twin of every food product/lot, that leave permanent traces stored on the blockchain layer, making possible to monitor where and when eventual irregularities are detected (Montecchi et al., 2019).

Coherence of information: whenever a consumer finds a product that respects the disclosed qualities in terms of physical conditions and safety of consumption, he/she will be more incentivized to purchase the good multiple times in the future, posing the specific good in a superiority position compared to rival products that may be not carry such traceability services. According to (Olson, 1972), the tools that consumers possess in order to judge the consistency and truthfulness of what is disclosed are mainly divided in two categories, intrinsic information and extrinsic ones. The first group represent all the physical attributes that are evident during the consuming of the specific good, the second group is composed by all the extrinsic information that help to shape a determined opinion about a product, such as marketing, other people's opinion or in this case the awareness of the product's origin. In the case of an "alignment" between expectations and actual characteristics, the result is satisfaction on consumer's side, blockchain system can enhance the possibility of "alignment" between intrinsic and extrinsic information, delivering to consumers the perception of having more control on what the purchase and consume.(Martinez et al., 2019)

4.4 Institutional Theory

The third organizational theory is the Institutional Theory, a paradigm that tries to describe how Companies are driven by internal and external pressures that orientate and converge to a common point their structure and goals, creating a sort of isomorphism. According to the theory, this convergence is determined by three different types of external forces, namely mimetic, coercive and normative (Dimaggio & Powell, 1983).

4.4.1 Mimetic Forces

The first type of force, is based on the assumption that a company, during periods characterized by uncertainty and indecision about the business orientation, seeks to emulate similar strategies of companies that, at least apparently, are recognised as more profitable and efficacious (Dimaggio & Powell, 1983). The decisions whether to adopt or not certain types of technology is clearly based on mimetic forces by organizations. Considering the case of blockchain technology and its relative early stage of life, it's quite uneasy and hurries to determine if mimetic forces are playing a determinant role if the present and future adoption of this paradigm. Because of the modest quantity of companies that have fully adopted it and because of the limited span of time in which also the more progressive organizations have adopt this technology (Lui, 2016).
It appears clear at this point, that for examining blockchain technology under an Institutional Theory perspective, mimetic forces cannot be the proper tool so far, so it's better to analyse the concept using the other two remaining types of external forces.

4.4.2 Coercive Forces

Coercive forces are the ones that arise when an economic or institutional actor, posed in a dominant and favourable position in terms of resources allocation, exploits this situation, applying coercive power to the ones who need that specific resource (Dimaggio & Powell, 1983). Given this statement, the main actors that could be able to dispose of coercive forces are consumers, parent companies and governs (Lui, 2016). Concerning blockchain adoption in the Agrifood sector, consumers pressure about a more transparent and reliable communication about food provenance and modalities of transformation and conservation can be a central factor in orientating companies toward an acceleration in the adoption of this technology. This aspect is relatable to every sector in which the provenance and the management of the product is the central concern for consumers, in addition, another favourable aspect of blockchain adoption is that for companies, after a necessary initial period of training and implementation of the technology, it can represent a way to lower costs, compared to expensive certifications or investigations (Ahl et al., 2019). In this favourable scenario, once an hypothetical profitable adoption is done, parent companies may require to their peers along the distributive chain to adopt blockchain in order to improve efficiency and competitive advantage. Linking this last concept to governmental rules, sectors such as agrifood and pharmaceutic, can be forced to adopt blockchain in order to guarantee transparency and reliability about product's origin and handling, thus favouring a diffused adoption of the technology.

4.4.3 Normative Forces

Normative pressure, deals with the external forces that push a determined company to act and shape its strategies considering collective expectations regarding determined organizational contexts. These suppositions are initially shared on an inter-organizational dimension before developing into collective norms (Dimaggio & Powell, 1983). In cases of innovative technological adoptions, generally normative pressures are originated from professional organizations and industry trade groups, so from a company point of view is very important to stay focused on the current trends and direction that collective organizations are undertaking in order to stay updated and maintaining network relationships vital in today's interconnected world. According to (Hartley et al., 2022) "Organizations that participate in industry blockchain groups or a blockchain consortium are more likely to face normative pressures than those that are not part of such groups". So it appears clear that, also regarding blockchain adoption, the more collective is the structure of the group in which an organization takes part the higher will be the pressure coming from normative forces. We can take as an example IBM Food Trust, that perfectly represent the framework of a consortium blockchain, in which whoever takes part in the system is “pushed” to follow the modalities and approaches, indicated firstly by the parent company and as a consequence by all the already present participants.

4.5 Network Theory

The fourth organizational theory focuses more on the relational dimension established between the different actors belonging to a determined system/organization. It can be said that every sort of organization is composed by nodes and ties, in which the first represent all the actors or singular entities taking part in a collective system, while ties represent the relational boundaries amidst nodes. This relational framework create a situation in which none of the nodes present in the system is completely separated from the others, indeed every one of them influence, with variable degrees, the others. It appears clear that Network Theory take into account in a considerable way the social dimension inside of a system of actors, giving the possibility of studying all the singular social capitals combined with the modalities and the scopes of social transitions between the actors. Given that, it’s important to mention that Network Theory, gives a great importance to the variable influence that the singular entities can have towards the others and to the whole organization, depending considerably on the quality and intentions in which communications and interplays take place (Spina et al., 2016). In other words, Network theory tries to take in consideration aspects both from a macroeconomic perspective and from a microeconomic perspective, incorporating aspects of both sides, to depict the causes that shape the economic system (König et al., 2011).

Considering the complexity and high degree of interconnected ties that characterize today’s Agrifood supply chains, blockchain technology can have a considerable impact in managing and transmitting information, goods or services between peers belonging to the same chain. In the next section will be described the possible results of combining blockchain technology to the traditional economic networks characterized by two principal notions: immediate cash transactions and contractual obligations (debt and credit relationships).

4.5.1 Digitalized Assets

Blockchain paradigm permits to translate tangible and intangible assets into a unique digital version of them. The insertion of this digital copy into the blockchain ledger, permits to manage the assets in various activities such as ownership certificates, selling and buying, or audit track. This innovative digitalized form in which resources can be depicted, could permit to whoever handles them to have a panoramic and functional vision of the totality of assets. This characteristic can favour external or internal assessments and evaluations within various levels of control, from internal business unit control, regulatory compliance within firms, assets and liabilities evaluations from banks and so on. These possibilities that blockchain can offer to the whole financial and non-financial network between industry and regulatory level can increase consistently the reciprocal dialogue between the part, ensuring a transparent, reliable and tamper-proof system of communication. Of course, agrifood system can benefit from this tool, given that it is characterized by intense financial and non-financial activities, indeed having a whole vision of all the assets belonging to a specific system could be useful to prevent future financial crises, by creating algorithms able to unmask possible systemic failures at initial stages. In addiction the hashing script characterized by the private/public keys mechanism, renders impossible to proceed with any sort of unauthorized transaction, preventing illicit and hidden exchange of goods and money. So at this point it appears clear that a proper blockchain implementation among the whole supply chain combined with a total digitalization of the assets and liabilities belonging to each node of the network, could permit to lower the systemic risk of a financial system, while impeding any sort of off-balance transaction. From an audit perspective this aspect is quite revolutionary, because it could permit a faster and more precise ex-ante and ex-post control, resulting in a power full to all the dimensions of auditing control. Of course, in order to properly run this type of transparent interplays, the blockchain should implemented on an all-inclusive dimension, without omitting any asset and liability belonging to every actor's balance sheet (Treiblmaier & Beck, n.d.).

4.5.2 Blockchain based asset evaluation

As we have said, a proper asset registration on the blockchain ledger is beneficial at an aggregate level for an enhanced traceability and audibility of industrial activities, but every asset has to be subject to a monetary evaluation, blockchain combined with supportive technologies can be beneficial also in this case. Indeed the digitalization and subsequent insertion into a blockchain-based ledger can bring to an autonomous and immediate evaluation by the system itself. The evaluation would be smart contract-based, as the example of the Bext 360 company, which gave the possibility to growers of coffee beans to make their coffee beans evaluated by optical and physical sensors, which through a smart contract, immediately gave a tokenized value to avery single coffee bean, ensuring a complete neutrality and precise evaluation process. Thinking from a balance sheet perspective, blockchain technology would permits assets to be evaluated continuously in real time or at predetermined intervals, in automatic way, transforming the traditional historic cost-based evaluations, giving a more faithful representation of market value. This innovative evaluation method can be beneficial not only from a regulative perspective, permitting auditing organs to rely more on financial dislosures by firms, because of the automated and algorithm-based asset evaluation method, but also on a peer-to-peer level, the level of trust between contracting firm could be enhanced by the transparency and precision ensured by blockchain based evaluation. This innovation could permit firms to establish business collaboration even with unknown suppliers/buyers, from the moment that they adhere to the same blockchain based evaluation system, lowering the cost of eventual controls in order to verify the reliability of a possible business partner (Treiblmaier & Beck, n.d.).

4.5.3 New shared Business Processses

The interoperability and decentralization characterizing blockchain technology can bring to another important outcome, specifically, the sharing of determined business process creating a network of pre-setted services from which all the participants in a value chain can benefit from. A clear example of that is represented by IBM Food Trust project, in which the central owner of the ledger (IBM), offers to everyone who want to join the network , paying a variable fee depending on the quantity of services desired, the possibility to benefit from various services regarding food traceability and security processes. This could be beneficial to those companies that may don't have enough resource to autonomously implement blockchain based processes, or for those firms that would face too expensive cost in order to implement one; in this cases blockchain-based shared business processes could be an enhancing factor in term of cost savings and market differentiation (Treiblmaier & Beck, n.d.).

4.6 Resource Based Theory

Resource based Theory studies the factors regarding determined positive achievement in a market completion landscape, that firms possess in order to differentiate themselves from the others. The fundamental basis of this theory is that, in order to accomplish winning results compared to business rivals, a company must possess "rare, valuable and difficult to imitate" (Barney et al., 2001) resources and competences. From this theory perspective every company is none other that a set of tangible and intangible assets that together help to build a market position inside of a determined sector. Blockchain technology can perfectly fit in a competitive resource based view, assessing if its impact can be a competitive advantage or not. Resource based view is the principal theory in terms of management strategy, indeed it study the hard-to-replicate resources that a specific company or organization try to handle in the most competitive way possible. It is not only a matter of which resources a company possess because, as we have seen in Institutional Theory paragraph, if a firm successfully manage innovative resources, competitors will immediately adopt an imitating strategy (Li et al., 2021).

Indeed RBV try to understand also the way in which certain resources are used, in order to overcome market rivals in terms of business performance.
In the next section will be depicted various perspective from which will be possible to approach blockchain technology from a competitive and managerial point of view.

4.6.1 Performance competition

Thanks to blockchain technology private and important information can be inserted in a secure way on the decentralized ledger, giving the possibility to users of a determined supply chain to by-pass third party mediators, avoiding two important issues: the risk of external manipulations and facing high transaction costs. Indeed, from a survey conducted by Deloitte in 2019 (Pawczuk L., 2019), a sample of 1386 companies' managers was asked, whether a blockchain implementation at a company level would be good or not regarding business performance and competitive advantage. The results stated that the 86% of the interviewee concurred on the positive approach that a proper blockchain implementation could have on business strategy and the pertinent performance. In addition roughly 2/3 of the participant stated that not implementing this tool at a company level could be detrimental for the future business position of the Company.
A proper example could be the intervention of Walmart in the Chinese Food market, in which due to the necessity of a speedy intervention in order to track the provenance of food products, blockchain implementation permitted to cut the time needed to conduct a complete traceability history of a product, from many days to few minutes, clearly creating a great improvement (Shanley, 2017).
However it's clear that a proper and successful adoption of blockchain technology is achievable when there is a right balance between internal and external contexts, posing an high degree of coordination for all the components of the supply chain, both vertically and horizontally. Below will be reported three important aspect of managerial conditions directed to a proper implementation and management of blockchain technology in a supply chain perspective.

Internal coordination: one of the most important issue talking about whatever innovation regarding supply chain practices, is the long term perspective in order implement in the most effective way technological changes. The absence of this long term view could be the cause of future breakdowns, that can be dangerous in terms of business strategies and additional and unexpected costs (Govindan & Hasanagic, 2018). A proper and well-planned and preconceived blockchain implementation strategy is mandatory, also because the cost to launch this technology at an industrial level are very high, both in terms of resources and time. Managers have to properly design an investment plan in terms of hardware and software and well trained staff able to manage and exploit all the capabilities of this technology, also because the energy demand is very high. One of the main challenges is the fact that blockchain in order to operate at its maximum has to encompass every aspect of supply chain, thus supplanting the pre-existing system. This replacement is a very sensitive transition that can create deep internal changes, potentially creating negative outputs (Jharkharia & Shankar, 2005).

External coordination: also regarding the communication between companies adopting different blockchain systems there could be some challenges, so it's very important for different business partners to previously accord on which system to implement, in order to exchange digital information, assets and services in the most smooth way possible. Additionally since a supply chain is commonly a sequence of different entities working on the same line, a blockchain based SC has to encompass from the first actor (growers, farmers) to the last (retail companies) a coordination system able to create a communication channel, in order to exploit the speediness and security features typical of blockchain technology. A good coordination however comes also from a mutual trust between the nodes, blockchain technology can help deeply in avoiding egoistic and asymmetric value delivery within a determined system, a proper consensus mechanism is vital to limit the possibilities of secret agreement that possibly can favour illicit groups of actors (Treiblmaier & Beck, n.d.).

Extended competences: in the 4.0 industry era, characterized by a continuously changing and always updating environment, companies' managers are asked to possess a vast range of skills, encompassing a greater number of aspects of a company's business units compared to the traditional managers that were asked to possess a specialized deep knowledge. Blockchain technology in a supply chain dimension encompasses many intra and inter-industrial activities that may be hard to cover for old school managers to adapt. Indeed the most required resources when dealing with a technological innovation, are the intangible resources (human skills), necessary to manage the hardware, these type of intangible assets are the most hard to replicate and interchange. Managers have to possess firstly an appropriate business knowledge about blockchain functionalities and how it can shaped in order to meet the needs of a changing business environment. For instance, thinking about agrifood supply chain's final step, namely the relationship with consumers and all the related efforts to increase their trust toward the brand, a good blockchain manager should think about solutions related to an interface technology shaped in order to connect clients to their requires. Beyond business knowledge, managers appointed to handle a blockchain based supply chain, have to possess at least knowledge of technical management if not proper and specific technical abilities. Technical management and the ability to direct technical employers to add, delete or modify blockchain elements and shape the system in all its different parts on order to obtain the most efficient business outputs possible. Also inter-relational abilities are a focal point when dealing with blockchain implementation, given that a complete implementation along any supply chain will cover multiple sectors of a company (Kim et al., 2011) , making vital for the well-functioning of it to disclose in an exhaustive and reliable way all the necessary information, in order to acquire legitimacy from a costumer and regulator's side.

4.7 Transaction cost analysis

The last organizational theory that we are going to use in order to assess blockchain technology potentialities is Transaction Cost Analysis, a theory that starts from the hypothesis that business strategies and resulting decisions are based also on transactional costs as well as the price of goods and services . In actual global landscape, more than 50% of the entire productive system is characterized by transnational movements (Ortiz-Ospina E., 2014), as a consequence supply chains have to find new solutions for enhancing trust and reliability, creating a flourishing situation for blockchain intervention. The ideal situation for Transaction Cost Theory, is the one where the total costs regarding a specific type of transaction are minimized, in order to achieve this results information asymmetries and transparency of communication are essential. In order to use properly Transaction cost analysis, two fundamental concepts have to be taken in consideration, namely opportunism and bounded rationality (Williamson, 1973). The first concept deals with the probability that one of the contracting parties acts with an egoistic mentality, such as omitting important details or seeking to violate contractual clauses. The second concept instead, focalises more on the bounded reasoning characterizing every human being, that may provoke misconception and misunderstandings provoked by a limited processing capability regarding disposable information, that in this case could provoke additional costs in a supply chain perspective. In this landscape is clear that the key aspect in order to reach the best possible condition regarding transactions is the elimination of uncertainty, Transaction cost theory encompasses two type of uncertainty:

Environmental uncertainty: it is related to external factors, for instance regulations and governmental directives subject to changes during the years, or macro-economical factors that can create a temporary absence of information availability (as the case of Covid-19 pandemic)
Behavioural uncertainty: this type of unpredictability is the result of unclear human behaviour, in this case derived from scarcity of clear communication between the contracting parts.

According to (Rindfleisch & Heide, 1997), transaction cost theory is mainly affected by three issues, concerning the optimal governance structure in order to obtain the best outputs in terms of reducing uncertainty and transactional costs: safeguard, performance measurement and adaptation. In the next section these problems will be exposed and successively blockchain technology will be proposed as a solution.

4.7.1 Safeguard

“The safeguarding problem arises when one party of a transaction has to invest in specific assets that have little to no value outside that one particular relationship” (Williamson, 1973). In this scenario, specialized investment force both the contracting parts to reciprocally rely upon each other, indeed buyers don’t have the possibility to change suppliers because of the bounded supply of that specific good/service while the same supplier needs the buyer in order to make an economical result. The risk is that one of the two contracting parties exploits its greater market power in order to erode the other’s part profit in favour of self-interests. A common case can be seen in big retail companies that force small and rural suppliers coming from developing countries to lower their selling prices and eroding their profits, serving themselves of information asymmetry strategies and corruption attempts. A proper blockchain implementation can lower this power asymmetry, as we have seen in Chapter 3, Bext360 solution can be a good example. First of all, it ensure transparency in the pricing process of the good sold thanks to the impartiality given by optical scans linked to a smart contract able to determine a transparent price for each coffee bean. This immediately leads to the elimination of the demand for inter-personal trust, indeed it iss replaced by the blockchain system itself, avoiding the risk of opportunistic behaviours by one of the two parts, making the price variance exclusively based on food characteristic. Of course the main problem of blockchain implementation is due to high cost and need for well trained personal in order to run the system at a comprehensive level, that’s specifically a supplier’s problem given that in developing countries such resources are difficult to find unless big Companies dispose the willpower to do that (Schmidt & Wagner, 2019b).

4.7.2 Performance measurements

Another source of uncertainty can be found in the complexity to evaluate performances concerning a transactional operation, as(Hobbs, 1996), states : “there is public information available to all parties but also private information which is only available to selected parties, meaning that all parties to the transaction no longer possess the same levels of information”. For example sensitive details can be hidden by one of the contracting parts in order to force the transaction guidelines in a favourable way. Decentralized ledger technologies can avoid this because of the immutability and indelible nature of past transactions, that can be red by all the members of a blockchain system in order to verify if the transaction that is going to be agreed is based on fair criteria; also considering the fact that unfair recorded behaviours can be very damaging for the brand awareness of a determined firm. Another source of prevention that blockchain implementation can guarantee is the fact that companies can no more hide or lie about food handling and transformation processes, because of the recording of information along the entire supply chain. This could prevent companies to avoid complaints and accusation from the consumer’s side whenever a food diseases caused by the production or retailer’s side erupt. The fact that companies have to record every data supported also by other monitoring technologies such as sensors devices or RFID, can ensure a public visibility and transparency of the whole process. In the case of food industry this ex-post verifiability, this possibility given by blockchain recording mechanism is vital for the intrinsic nature of food and the possible catastrophic consequence that an improper food processing can have to the global population. The possibility to evaluate supply chain performances can be beneficial both to final consumers as well as power-limited suppliers that see the possibility of a fair and transparent price estimation (Schmidt & Wagner, 2019b).

4.7.3 Adaptation

Adaptation obstacle concern the fact that environmental uncertainty creates unfavourable situations in which conducting a balanced transaction decision. Indeed changes in the political and macro-economical landscape can break down even the most long-established business partnerships due to variations in the demand-supply curve. After such changes in the contracting conditions may bring to additional cost in order to re-adjust the terms of agreements continuously. (Grover and Malhotra, 2003).

This type of uncertainty can be mitigated by blockchain intervention principally with two types of transparency:

Internal transparency: it enhances openness and communicability at an intra-company dimension, helping managers in the strategy planning process through transparency of information and accessibility of data stored. Through a transaction cost saving plan, a company is free to allocate the resulting savings in order to optimize other business units or directing those savings whenever potential environmental uncertainty can occur (Tang, 2016).

Supply chain transparency: positive effects of blockchain implementation can be found also at an external level regarding a company dimension, specifically along the supply chain, comprehending all the vertical business relationships that connect all the actors of a determined distributive channel. The effects of the enhanced transparency are translated into new possibilities of information delivery and distribution to all the partners involved. The disintermediation characterizing distributed layers can provoke additional cost saving that ca be directed to enhancing the whole efficiency and speediness of operational process, distributing a value increment potentially to every component of the chain, consumers included (Schmidt & Wagner, 2019b).

Recapitulating all the notion regarding Transaction Cost Theory, this proposal assumes that companies need to manage their transactions also during uncertain periods, both internally and externally. Blockchain can be a solution in order to minimise these phenomenon thus lowering renegotiation costs. Another feature of distributed ledgers is the fact that companies need no more to establish long term relationships in order to trust other business partners, indeed blockchain can avoid opportunistic behaviours minimizing information asymmetries and offering visibility of all the past transactions of a determined firm, democratizing the pricing of goods.

4.8 Final chapter considerations and research questions

In this fourth chapter, six organizational studies were used as a tool to discuss the actual blockchain related literature regarding the supply chain applications, namely agency theory (AT), information processing theory (IPT), institutional theory (IT), network theory (NT), resource-based view (RBV) and transaction cost economics (TCE). From this literature review, it has been possible to outline the actual blockchain applications concerning supply chains in general, and more specifically related to Agrifood system. Successively future applications have been proposed basing the hypothesis on the notions acquired during writing of this elaborate, adapting them throughout the lens of every single organizational theory, taken in consideration.

Below will be present a summarizing table in which will be reported the six organizational theories used to approach blockchain technology in Agrifood supply chain, and additionally will be presented a set of theoretical questions that will serve as a starting point for the research reported in the next and final chapter and a suggestion for future researches. The research will be conducted using Crunchbase, a platform designed to find business information about private and public companies, restricting the sample of analysis to early start-ups focused on blockchain solutions designed for Agrifood sector, from which possible answers will be extrapolated from their whitepapers.

Table 1: Organizational Theories and related applications and questions

Organizational Theory	Blockchain Applications and Future Directions	Research Questions
Agency Theory	-Agency theory can be a useful tool in order to assess the information asymmetry characterizing the principal-agent landscape, in which blockchain can eliminate the need of intermediation, creating a new digital and automatic trust process.	-How does blockchain Influence the rapport between agent and principal? -Can blockchain Influence the trust mechanism regarding business relationships? -Can smart contracts help the company to achieve collective goals saving money destinated to middle-mans?

Information Theory	-Information theory bases its assumption on the uncertainty-reducing role that a proper information delivery can have in reducing business risk. -Blockchain can enhance transparency of information flow, delivering an homogeneous value addition to all the actors belonging to food supply chain, especially regarding the consumer side.	- What can be the degree of uncertainty reduction resulting from a blockchain implementation? -In which way can blockchain optimize information processing capacity? -How can blockchain enhance food provenance transparency and reliability of disclosures?
Institutional Theory	Institutional Theory helps to understand the reasons behind business strategies of companies, and the tendency to converge to similar frameworks thanks to external pressures. Blockchain technology can help companies to reach an empowered public legitimacy thank to its consistency.	-Which is the most blockchain-related isomorphic pressure regarding Agrifood supply chains? -Why blockchain implementation should follow an institutional theory perspective in Agrifood industry?
Network Theory	Network theory studies the modalities and approaches through which companies interrelate with each other. The new possibilities in terms of transparency of inter-companies communications and the permament storage of historical transactions offered by blockchain, can give new possibilities supplanting traditional and more unreliable communication channels.	-Can inter-personal trust be replaced by blockchain technology? -In which way communication channels change thanks to ner instruments such as blockchain? -How can blockchain alter traditional business reltions?
Resource Based Theory	Resource based theory takes in consideration the amount of rare and hard-to-imitate resources possessed by a company, and the strategies used to use them in the most profitable way. Blockchain technology can help managers to best administrate company's resource through automatization and tamper-proof capabilities, in order to prevail on business competitors.	-Which are the blockchain characteristics that can constitute competitive advantage? -In which way can blockchain affect pre-existing resources?
Transaction Cost Analysis	This theory helps to identify the causes of determined business strategies, not only on a price based view, but also considering the costs related to transactions. Blockchain technology can lower the transaction costs changing the traditional contracting practices, limiting opportunistic behaviours and avoiding costs related to low level of certainty, permitting to have safe business relations also with unknown partners.	-In wich way can blockchain alter transaction costs? -How can blockchain limit costs regarding supplier/buyer relation? -Can blockchain permit to enlarge the number of possible business partners, not limiting companies to trust only long-term based business partnerships?

Source: Author's elaboration

Chapter 5 : Research Question and Methodology

5.1 Developing the research question

Blockchain technology is still in the initial stages of adoption, so additional researches are needed to fully understand the potentialities that can impact the economic and organizational channels through which human relations take place, in particular this elaborate focuses on Agrifood supply chain applications. However regarding literature research there is one issue to take into consideration, namely the research-practise gap, a misalignment between the real applications of a determined topic and its theoretical counterpart. This research gap is particularly present when dealing with innovative technologies such as blockchain, because of the scarce information regarding the continuously developing and changing practises, an accurate and real time theoretical update is a very hard task. The food chain fit perfectly with blockchain functioning mechanism, especially regarding transparency of processes and clear and trustable disclosures, a topic that is constantly gaining importance toward consumer’s trust. As we have seen during this elaborate, food traceability can be useful to prevent or immediately detect the sources of possible food-borne illnesses, representing a possible fundamental tool in order to preserve public health. As we have seen in Chapter 3, blockchain technology, in order to be fully implemented and creating the best possible value, has to be supported with additional technologies such as Artificial Intelligence and Machine Learning, Remote sensing and satellite imagery, IoT devices and Optical scanning technologies. As mentioned before the misalignment between theory and practise is difficult to evaluate only from theoretical sources such as academic papers, indeed the research findings that will be reported in the next chapter will be derived from a research on actual start-ups that are operating in the field of food and beverage supply chain supported with blockchain technology. The start-up perspective is considered to be more faithful regarding the actual trend of blockchain applied to food distribution, because it gives a faithful and realistic representation of the actual applications in this field.

Given that, from what has been elaborated during this thesis, and the need to cover the existing research-practise gap, 3 fundamental questions have been addressed in order to conduct this research:

RQ1: What are the main benefits that a blockchain technology implementation can bring in terms of transparency, security and trust in food supply chains?

RQ2: Which are the most adopted supporting technologies in order to optimize food supply chain management? How are they implemented in order to operate with blockchain?

RQ3: Who are the main beneficiaries of the value created by blockchain implementation in food supply chains?

5.2 Methodology

In order to answer the research questions, an application analysis has been applied in order to extrapolate the most close to the reality data possible regarding blockchain applications in food supply chain system. As reported by (AVI Networks, 2022), "Application analytics provides insights into the performance of an application by producing real-time analysis through visualization of data. The application insights analytics include IT operations, customer experience and business outcomes. This allows enterprises to quickly troubleshoot performance questions and root cause issues in order to make needed changes for efficiency in real time". The application analysis has been applied using an online platform for company insights, comprehending early-stage startups, a reliable source of information in order to figure out actual and future applications regarding blockchain based supply chains. The selected companies will be deeply analysed basing the research on their disclosed whitepapers and related web sites, in addiction, when it has been possible to find them, also customers experience will be taken in consideration, in order to give the most neutral and objective point of view, needed to answer the proposed research questions.

5.3 Data Collection

Data were gathered from the above mentioned online platform Cruchbase, representing a leading destination for company insights, comprehending early-stage start-ups, the platforms furnish various voices to filter the results: under the general "Description Keywords" the word used was "Blockchain", while under the "Industry" voice, under the "Agriculture and Farming" option were selected various categories such as "Agriculture", "AgTech", "Farming", "Horticulture" and "Livestock". I've decided to not consider all the companies composed by less than 11 employers, in order to increase the consistency of results, the resulting companies that responded to all this prerequisites were 47, but after a first research, 14 of the suggested companies were found no more active, so the final sample of analysis was composed of 33 companies.

5.4 Data Analysis

The data analysis began with the categorization of all the selected companies that responded to the prerequisites required by this kind of research in an Excell spreadsheet. Then basic information such as foundation dates and companies headquarters country, in order to have a geographical and chronological overview of the cross-section, that permits to figure out in which areas of the world blockchain-based agrifood supply chain applications are developing the most. After this first categorization, three additional columns were created in order to gather all the possible information useful to answer the three research questions, these data came from different sources, the first one was Crunchbase database, from which it was possible to gain general information such as Total funding amount, Employee's profiles and investors. Then the second source of information came directly from the companies web sites, a good source of information in order to focalize the current applications and the future directions of blockchain technology in this sector utilizing the disclosures of the actors involved. The last source of information, when it was available, came from specific case studies, in which were reported actual collaborations between the selected companies and the actors to which the services provided were designed for, this source was useful in order to assess the outputs that came from the these companies business activities. Finally, the most recurring topics were individuated thanks to COUNTIF Excell's function, in order to pinpoint the most persisting trends regarding each research question.

Chapter 6: Findings

6.1 Research Findings

In this Chapter it will be presented all the findings coming from the research described in the precedent chapter. First of all, after presenting in table 2, all the 33 companies taken in consideration for the research, will be reported an initial overview of the research, discussing the geographical distribution of the companies, the dimensions and other general issues. After this introduction all the three research questions posed in Chapter 5 will be answered singularly, basing the responses on the information gathered from the cited sources.

Table 2: Companies list

NAME	WEB SITE	COUNTRY	FOUNDATION	ABOUT
AgriDigital	www.agridigital.io	AUSTRALIA	2015	AgriDigital is an integrated commodity management solution for the global grains industry.
GrainChain	www.grainchain.io	USA	2013	The GrainChain system greatly increases transparency and accountability within the agriculture business by eliminating disparate and wasteful paper trails, eliminating the opportunity for fraud and dramatically reducing time and costs
Avenews	www.avenews-gt.com	ISRAEL	2017	Avenews is a fintech company connecting two industries : the financial industry and the agricultural industry.
Bx Technologies	www.bx-earth.com	UNITED KINGDOM	2020	Bx is a climate-tech company, we help food brands remove emissions in their food supply chain
Bext360	www.bext360.com	USA	2016	Its “bext-to-brew” platform utilizes IoT, blockchain, machine vision and artificial intelligence, to transform the supply chain

Gavea Marketplace	www.gavea.com	BRAZIL	2021	Gavea is a blockchain commodities exchange that simplifies the trading, execution and settlement of physical commodities
Ecotrace	www.ecotrace.info	BRAZIL	2018	Ecotrace is a blockchain-based end-to-end commodities traceability platform,
AgUnity	www.agunity.com	AUSTRALIA	2017	AgUnity is a global technology platform that empowers the thousands of organizations working to address UN SDGs with a cost-effective means for connecting with and supporting remote people in a truly meaningful way.
Rice Exchange	www.ricex.io	SINGAPORE	2017	Rice Exchange is a digital blockchain-enabled rice trading platform bringing transparency, liquidity, security and improved access to the $450 billion rice market.
Vietnam Blockchain Corporation	www.vietnamblockchain.asia	VIETNAM	2016	developed blockchain apps of loyalty points management, digitalidentification, online voting and so on.
Transparent Path spc	www.xparent.io	USA	2020	Transparent Path spc is an advanced technology provider focused on real-time visibility for our most critical supply chains.
KHETHINEXT	www.khethinext.com	INDIA	2017	KHETHINEXT is an integrated digital platform to enable agriculture transformation through smart farming.
AGTools	www.agtechtools.com	USA	2017	AgTools provides game-changing intelligence to the agriculture market through up-to-the-moment statistics that affect time, cost, supply, demand, throughout the produce chain of food
Producers Market	www.producersmarket.com	USA	2017	Agricultural system where Producers earn a living income, which empowers resilient communities and ecosystems. Buyers can connect directly with producers, bridging the gap between source and consumer.
Grain Discovery	www.graindiscovery.com	CANADA	2018	Grain Discovery is an online marketplace leveraging blockchain technology to create efficient, transparent, and secure transactions.

Cortex Technology	www.cx.technology	UNITED KINGDOM	2003	Top Russian agricultural business network.
Epik	www.epik.ai	USA	2019	We work with organizations to explore use cases where blockchain makes sense. Both in solving supply chain issues or working on sustainability projects, there are real ways to apply blockchain technology.
Agrotopus Agricultura Digital	www.agrotopus.com.br	BRAZIL	2016	Agrotopus is a IoT, AI and blockchain company that provides end-to-end tracking and management solutions for agribusiness chains.
Averta Strategy Pvt. Ltd	www.avertastrategy.com	INDIA	2017	Currently exploring new technology avenues like IoT, AR, Blockchain, AI and collaborating with many business houses & agencies globally to explore new business horizons.
Jivabhumi	www.jivabhumi.com	INDIA	2016	Jivabhumi is an agri-tech platform for connecting farmers directly with institutional buyers and consumers.
Agri10x	www.agri10x.com	INDIA	2018	Agri10x envisions transforming the roots of the global rural economy by integrating the entire Agri value-chain through a digital cooperative platform by harnessing emerging technologies.
Reactive Space	www.reactivespace.com	PAKISTAN	2017	Software solutions
GFresh Agrotech	www.gfreshagrotech.com	INDIA	2019	The company is revolutionising the vegetable supply chain & creating significant impact by empowering small farmers and getting rid of middlemen who manage an ineffectual supply chain
Zignar Technologies	https://zignar.tech/	CANADA	2020	Greenhouse agriculture applying various standards
Producers Token	https://producersmarket.com/	PUERTO RICO	2017	This new platform of the agricultural value chain will align universal values of transparency and equity in a direct system that empowers producers and consumers.

Beyond IoT	www.beyondiot.ie	UNITED KINGDOM	2004	. It specializes in research, IoT, AI,software, hardware, data analytics, blockchain, Agritech, fintech, industry4.0, energy, water, people behavior, sensors, business development, enterprise Ireland, EU, and innovation vouchers.
Food Agility	www.foodagility.com	AUSTRALIA	2017	They create new data-driven technology for the agri-food industry using artificial intelligence, robotics, blockchain, sensors, advanced data analytics and more
The Fork	www.thefork.online	NETHERLANDS	2017	The fork offers in house blockchain courses and training that assist companies in the agri-food industry that implements Blockchain technology
Vitalapia - Orgakinetic	www.vitalapia.com	MEXICO	2007	Orgakinetic is a circular system to produce continuously healthy organic fish and crops, monitored by IoT, AI, and Blockchain technology
GREENS	www.greens.id	INDONESIA	2020	GREENS enables hyperlocal food system everywhere using portable smart growing units on web3 ecosystem.
Trace AgTech	https://traceagtech.com/	INDIA	2016	Trace Farm Management Software is a complete digital solution integrated in technology to resolve the challenges throughout the Supply Chain
CIED BV	www.cied.eu	NETHERLANDS	2017	Dutch agri-tech company is building a customized blockchain-based farm-to-fork traceability system that can help you predict how much you can trust your food.
Block Commodities	www.blockcommodities.com	UNITED KINGDOM	2011	Block Commodities is creating a new platform to promote economic growth while creating opportunities and empowering communities, through the vertical integration of primaryindustries down to consumers via a blockchain-based supply chain.

Source: Author’s elaboration

6.2 Research's overview

In the table 2, are reported general information about the selected companies, however these information can be a useful tool to figure out the actual trends regarding blockchain-based food supply chain's applications. First of all, it's interesting to highlight the fact that the first position for the most recurrent country in this list, with an occurrence of 6 companies, is occupied by an emerging company such as India, a country that in recent years is heavily investing in technological development, and probably is trying to respond to foodborne illnesses issues, a peculiar topic regarding this specific country, in a modern and tech-based way. The second and third positions are occupied by two first-world countries, namely United States and United Kingdom, respectively with 5 and 4 companies, less surprising countries compared to the first one, given the their historical technological leading positions, especially regarding the United States. From a foundation date point of view, it has been noticed that the most recurring years were those from 2016 to 2018, the 36.3% of the analysed companies were founded in 2017, evidently those years corresponded to the first expansion of blockchain's applications concerning industrial applications such as supply chain's systems, while immediately after Bitcoin introduction in 2008, blockchain applications were circumscribed to cryptocurrency field. Another interesting aspect is that the foundation of new start-ups during Covid-19 pandemic has drastically diminished compared to previous years, a clear proof of how the cited epidemic has slowed down the pace of economical and technological expansion.

6.3 RQ1: What are the main benefits that a blockchain technology implementation can bring in terms of transparency, security and trust in food supply chains?

The first research question focalizes on the operational improvement that blockchain implementation along the food supply chain can bring in terms of transparency, trust and security, the three most recurrent aspect observed during the literature review conducted in Chapter3 and Chapter 4. Essentially, given that all the companies analysed were operating in the food supply chains, I've noticed a coherence between the disclosed benefits declared by all the companies and the literature review previously conducted, also if, a more in-depth study on actual applications on this topic can guarantee a more precise and real panoramic on this issue.

First of all, for what concerns transparency, many references were founded during this research, all of the companies declared to exploit blockchain's peculiar characteristic, such as tamper-proof structure and immutability of data recorded as necessary aspects for ensuring transparency in an integrated and vertical system such as a supply chain. The most cited blockchain related tool to ensure transparency has been the use of smart contracts, to execute automatically contractual clauses, concerning the trading of food commodities, whenever specific condition are met. As the example of the US-based GrainChain company, whom CEO Luis Macias stated that "Our solution combines blockchain and IoT-driven technology to verify and auto-execute smart contracts, creating fully automated and digitized workflows at every stage. The GrainChain platform provides a central, single point of truth that brings all participants on the supply chain together with transparency, efficiency, and reliability of data"(SAP Startup Spotlight, 2021). Transparency however not only deals with the transaction point of view, but also it can be intended as transparency of operational results achieved by blockchain implementation. As the example of Producer Market, a platform designed to align stakeholders around shared values of transparency, trust and economic equity that ensure a clear and transparent disclosure of food related information thanks to a "clear metrics for success, tracking product sales through the brand's specific e-commerce tools and retail client sales, as well as measuring analytics through QR code scans, social media activity, and newsletter signups"(Producer Market, 2022). Therefore, for what concerns transparency I have noticed that companies have put great emphasis in ensuring visible and reliable information about the food journey, from farm to fork, creating, also thanks to supportive technologies, a hand lens system that permits professional buyers or common consumer, to access to an amount of information that wasn't possible without blockchain's intervention. Only 8 companies out of the 33 examined, don't offer a step-by-step traceability service along the entire supply chain, instead they operate only as commodities exchanges, referring to blockchain related transparency gains only from a financial perspective.

Also for what concerns security, the concept can be divided in two perspectives, one referred to transaction and trading of food, and one referred to food quality and safety of consumption. The first one rely on the hash coding that characterize every transaction made on a decentralized ledger, permitting to have an immutable and always visible chronology of every trade made on a specific platform. As the case of the Singapore based company Rice Exchange, a rice-trading platform adopted in more than 60 countries that "digitalizes rice trading using blockchain distributed ledger technology. Buyers, sellers and service providers connect in a digital environment, efficiently conduct trades and arrange insurance, shipping, inspection and settlement with the assurance of verifiable data and seamless integration. Once a trade is agreed, the platform generates a standardized set of documents including the invoice, bill of lading, inspection certificates, the shipping advice and insurance documents. A hash is created for each action and stored in the immutable audit log" (Rice Exchange) This peculiar blockchain tool can revolutionize the security of complex systems such as international food exchanges, because an immutable audit log can be subject to ex-post inspections, aimed to find eventual fraud or illicit past behaviours, discouraging future criminal attempts.

The second perspective about security that I have encountered during the company analysis is related specifically about the disclosure of every step of the journey that a specific product has to complete before reaching the market, the 78.7% of the companies ensure reports and updating about this topic. A great example can be GrainChain, which offers a complete set of applications that assist every type of user (producers, storage operators and buyers) in obtaining complete and secure information about product at every stage of the process. Indeed they offer all data from seed to harvest (seed receipts, fertilizers, geofenced crop maps) with their Seed Audit service, for what concerns storage management they offer a digitalized overview on processes and operations in real time storing them in an immutable way, and in case of more complex product transformation they also offer a "complete transparency and real time status updates of the commodity as it progresses through the processing plant from raw material to finished product. Reception, quality and quantity measurements and organization of multiple production batches all are captured automatically and digitally" (GrainChain). Of course a focal aspect of every supply chain is the logistic aspect, for which GrainChain offers a rapid and elastic method for connecting producers and carriers, indeed they created a system in which growers can schedule pickups and deliveries whenever they require it, while carriers can accept the request or organizing future deliveries and receive payment directly from a mobile app.

All these new possibilities offered by immutable recording offered by blockchain implementation are designed to give a real time panoramic of all the situations that permit to transform raw materials into finished products, giving the interested parts the possibility to monitor if a specific product has been handled in compliance with legal standards.

Decentralized systems like blockchain platforms, rely on a consensus mechanism that permits to overcome the need of resorting to third parties middle-mans, indeed the totality of the analysed companies declared to offer a service to connect directly buyers and sellers, diminishing operative costs and enhancing transparency.

6.4 RQ2: Which are the most adopted supporting technologies in order to optimize food supply chain management? How are they implemented in order to operate with blockchain?

Blockchain technology doesn't represent a stand-alone tool in order to offer a complete and exhaustive set of traceability answers regarding a specific product offered by a company, indeed it has to be supported by other technologies such as IoT, QR codes, Machine learning, Artificial Intelligence, RFID and GPS technologies. The companies analysed offered various levels of traceability services, therefore the technological equipment offered by every single company varies depending on the depth of the product offered, indeed a platform limited only to exchange of commodities won't need the same technology compared to a company that provides end-to-end tracking and management solutions for agribusiness chains. The most common technologies observed during this research were those designed to track the position of food during the shipments needed to complete the supply chain's journey, namely RFID and GPS geo-localization, only one of the companies, Avenews, a company specialized in financing SME's agribusiness in the African continent, hasn't disclosed any use of similar technologies. Other two technologies used by every of the companies analysed are Artificial intelligence and Machine Learning, two fundamental tools that combined with blockchain storage mechanism can ensure an efficient and organized way in order to analyse all the data coming from an integrated supply chain system. As the example of Avenews, that although it offers only a financing platform for growers, it exploits the potentialities of AI and ML in order to handle costumer's data for generating personalized offers that best fit with every single user (AveNews). Another interesting application of AI and ML was used by BX Technologies, a UK based company focused in helping food producers to reduce their emissions, they combined Artificial Intelligence, Machine Learning and blockchain-based smart contracts, creating a system that "takes historic soil data, combines it with farming practices and suggests ways to transition to regenerative farming successfully. We use machine learning to discover the most effective regenerative practices and create improvement plans for every grower." (Bx Technologies) After this combined evaluation, the system generates automatically two types of asset token, namely Bx Carbon Offset Token (COT), which can be defined as a voluntary carbon removal credit and ESI (Ecosystem Services Improvement) Token. The second one represent the total value of a determined portion of land following several standards such as Biodiversity, food production and carbon sequestration, they represent a licence to access COTs on a preferential basis. This system is designed to create additional profits to those growers that apply the most environmental-friendly practises, incentivizing less developed growers to convert to more sustainable practises, creating added value at an aggregated level.

However the technology that can permits a deep and complete quality monitoring and trustable tracking of food is IoT. As stated in Averta Strategy's overview, an Indian start-up specialized in providing technological solutions for business problems, "An IoT ecosystem consists of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments. IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analysed or analyzed locally."(Averta Strategy). Indeed IoT, with a proper integration of other technologies such as the previous ones analysed above, can revolutionise the supply chain's management of agrifood products, as the example of Zignar Technologies, a Canadian company specialized in developing cyber-physical systems for Industry 4.0. Their traceability journey starts with the capturing through IoT devices of parameters like PH, humidity, temperature and CO2; then computer vision is adopted to monitor the growth of the plants and discover possible diseases that can occur to them, mixing these information with ML algorithms will produce optimal advices for growers, always storing in real time all the information on a blockchain ledger. Zignar's experts state that a proper integration of their technologies can increase the production of tomato growers from 125 ton per hectare per year, to 600 tons, creating a huge profit gain (Zignar Technologies)

Once last citation goes to the Australian FinTech innovator AgUnity, a company that is launching a digitalization project in Ghana, in order to empower the "Last Mile", the initial segment of food supply chain, in rural and poor countries such Ghana, in which growers still lack of several conditions such as lack of visibility, reliable data system, trustworthy records and education. Indeed AgUnity, for giving these communities the opportunity to connect with possible buyers not reachable with the rural and traditional channels, made available an affordable smartphone, which through is possible to run their mobile application even offline. Whenever a proper internet connection is not available the data will be stored and cached locally in the system, until the user gets access to the network.

6.5 RQ3: Who are the main beneficiaries of the value created by blockchain implementation in food supply chains?

As we have seen after this company research and the literature review in the precedent Chapters, blockchain implementation can be an enhancing tool if well integrated in a supply chain, in this paragraph I will discuss instead the value chain that this paradigm can create, and the different recipients of the value distributed. The actors belonging to a food supply chain can by divided in four macro categories: Farmers/growers, professional buyers and sellers, retailers and consumers. The notion "from farm to fork", a well present mantra in all companies that seek to supply a complete traceability service, introduce itself the fact that the added value is distributed both to farmers and final consumers representing the two extremities of the value chain. We can find an exception to this in the 8 commodity exchanges analysed during this research, indeed they focused in enhancing and facilitating the trading of commodities between professional buyers and sellers, representing the first and the middle part of the chain. The value added for this type of companies is the fact that professional buyers are enabled to achieve price discovery in both familiar and less familiar origins (Rice Exchange).As the example of Gavea Marketplace, a Brazilian digital commodities exchange, that with a combination of blockchain, Machine Learning and AI enables the trade of soybeans and corn, offers tailored 100% digital contracts, signed with ICP-Brasil certificates, ensuring traceability and data transparency, while reducing transaction and operating costs through the removal of middle mans, thus distributing value both to buyers and sellers.

For 13 of the companies analysed, small and medium producers are the main beneficiaries of blockchain implementation according to the disclosed information on the companies side, indeed great attention was placed in enhancing the grower's independence from middle-mans, giving them the possibility to access and put in contact potential business markets not reachable otherwise, and at the same time reducing transaction costs. A clear example of these efforts is represented by Producer Market, a company that is trying to directly connect producers and farmers to buyers, indeed they state that even if producers create the physical value of food supply chains, intermediaries subtract a great portion of the initial value at the expense of farmers. USDA indeed has declared that, in average, every dollar spent, approximately only 8.5 cents goes directly in the producer's pockets, not to mention the fact that usually they are also the last to get paid for their services. Producer Markets seeks to invert this trend by creating a decentralized digital system that permits producers to scale the value chain, connecting them directly to consumers, directly executing smart contracts between the two parts, in addition, every transaction made will produce bonus equity token for producers, that can sell them to individuals that seek to invest in the company (Producer Market, 2022).

For what concerns the creation of value in undeveloped and rural areas, 6 companies deals with the implementation of digitalized food supply chain in countries that otherwise will face huge obstacles in finding proper business partners and conducting safe and secure food processes. One virtuous example can be found in Khetinext, an indian digital platform specialized in the transformation of agricultural practises in undeveloped areas. They base their core business through 4 pillars, the first one is reducing cultivation costs through providing farm inputs directly from manufacturers reducing the prices. The second pillar consists in facilitating financial connections and providing schemes and credit facility for purchasing farm inputs while providing access to crop insurance. Then they the company, through a proper traceability of farmer’s food products ensure more remunerative prices thanks to an enhanced quality and reliability of process information, rising the price of the products. Finally, thanks to a combination of AI and Machine learning, they provide specific data-driven advisory insights in order to optimize farmer’s crop management. Currently the company is the first Integrated Digital Platform for enabling agricultural transformation through Smart Farming, with more than 4900 Indian farmers registered on the platform (KHETHINEXT, n.d.). Companies like Khethinext, through the modernization and transformation of third world agrifood economies, are giving a revolutionizing opportunity and visibility to those areas that never had the chance to develop their business collaborations, thus creating an immense value added.

The end of the value chain, is occupied by final consumers, a category that directly or indirectly is interested by all the companies analysed, because the final recipient of every food supply chain is the person who consume the specific product. Consumers will benefit for obvious reasons from an enhanced transparency and traceability systems offered by blockchain and supportive technologies implementation in the food supply chain. Also because the physical action required to do so, is often only the scan of a QR tag that immediately will consent the interested part to have the guarantee of quality standards respect and information about the provenance of the products presents on supermarket shelfs. The value added for consumers is not limited only to an increased transparency of processes, but also, regarding those companies that are involved in reducing the distance between producers and consumers, it can be represented by a consistent cost reduction of products, which prices are no more increased by intermediaries intervention.

Chapter 7: Conclusions

During the elaboration of this thesis, we can affirm the revolutionizing possibilities that blockchain implementation in industrial supply chain, in the specific case related to agrifood system, can bring to thriving outputs in terms of optimization of processes and creation of an aggregated trust environment. Indeed, during the consultation of numerous academic and professional papers, the widespread opinion about blockchain technology intervention, is that it can potentially be as disruptive as the Internet's advent. For example World Economic Forum sustained this theory, stating that this technology will be part of the six "mega-trends" that are going to revolutionize the industrial processes, including supply chain's key activities in the decade 2020-2030 (Kshetri, 2018).

To sum up the main benefits emerged during the development of this elaborate, we can highlight the positive consequences that blockchain can bring in terms of transparency and systemic digital trust obtainable thanks to the specific structure and functioning of this technology. Indeed the robustness and tamper-proof nature of this tool, can bring an unconditional trust for those actors involved in industrial supply chain systems, as soon as the users get in confidence with this technology. The fact that blockchain systems can create a "digital twin" of every physical aspect of a supply chain, namely materials, employers, business agreements and processes, storing the information in an immutable and always visible way, brings a new level of transparent visibility to all the actors involved, creating a system of mutual assessment between the interested parts. The possibility to monitor, also ex-post, every component's activities discourage every possible fraudulent behaviour along the supply chain, reducing in a consistent way all the information asymmetries that can occur dealing with international and vertical industrial systems.

However, blockchain itself, constitutes only a revolutionizing tool in order to store information in a different way, concerning the traceability of food products along complex supply chains, this technology has to be assisted by supportive technologies like IoT, RFID, GPS, Artificial Intelligence; Machine Learning, physical and chemical sensors and smart tags. During the company analysis we have witnessed various degrees of technological implementation depending on the core business of every single company. Excluding those companies designed only as blockchain-based commodities exchange, we can suppose that in order to deliver to final consumers a completely affordable and complete set of traceability information, the data inserted on the layer, from farm to fork, have to come from automatized sources (IoT, sensors, M2M, AI), in order to avoid possible manual storing of incorrect and fraudulent information.

For what concerns the different functionalities that can characterize different blockchain systems, such as the consensus protocol, cryptography, validation and control system, what emerges from the company analysis is that the optimal type of blockchain ledger is the permissioned one, also known as private blockchain. This aspect can arise future debates whether such solutions are only a different way to build centralized ledgers, moving away from the initial concept of public and decentralized ledgers proposed by (Nakamoto, 2008), where every one could potentially become a node of the system. However, dealing with supply chains specialized in such a delicate and important product such as food, need a greater level of control respect to a public blockchain. Indeed after the elaboration of this thesis, I strongly believe that, regarding the analysed field, permissioned ledger is the optimal framework, because it permits the constitution of private platforms where all the "permissioned" participants can audit and being monitored in a reciprocal way, creating a close but transparent business environments.

A proper and complete blockchain implementation in the supply chain management, will involve several business units and different key activities specific of a determined business environment, bringing the need of an integrated internal and external coordination, as it has been highlighted during the Resource Based analysis in chapter 4. Indeed a great effort will be need from future operational managers, in order to properly manage and integrate blockchain in already existing business channels, also considering the eventuality to revolutionize completely pre-existing business structure. Given that, the biggest challenge from a managerial point of view will be the optimal allocation of resources regarding two fundamental aspects: an efficient disposition of a proper blockchain system supported by proper technologies, and the intervention of human capital, possessing the appropriate know-how in order to manage the system in the best company-oriented way.

Of course, like every new technological paradigm at early stages, also blockchain technology presents various weakness that can potentially slow down the diffusion at a large scale, as it has emerged in the final part of chapter 3. The principal challenges regarding blockchain adoption in supply chains in a global and diffused scale are the high energy demand that the system require in order to work, the current need of specialized human capital able to handle such a complex system, and the disparity of possible implementation of such a complex and sophisticated technological tool, regarding third world countries. Given the relative new introduction of this technology, especially regarding industrial applications, there is the need of future researches and a greater quantity of practical implementations, in order to find methodologies designated to overcome such problems.

In conclusion, it can be affirmed that blockchain technology can effectively revolutionize in a positive way the actual food supply chain channels, enhancing the transparency and security, both in terms of economic exchanges, thanks to smart contracts and storage mechanism, but also in terms of food security and reliable and easy to access traceability information. In terms of value delivery, also thanks to the conducted companies research, it has emerged that a proper blockchain industrial implementation in food supply chains, delivers a distributed value addition to every component of the system, in particular those who were in an inferiority position regarding information asymmetries. However, despite these positive findings, blockchain adoption is still in its embryonal phase, managers and start-up innovators, indeed have to focus on a digital conversion of the actual supply chain's key activities, in order to transform blockchain technology in a precious competitive advantage, and not only a supportive technology permitting a safer storage of information.

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