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Blockchain technology in meat supply chain

Economic and operational implications

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Abstract

In this writing we will analyse the possibility to apply blockchain technology in food sector to improve food traceability and transparency, trying to go beyond the hype and examine the economic and operational implications of such a choice.

The high interest for this technology in this particular field is due to the increasing demand of secure and transparent information about the food we purchase and the growing curiosity about its history and provenience.

To assess whether this interest is real and to what extent people understand the potential of blockchain technology application and is concerned about the information it could provide, we will conduct a market research to understand how this forthcoming phenomena is perceived by people and how it will influence purchasing behaviour.

On the other hand, the implementation of this technology is particular since it requires to involve multiple actors on the supply chain exceeding the traditional barriers of information sharing between companies.

The study will consider both customer and enterprise points of view to find a balance point between the expected outcomes and the efforts required and will pay particular attention to operational issues that companies need to face starting this kind of project with focus on the application of this technology in the beef meat supply chain; moreover we will see the economic implications that could arise from the application of blockchain technology as a consequence of disintermediating, speeding up processes and contrasting transaction costs.

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Introduction

The application of blockchain technology has drawn the attention of many businesses and scholars in recent times, who has been exploring the possibility to apply this technology in many contexts and for different purposes.

Due to its main features, it has been considered by many experts a potentially disrupting technology and has been compared, in terms of innovative potential, to the advent of internet.

The interest for Blockchain encompasses multiple business areas, from its primitive conception as the basal technology of Bitcoin system, this interest moved to supply chain management opportunities and to health care sector benefits it can bring, only to cite some.

The idea is that a system in which data that is shared, protected with cryptography and cannot be tampered can revolutionize the way many processes in our life are done.

This study will try to go beyond the hype and explore the potential benefits and the operational complexities behind the adoption of this technology as a tool to improve efficiency in supply chain management, in particular in the case of its parallel value as a transparency and traceability booster in the food chain.

Since food consumers are more and more concerned with the origin and history of the products they purchase, the possibility to certify information that interests people through a trustable system that doesn't require intermediaries represented a further incentive for food companies to become pioneers in the adoption of the system, since it adds customer value and increase the capability to instantly trace back the origin of products, making it easier to manage possible food safety alerts.

While representing a possibility to improve supply chain efficiency and control and to enhance company's reputation and image, it could imply also long run economic benefits for companies which choose to adopt it, because of its intrinsic lowering effect on transaction costs and its risk contrasting nature.

Beyond internal benefits that will be examined in chapter 2, the last chapter will analyse the gap in customer satisfaction about meat industries' information providing and its instruments.

Actual marketing strategy in this sector is more and more concerned with transparency, while claims and information systems are still not clear or trustable to a big part of consumers.

The final survey will deepen in people's perspective on what is the state of the art on meat traceability systems and in what consumers are more concerned about.

Chapter 1

THE POTENTIAL OF BLOCKCHAIN TECHNOLOGY

1.1 Blockchain technology

Blockchain is a technology invented in 2009 by Satoshi Nakamoto[1] as the basis of Bitcoin cryptocurrency transactions.

Blockchain technology underlying Bitcoin world enables peer-to-peer exchange of money worldwide without the need for bank institutions or other intermediaries, due to its distributed and immutable structure.

Indeed, a blockchain is a data structure in which data are assembled in *blocks*, these *blocks* once written into the digital register, are shared with all the participants of the network, and no one can change them: their integrity is granted by the use of cryptography.

There is a diffuse confusion by uninitiated people about Bitcoin and Blockchain, a lot of people see the two words as barely synonymous, in reality, this technology

[1] Satoshi Nakamoto is a pseudonym which indicates a person or group of people who invented Bitcoin cryptocurrency system

which permitted the development and diffusion of Bitcoin as a free transaction vehicle, is being discovered as a technology with a huge potential due to its core features.

Technically, a blockchain is a Distributed Ledger Technology (DLT), a shared and immutable digital register in which the data are grouped into pages, called blocks, linked in chronological order (hence the name blockchain: chain of blocks), which allows to certify the information entered thanks to their immutability and by spreading the same register to the so-called *nodes*, the participants of the network.

If the nodes that make up the blockchain network validate the transaction, by checking the digital signatures of those who proposed it and the correctness of the content, the information is written within the register, it will be visible to the other actors of the network and can no longer be changed.

The information that you want to certify is entered in blockchain through specific transactions, an attempt to modify a transaction along the blockchain would automatically make all subsequent transactions invalid.

The market for blockchain technology is rapidly growing, "IDC[2] expects blockchain spending to grow at a robust pace throughout the 2018-2023 forecast period with a five-year compound annual growth rate (CAGR) of 60.2%. Blockchain spending in 2019 is forecast to be $2.7 billion, an increase of 80% over 2018." (International Data Corporation, 2019)

1.1.1 Blockchain technology in Italian legislation

Italian government is being a pioneer in the legislative definition and validation of distributed registers and smart contracts, in February 2019 there has been a

[2] International Data Corporation (IDC) is the premier global provider of market intelligence, advisory services, and events for the information technology, ICTs and consumer technology markets.

proposal for amendment no. 8.0.3 to the DDL n. 989 and approved by the senate, which includes the definition of distributed ledger technologies as follows

«Technologies based on distributed registers" are defined as technologies and computer protocols that use a shared, distributed, replicable, simultaneously accessible, architecturally decentralized register on cryptographic basis, such as to allow the registration, validation, updating and archiving of data both in clear and further protected by cryptography verifiable by each participant, not alterable and not modifiable.» (PATUANELLI, 2019)

Also smart contracts, prior identification of involved parts and with a process which will be identified by AGID[3], will satisfy legal requirements of written form of contracts, a smart contract in Italian legislation is identified as:

«a computer program that operates on technologies based on distributed registers and whose execution automatically binds two or more parts based on predefined effects.» (PATUANELLI, 2019)

The government with this amendment is aiming to release a guideline containing the requirements for the legal value of those two technologies.

Since these are trust-based technologies, analysts consider smart contracts and distributed registers as potential turning points in many different areas, such as the certification of the origin of products, education, transport, mobility, maritime navigation, land registers, business registers and health, to transform the way in which these services are provided.

To this end, the collaboration of the university world and research with local operators should be encouraged to define priorities and develop technological, organizational and social innovations and solutions, able to face environmental and nutritional challenges, so as to promote the sustainability of the agro-industrial chain and contribute to the creation of new jobs.

Some useful suggestions, in this sense, are proposed by FAO[4]. According to the FAO Report 2018 (Tripoli, 2018), DLTs provide a unique

[3] The Agency for Digital Italy (Agid) is the technical agency of the Presidency of the Council with the task of ensuring the achievement of the objectives of the Italian Digital Agenda.

[4] Food and Agriculture Organization of the United Nations

opportunity for the agricultural sector. The technological platform introduces a new concept of digital trust aiming to reduce the uncertainty between buyers and sellers, bringing efficiency, traceability and transparency to the information exchange, which is fundamental for the agricultural sector and the entire global economy. In its report FAO affirm that DLTs can help governments achieve their public policy goals for inclusive economic growth in agriculture, rural development and food security, and can act as a catalyst for sustainable development goals.
The Report concludes with the hope that agriculture focused organisations should continue to improve their knowledge base, and organise the technical assistance needed to prepare and support agricultural actors and regulators to play an active role in blockchain-enabled agricultural value chains.

1.1.2 Blockchain technology potential fields of application

Many areas of business and public services are considering the use of distributed ledger technologies for quite different purposes.
Here, a rapid overview of most important areas which demonstrated interest in DLTs and respective expected benefits of the application.

- *Money exchange*

Maybe the most popular application of the technology thanks to the mass media attention to Bitcoin cryptocurrency, this use of the technology could have a huge revolutionary impact in exchanges, despite serious structural issues of this hypothetic, maybe utopian system, are still not been solved.
Cryptocurrencies[5] can enable people worldwide to instant, secure, and frictionless exchange of money, and blockchain technology can provide the permanent record storage for their transactions. Where cryptography and economy meet, a new

[5] A cryptocurrency is a digital or virtual currency that is secured by cryptography, which makes it nearly impossible to counterfeit or double-spend.

discipline called cryptoeconomics is proposed by some authors, and defined in 2015 by Vald Zamfir, a researcher for Ethereum foundation[6], as:

«A formal discipline that studies protocols that govern the production, distribution and consumption of goods and services in a decentralized digital economy. Cryptoeconomics is a practical science that focuses on the design and characterization of these protocols. »

Babbitt and Dietz instead give a definition of cryptoeconomy as an economic system which is not constrained by geographical, political and legal institutions, in which blockchains substitute trusted third parties constraining behaviour of the transactions, which are recorded on a decentralized public ledger. (Babbitt & Dietz, 2015)

Traditional monetary systems require to trust a central authority (i.e. a bank) that money transfers will be not tampered with.

Blockchain technologies can make this method of financial exchange become obsolete, by providing a trusted environment where there is no longer the need to rely on a third-party to ensure money transfers, creating an independent peer-to-peer network, self-regulating through the technology itself.

- *Government - Digital identity management*

Some technologically advanced countries and regions are already experimenting this way of gaining efficiency through sharing in a secure way data about people across different organisation contrasting time waste and unpractical bureaucratic practices.

South Tyrol, in collaboration with SAP[7] is planning to de-bureaucratize the process of Public Administration using Blockchain to verify and share citizens' documents and information between different local entities in an effort to fight inefficiencies and time waste linked to multiple modules compiling and need of communication

[6] Ethereum is a decentralized Web 3.0 platform for creating and publishing peer-to-peer smart contracts
[7] SAP is the leading European provider of management systems.

between public entities for personal information collection, without contrasting with European regulations in data protection.

- *Property management - smart contracts*

Real estate industry has often complex and slow procedures, with prevalence of paper-based documents; adopting blockchain technology in the real estate market for essential functions as payment, escrow and title could lead to huge cost savings and efficiency gains, nonetheless it could reduce frauds, make transactions faster, internationalize markets and increase financial privacy.
Blockchain technology could simplify the work of title companies, title insurance companies and make property title management process more secure, with improved property ownership record tracking, with benefits to data retrieval process allowing to save time and money wasted to go to town, district, region or state government offices to obtain information from paper files.

Thanks to DLT and smart contracts[8] technologies, real estate market can become more fast and trustable with for example the DLT driven verification that the seller actually owns the property and has the right to sell it, or that the buyer has the funds to buy it; this kind of transactions are based on smart contracts and work on an “if this then that” logic, in this way controls can become automatic and precise.

- *Health sector*

Similar to what happens for Digital Identity Management, there is a huge efficiency gain in sharing personal medical information in a secure and privacy-protecting way between different medical organisations, blockchain in this field can improve system interoperability and accessibility of medical records creating a virtual medical system moving beyond organisational and local boundaries (RJ Krawiek, 2016)

[8] A smart contract, also known as a cryptocontract, is a computer program that directly controls the transfer of digital currencies or assets between parties under certain conditions.

- *Supply chain management - Food traceability, safety and quality*

Blockchain has being discovered to be a possible game changer in the organisation of the supply chain and its management, enhancing efficiency and lowering risk, while cutting transactions costs.

In a blockchain environment, food products can be seen as assets with certain features, moving through different locations, companies and actors before coming to the consumer; the potential of DLTs for food industry leans in its ability to provide full control and transparency along the supply chain in a sector in which they are thoroughly needed.

This areas of interest will be object of more accurate study and will be discussed in-depth later.

1.2 Typologies of blockchain

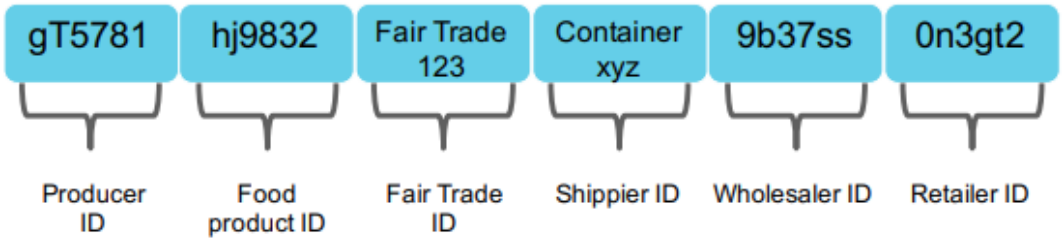
Blockchain has no rigid structure to apply in every context but its form and functioning changes in light of its scope, and in particular when used in supply chain management in light of the structure of supply chain, the nature of the product that we're going to trace and certify, and what we're going to certify.

Blockchain technology will make it possible to record and certify information concerning:

1. Conditions at production plants and any certifications attributed to the production site, for example those concerning work safety, animal welfare etcetera.
2. Tracking of *food units* along the supply chain, intended as specific units, where their nature makes it possible. The creation of unknown identities is not

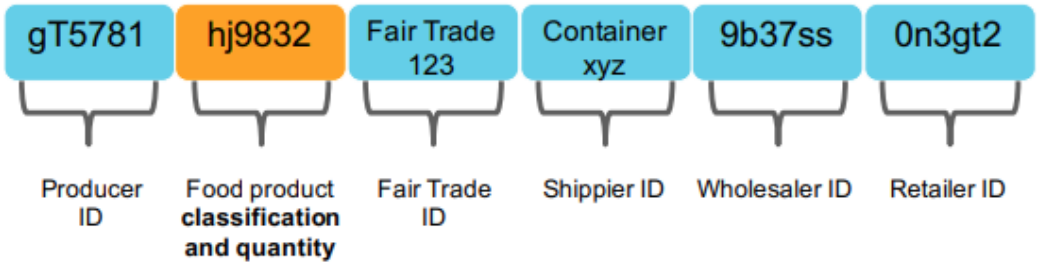
   possible and so the opportunity to double spend, i.e. to sell deceptively a product as certified if it is not associated to real registered certificate.

(It would be technically impossible to trace every blueberry or every grain of rice)



[Source:https://www.sklkommentus.se/globalassets/kommentus/bilder/publication-eng-blockchain-for-food-traceability-and-control-2017.pdf (1.11.2019)]

3. Tracking of *food volumes* along the supply chain, where the tracing of every unit is not technically feasible. This represent an important incentive against product manipulation and can be a game changer in markets in which there is a limited production with high quality standards and the risk of forgery and incorrect labelling is high and linked to quantities; this happens for example in markets of products with denominations of controlled origin, in which reconciliation of produced and sold quantities is a major issue for control organs.



[Source:https://www.sklkommentus.se/globalassets/kommentus/bilder/publication-eng-blockchain-for-food-traceability-and-control-2017.pdf (1.11.2019)]

There will be three types of users, with different user interfaces:

1. *Professional users*: producers, wholesalers, processing companies, packaging, transporters, retailers.

2. *Software and smart contracts managers:* a smart contract is a computerized protocol that executes the terms of a contract automatically, according to the *if … then* principle
3. *Consumers*: theirs is a passive interface, for consultation only, apart from providing feedback when required.

The blockchain is the part where file checks, contracts and transactions are recorded and archived, they can be public or private.
In a public blockchain, like for example Bitcoin or Ethereum, anyone has access to the totality of the transactions executed on a global scale in the same blockchain.
This means that all data entered in BC will be available to everyone.
In a private blockchain instead, the owner of blockchain can decide what information to share and who to share it to.

The hypothesis for now is that an authorized blockchain would be more attractive for business, that need data protection and could have privacy issues with competitor and partners; with a private blockchain you can certificate information needed by the customer about the product without publishing general data that are not fundamental to demonstrate the qualities of the product and that competitors and partners can see only what the company want to certificate.
In this way, trusted blockchain partners are allowed to validate transactions and blocks and the content validated and registered in blockchain may or may not be published.

There are different kinds of Blockchain implementations, with different degrees of freedom on how blockchain can be tailored towards the specific use case, an implementation with a high degree of freedom is fully adjustable to the business, but on the other side it can be difficult to set up and maintain because it requires the full understanding of the underlying code base.
Here is a rapid overview of different actual implementation methods offered by the blockchain provider market with different degrees of freedom and implementation difficulty.

- *Blockchain as a Service (Baas)*

Blockchain as a service is a software providing model in which a third party (e.g. *IBM Bluemix Blockchain, Amazon AWS Blockchain Solutions, and Microsoft Azure Blockchain workbench*) hosts an application and offers its functionality through the internet.

- *Blockchain first*

It is an implementation that requires to work directly with the blockchain tools and stack, requires a complete assembly, the benefit of using a *Blockchain first* implementation is that this allows maximum degrees of freedom and innovation. Bitcoin and Ethereum are examples of blockchain platforms created from scratch using directly blockchain tools, many blockchain service providers use this implementation method to create their services.

- *Vertical solutions*

Vertical solutions are industry specific solutions basing on private blockchain infrastructure, some of these are more a distributed ledger solution than properly blockchain solutions, a distributed leger solution is a subset of a blockchain solution

To clarify the difference between a distributed ledger and a blockchain, we can say that the DL is a database spread across several nodes or computing devices, each one replicating and saving an identical copy of the ledger, the structure of the blockchain makes it distinct from other kinds of distributed ledgers: data on a blockchain is grouped together and organized in blocks that are then linked to one another and secured using cryptography creating a continuously growing list of records. Its append-only structure only allows data to be added to the database: altering or deleting previously entered data on earlier blocks is impossible.

- *Development platforms*

The implementation of blockchain technology can also be carried out through specific development platforms that allow rapid development with a strong focus on blockchain programmability. An example of a diffuse development platform is Hyperledger.com by Linux Foundation that offers different blockchain frameworks and tools suited for different industry and specific needs as for example *Hyperledger Iroha* – with focus on mobile applications, *Hyperledger Burrow* – a permissioned smart contract machine, or *Hyperledger Fabric* – enterprise DLT with privacy support, that will be object of a more in-depth study in the next chapter. (Linux Foundation Project, 2019)

1.2.1 Hyperledger Fabric

Hyperledger Fabric is actually the most widely used private blockchain, used primarily in enterprise settings to make transactions between multiple businesses more seamless and efficient, hyperledger fabric has a modular design which means that businesses can plug in different functionalities to suit their particular needs

Like all blockchains, Fabric records a list of transactions in a chronological ledger.

In fabric the definition of what get transferred is called an asset, which can be anything with monetary value, from whole food, cars to currency features, hyperledger fabric allows the businesses to set their asset types and value themselves.

Assets are represented as a collection of key value pairs with state changes recorded as transactions in the ledger, hyperledger fabric provides the ability to modify assets state using chaincode, chaincode is the software defining an asset and the transaction instructions to modify those assets, in other words it is the business logic; smart contracts that are deployed to the fabric ledger execute the chaincode instead of having each one their own business logic.

Fabric provides a membership identity service that manages user IDs and authenticates all participant of the network, a specific user ID could be permitted to invoke a chaincode application but be blocked from deploying new chaincode, this information network also assigns network roles by node types.

There are two node types: *Peer nodes* and *Ordering nodes*

Peer nodes are responsible for executing and verifying transactions, o*rdering nodes* are responsible for ordering transactions and propagating the correct history of events to the network, this is done to increase efficiency and scalability by allowing peer nodes to batch and process multiple transactions simultaneously. The network consensus protocol[9], which the businesses in the network can customize, is then implemented by the ordering nodes to create a single true record of transactions.

Consensus is sometimes mistaken with validation, which is a different process taking place in blockchains, the validators control that the transactions are legal, there are no double spends, they're not malicious and so on, while the consensus is about determining the ordering of events in the blockchain and coming to an agreement about this order.

Fabric's ledger is then composed of two components: a *blockchain log* to store the immutable sequence record of transactions in the blocks and the *database state* to maintain the blockchain current state; in the bitcoin blockchain there is no database and the current state of the chain is always calculated by going through all the transactions in the ledger.

For speed and efficiency sake hyperledger fabric stores the current state as well and enable the members of the network to do queries on it.

The purpose of the log is to track an asset provenance as it is exchanged among multiple parties, tracking an assets provenance is extremely important for business because it ensures that the agent who is selling the good possesses a chain of titles verifying their ownership of that; for food market this is even more important,

[9] A consensus mechanism is a fault-tolerant mechanism that is used in computer and blockchain systems to achieve the necessary agreement on a single data value or a single state of the network among distributed processes or multi-agent systems, such as with cryptocurrencies. (Investopedia, 2019)

since provenance of food can ensure its quality and its safety. In typical databases, where only the current state of an asset is caught and there is not a log of all transaction, tracking an asset provenance can become very difficult and time costly.

Adding the fact that often transacting businesses keep incomplete records of the assets transactions, it becomes nearly impossible, the reason many businesses used this system as long as they did was for the sake of privacy since the distributed ledger make that every party in the business network have access to all the transactions even if they weren't involved in them.

This was a deal-breaker for many businesses who were perhaps in the same business network as their competitors and didn't want to reveal their data or transaction with other parties to them.

Hyperledger Fabric solves this problem using private channels, restricted messaging paths which are used to provide transaction privacy and confidentiality for specific subset of network members: all data including transactions, member and channel information on a channel are invisible and inaccessible to any network members not exclusively granted access to that channel.

This allows any group that require private and confidential transactions to coexist on the same permissioned network.

So hyperledger fabric has a modular design that enables those core functionalities:

1. Members of the business can define asset types and the consensus protocol for ordering transactions.
2. They can set permissions on who can join the network and what kind of access each member should be grant.
3. To increase efficiency nodes are divided in two types: peer nodes and ordering nodes: peer nodes batching, verifying, processing transactions and ordering nodes logging and ordering those transactions in a chronological order

Fabric ledger itself consists in a database of the network's current state and a log of transactions stored in the blockchain for tracking each asset provenance.

Access on the network are added, updated and transferred using chaincode in the form of smart contracts deployed and invoked on the network.

1.3 Benefits and barriers of Blockchain technology

Benefits deriving from the application of the blockchain technology in a company can be both internal and external.
Internal benefit can derive to de-bureaucratization and optimization of informational process, for example the avoiding of document duplication, the standardization of data format and unification of databases, but also to the improved speed of the control over items in the supply chain, as in the case of the improvement of the replenishment planning thanks to the real time monitoring of stock, the quicker recalling and withdrawal procedures and the facilitation of quality controls trough blockchain and smart contracts technologies that can lead to a significant costs (and risk) reduction.

In addition to the reduction of costs and risks of non-compliance with the regulations linked to controls by the authorities, blockchains may provide benefits in the data entry process with considerable time savings and de-bureaucratization of the supply chain traceability processes, unifying the different communication tools and document formats required, now co-existing in food traceability process.

Another important aspect is the advantage of being able to obtain from a single source a multitude of data available for economic, technical and managerial analysis from which it will be possible to obtain information for process optimization and the decrease in operational risk deriving from deficient and inefficient systems.

The result of this data stream will be an interface which is accessible to the final customer where there will be the information that the company will decide to provide and certify through blockchain, and likely also a "commercial" part of the interface in which the company will have the possibility to enter additional

information or multimedia material such as photo and videos of the company and the production plants, advertising of products, cooking recipes etc.

Blockchain technology is thus a tool that aims to lower information costs for companies, institutions and consumers changing the structures of data storing and sharing, as illustrated in the image below.

[Source: https://www.provenance.org/whitepaper (14.11.2019)]

The external benefits include intellectual property related benefits as fighting frauds and black market and image and customer loyalty opportunities like creating loyal relationship with customers and raising company's image by proving the ethical and environmental behaviour of companies offering transparency of products and practices.

Blockchain related barriers instead are divided into two groups: operational barriers and strategic/tactical barriers.

Operational barriers principally concern the typology of the blockchain: the nature of items hardly affects the choice of what IoT device to use to track products, moreover, the tracking process can become really difficult for complex products, also due to the eventual reiteration of same components.

Strategic and tactical barriers are various and some derive from the novelty of technology, as the lack of existing standards and legal rules, or the uncertain impact on the cost structure.

Also the relation between blockchain and external environment hides some complexity points, the collaboration in a blockchain network requires the honesty of every company and the participation of every component of the supply chain, moreover, the involvement of certain types of companies can be complex.
Globalisation radically changed supply chain structure, geographically disjointed entities competing to serve consumers compose an intricate network in which inefficient transactions, pilferage, fraud and poorly performing supply chains are causing a raising trust shortage, that made emerge the need for better information sharing and verifiability.
«Traceability in this context is both an urgent requirement and a fundamental differentiator in many industries, including the agri-food sector. » (Costa, 2013)
Supply chain traceability management is further complicated by the costs of handling intermediaries, their reliability and transparency, avoiding the risk of competitive issues (both strategical and reputational) deriving from lack of transparency.

Chapter 2

Applying blockchain in the supply chain

2.1 How blockchain can help supply chain management

The potential of having a distributed register that cannot be manipulated including information of all the life of the product in all its stages can change the way in which firms operate and consumers chose in the future.

Not only provenience of food can be certified with DLT but also its transportation and stocking conditions, social and animal welfare certificates, age of food and its shelf life, and all other information required by regulators or interesting consumers and influencing their choices.

Another aspect is the contrast of counterfeit products, that cost to honest companies worldwide billion dollars per year, and the elimination of fake claims and consequent trust issues.

When talking about blockchain system we are not talking about a rigidly structured system which will be standardized for entire markets, but about customized systems that can be created basing on peculiarities of specific sectors, relying on DLT to certificate information that are needed to.

Companies are increasingly interested in supply chain management systems, facing many challenges to connect information and strengthen relationships among parties of the production process (producers, brokers, transporters, processors, wholesalers, retailers) who may be hesitant to share data.

Supply chain management system as it is today is outdated and unable to keep up with growing interconnectedness that the global industry presently demands. There are some issues on this topic that can be solved adopting DLTs and decentralized supply chain management system.

- *Slowness and trust issues*

Intermediary heavy authentication processes can make the supply chain very low, logistics speed is often hampered by multiple controls, mostly if the exchange is international, blockchain can certify the entity and features of the product to control authorities without the need for long documentary reconciliations. In traditional supply chain payment transactions are often not fast nor free because they need an intermediary and there is the risk to not receive the expected shipment or payment, the transactions are based on trust or costly third-part verification that can be replaced by automation and a better technological structure. Furthermore, smart contracts can enable released payment automation and can be used to hold payments between manufacturer and seller or seller and consumer in escrow. There's no more need to pay before and wait the product trusting on supplier, the payment will occur only after the shipment has arrived, authenticated and as promised.

- *Counterfeiting and Fraud*

People are more and more concerned with the authenticity and the provenance of the goods they buy, counterfeiting can damage customers but also manufacturers' reputation and business. To contrast this phenomenon, companies and authorities need to know what and how many products are stored in every location, this sounds very complex without a trustable and automatic certification and data

storage, but blockchain providers tried to find a solution developing platforms, like for example IBM food trust, where it is possible to control real time position and quantity of products storing worldwide through an easy consulting map, where information are secured by their immutable record in the BC distributed register. Italy is one of the countries for which the counterfeit products cost the most, the OECD-EUIPO report provides estimates for Italy, where “the cheap competition from counterfeited products led to the elimination of 88,000 jobs, which corresponds to 2.1 per cent of the total number of employees in sectors that are directly affected by counterfeiting”. (OECD and European Union Intellectual Property Office , 2019).

There are two stages of supply chain in which Blockchain can help contrasting forgery:

- *Procurement and production*

Long and complex global supply chains, varying data and reporting quality across the vendor base, together with lack of transparency needed to verify the authenticity of parts and raw materials and trace them back to their source make it complex to have full control of the components with the risk of inadvertent use of counterfeit components across the process that can compromise final product quality.
This situation leads to high control costs and potential reputational harms, lawsuits and recalls.

- *Sales*

Provenance proving is mined by clever manipulation of labels and reverse engineered product, and the problem is boosted by recent growth of online and third-party retail channels. This can lead to lost revenues and disappointment by the customer if inferior fraudulent substitutes don’t work as expected and don’t respect the true brand’s qualitative standard they’re paying for.

Blockchain, together with IoT can provide traceability and unique identification of items, granting the control of the entire chain of custody. Combining IoT sensors and distributed ledger technology can set up a model in which products across the entire supply chain can be tracked in nearly real time in an immutable way, assuring what traditional technologies are not able to.

2.1.1 Improving supply chain efficiency

Let's see the core architectural differences between the application of this technology in the finance sector and its application in organizational field as a supply chain management processes enhancer.
First of all, Blockchain in financial field is designed to enable transactions between an unlimited number of unknown users enabled to transact securely without the need of an intermediary, while in supply chain management field the network is designed to enable a limited set of known users aiming to achieve better performance for their business while protecting their operations from malicious actors.
The differences underpinning this specific application and the functionalities required bring out the need for new permissioned blockchains, new standards for representing transactions on a block and new rules to govern the system.
Visibility is still a challenge in large supply chains involving complex transactions, ERP systems and financial ledger entries have some important limitations.
An example of those limitation could arise from examining the risks associated to a simple transaction scheme: a retailer buys a product from a supplier and the bank provides to supplier the working capital needed to fill the order: inventory flows, financial flows and information flows are involved.
In a blockchain based system, at the moment of the order, even if no good or services are exchanged and no entries are added to the financial ledger, a digital token is signed for the order by the retailer, and the same happens when the

supplier eventually confirms the order; the third actor, the bank, will be able to see that the order has been placed in the blockchain since the parties will share this kind of data.

The benefits of this system are tangible because of the reduction of execution, coordination and traceability problems enabling actors to control the history of the transactions and hold counterparties responsible for their action, furthermore, the bank can improve loaning decision process by having directly the data of the actors' transactions without having to recur to tedious and error-prone physical audits and financial reviews, this naturally implies differentiated levels of access and a strong data privacy policy to avoid incorrect or dangerous behaviours. (Vishal Gaur, 2020)

Considering the increasing demand for blockchain data analytics, it is important to understand the way to efficiently access, integrate, and analyse data into this environment .

The data stored in blockchains are permanent and transparent to the entire network, this brings some data governance issues: although stored in encrypted form, data might be subject to brute force decryption attacks in the future if current encryption technologies will become ineffective, or more simply could cause unintended privacy leakages.

Therefore, it's imperative to carefully review these issues to develop adequate frameworks for blockchain data governance to structure an effective management and a proper use of blockchain technology.

Some of the functions performed by the blockchain can be automated with the help of smart contracts, which can automatically verify when contractual obligations have been met and enable the payment issue, record ledger entries or flag exceptions in which manual intervention is needed if something appears to be gone wrong.

This doesn't mean that blockchain aims to replace ERP systems, whose structure enable a quicker and more efficient storage and retrieval, but it will represent a point of convergence of data from ERPs of many different companies of the supply

chain and a tool for quickly tracking transactions of many forms (financial, inventorial, informational) that are not linked in this way in the traditional systems, giving the possibility of more efficient auditing and control and more transparency between different actors of the chain.

At the state of the art, ERP systems, audits and inspections can't rapidly and reliably connect the three flows, not enabling to real time track execution errors, that require time to be pinpointed through tracing the sequence of activities recorded in the available ledger entries and documents.

Auditing activity helps bringing to light supply chain inefficiencies but often lack to rapidly find out the causes that lead to those inefficiencies, for example locating expired products in retail stores doesn't rapidly lead to an explanation of the causes of the event, is it because of inefficient inventory management upstream, suboptimal allocation of products in stores, weak demand or inadequate shelf rotation?

It is possible to enforce supply chain operation integrating RFID tags to track items along their way down the chain, but the integration of RFIDs and of different ERPs can be complex due to their variety.

The ability to capture near real time information has increased years ago thanks to RFID technology utilization, enabling better decision making, RFID tags enable the tracking of units along the supply chain building a bridge connecting physical and virtual world and allowing virtually anything to be connected to the internet, recording their location and other information; BC technology can bring benefit to this system ensuring that information is not corrupted.

In this way, RFID technology allows to better manage inventory flows, reducing costs and promoting supply chain visibility.

Real time monitoring, collecting and analysing information are at the basis of IIoT[10], a subset of IoT allowing the optimization of manufacturing processes and of the response to demand driving business system to efficiency and flexibility

[10] Industrial Internet of Things is the evolutionary path of the industrial network through which each physical object acquires its counterpart in the digital world.

through information processing.

In blockchain ledger RFID plays an important role since incorporated with IIoT it allows the automatic entering of information into the blocks avoiding the necessity of manual data entry.

According to Jeyarai and Sethi, the aim of supply chain visibility is to automate the information sharing with trading partners adopting data sharing standards to integrate disparate organizational activities. (Jeyaraj & Sethi, 2012)

Gains in efficiency are possible also in banking processes, the processes to control the access to capital are required due to information asymmetry and they represent a cost that is detrimental both for banks and firms looking for a cheap credit, using blockchain technology a new way of financing can take place, with working capital provided automatically when an order is received and the payment obtained automatically by the bank when the seller is paid.

In the accounts payable management, although improvements in speed given by ERP systems, there is still a lot of room for improvement, order-invoices reconciliation, transaction progress tracking, term scheduling and reviews still require a lot of manual processes that can be diminished and speeded up through blockchain based automation. (Vishal Gaur, 2020)

To implement such systems, it is fundamental that permissions to join the blockchain network will be granted selectively and will give different degrees of freedom.

To ensure that data on blockchain correspond to physical assets and avoid errors or counterfeit products, physical audits to control the assets at their first step in the supply chain and a strong IoT devices integration are still required.

2.2 Economics of blockchain

Nowadays there is an abundance of data and information, blockchain can provide the building blocks for a trust system based on digital information and algorithms. A natural question that might arise since the no open access nature of private and permissioned blockchains is what makes their application different to a database upgrade.

The key point here is that the consensus mechanism is more decentralised that in traditional systems, the capability of tracing offline assets recording their origination and path of ownership in a tamper proof manner enhances the concept of traceability in the supply chain; nonetheless blockchain combined with IoT can boost assets exchange speed by providing a secure environment in which items can be tracked and exchanged minimizing the risk of fraud and bypassing the need for a trusted third party, ensuring that only transaction parties which are in possess of the required digital signature can execute the transaction.

The origin of ledgers is very old, it dates back to 15th century Venetian Republic's development of bookkeeping, which has not seen radical changes till our years and still keeps its centralised nature.

A technology that enables to re imagine bookkeeping and ledger structures, making decentralized solutions technically possible, hides the ability to run down three exponential cost curves:

- Moore's law: Cost of processing digital information
- Kryder's law: Cost of storing digital information
- Nielsen's law: Cost of shipping digital information

(Wiles, 2015)

We can see blockchain as a technology rapidly running down a learning curve and whose costs are quickly lowering, due to the competition on this technology providers' market; however, it is a radically changing and impactful system that

presents high switching costs, network effects and business implications, so its expected substitution pathway is non-linear.

There are different visions about the development and spreading pathways of this potentially disruptive technology, Buterin argues that there is no “killer app” that will boost the diffusion of this system but rather a long tail of marginal use cases among particular groups, adding up a lot to the phenomenon: this diffusion trajectory will unfold as sequential applications will be discovered and adopted in an entrepreneur-led market process of industrial dynamics. (Buterin, 2015)

Often, evolution of complex systems follows a centralization to decentralization pattern; the reason is that a centralized structure is the simpler to create and the one in which it is easier to establish and enforce rules, making it simpler to create clear hierarchies and to adjudicate disputes.

But when the established power becomes vulnerable to exploitation, risks as inflation, corruption and rent-seeking appear, and costs to maintain the power begin to accumulate, making the order brought by the centralized system fragile. However, when these powers become vulnerable to exploitation, costs to maintain these features begin to accumulate, and risks as inflation, corruption and rent-seeking appear, so the centralized system bring order, but this order can be brittle. The shift from centralization to decentralization can lower these cost as costs of decentralization fall due to technological progress (consider for example computers and cryptography) and make the system more robust, flexible, secure and efficient.

In this context some foundations have started to research to develop possible solutions to promote and apply decentralized systems, a leading example of this endeavour is Ethereum; as we can think about Bitcoin as a cryptographically secure transaction based state machine (a specialized technology), we can consider Ethereum as a project attempting to build the technology on which the transaction based state machine concepts may be built (a generalized technology). (Buterin, V., 2013)

Ethereum is aiming to become a superior foundational protocol which will enable other decentralized applications to build on its top giving them plethora of tools to work and giving to these application the ability to gain full benefits of Ethereum scalability and efficiency; this is meant to enable people to interact each other with confidence in possible outcomes no matter with which other individuals, organisations or system they were interacting.
In Ethereum agents can write and execute smart contracts, from which decentralized applications, like including Distributed Autonomous Organizations (DAOs), can be created.
A decentralized autonomous organization (DAO), sometimes labelled a decentralized autonomous corporation (DAC), is an organization represented by rules encoded as a computer program that is transparent, controlled by shareholders and not influenced by a central government. (Social Science Research Network (SSRN), 2017)

2.2.1 A transaction costs perspective

TCA is concerned in all levels of exchange of products, services and information within and outside organizations, Blockchain immutability leads to a condition of ubiquitous trust based on the operations transparency and this will probably transform organizational sizes and structures.
Transaction costs approach is also concerned with contracting, with costs being generated through drafting and negotiating, through managing relationships and information and to enforce agreements; the use of smart contracts influences this costs automating processes and eliminating the impact of bounded rationality while discouraging opportunistic behaviour.
Operational efficiency can be divided in cost-based efficiency and time-based efficiency, the first concerning costs of manufacturing and quality while the latter concerning manufacturing lead time and delivery speed and reliability.

The gains operational efficiency can derive from Blockchain and smart contracts implementation include reducing costs by removing intermediaries and functions developing transaction related trust, boosting supervision capability (and thus efficiency), eliminating issues linked to withholding payments and lowering the costs related to legal, court and tax consultant fees when it comes to enforce a legal agreement.

The influence of Blockchain technology according to Morkanus et al. (2019) occurs in three different determinants of operational efficiency, notably resources, routine and capabilities.

Transparency and trust can make organizational resources more fluid opening to non-traditional ownership frameworks; the automation of business processes allows human resources to focus on more value-added activities thus facilitating the increase of capabilities. (Morkunas, Paschen, & Boon, 2019)

Blockchain is a disruptive technology that can radically change the way contracts are done and organizations are structured, according to TCE – Transaction costs economics[11]; instead of having as the basic unit the choice over scarce resources as it is in neoclassical economics, in TCE the transaction is the basic unit.

«Economizing in production costs lead to an efficient allocation of resources, while economizing in transaction costs lead to an efficient institutional structure of economic organization and governance. » (Sinclair Davidson, 2016)

Market is an efficient governance institution when we have single contracts and a pure exchange economy, but not when coordinated investments through time or ongoing and frequent relations between parties are required by the economic activity, (Sinclair Davidson, 2016) in those cases there is the need of different governance institutions, for example relational contracting and hierarchical firms. So why some transactions are better taken in hierarchical structures as firms rather than in the market?

[11] NIE originates in the work of Coase (1937, 1960), who explained why firms exist by positing the idea of transactions costs of using the market.

According to TCE, in transactions that involve opportunism, asset specificity, and frequency the hierarchical structure is more efficient.
We can think about the same question including blockchain as an institution, why is it more efficient to make transactions in a blockchain, rather than in firms or markets? (Sinclair Davidson, 2016).
Basically, radical public transparency and crypto-consensus mechanisms assured by smart contracts inside a blockchain can eliminate opportunism, this allows this new institution to outcompete relational contracts (which needs trust between parties) and traditional organizational hierarchies.
But the obvious problem is that blockchains only work on complete contracts, «whereas most in-the-world firms are largely made of incomplete contracts». (Hart, 1989)
What do we exactly mean with complete or incomplete contracts?
Measured against the complete contract benchmark, an incomplete contract does not take into account some of the relevant variables, economic agents often sign those contracts because of their bounded rationality and the lack of verifiability of the variables which pertain to contract fulfilment. (Schwartz, 1992)
Taking into account all contingencies that can affect a transaction is barely impossible, contracting parties sometimes don't know the optimal response to identifiable contingencies that should be stated in the contract or assess its completeness.
Hence a 'more complete' contract in this context, we refer to one that tends to specify every dimension of the transaction, not necessarily using all the relevant information.
«A contract is thus more complete than another when it gives a more precise definition of the transaction and of the means to carry it out. »
(Saussier, 2000)
Transaction cost economics states that the inter-firm level of contractual completeness, as defined above, reflects a desire by the parties to save transaction costs.

The desire of the parties to save transaction costs, according to TCE is reflected in the inter-firm level of contractual completeness.
Transaction costs can thus arise from:

- Uncertainty, or unforeseen contingencies
- Cost of writing contracts
- Cost of enforcing contracts

Smart contracts combined with blockchain can substantially lower information asymmetries and thus efficiency problems through facilitating transactions and contrasting adverse selection and moral hazard[12] by enabling to load significant numbers of low probability state contingencies into contracts making it possible to lower the complexity cost of writing contracts and consequently the transaction costs.
From Williamson's perspective, firms have the power to contrast opportunism in two aspects, the first is granting cohesion and a unique direction and decisional entity provided by hierarchy where there is the need of planning and coordinating joint inputs (as a consequence to asset specificity); the latter is to contrast an issue of the market structure represented by the ability of agents to exploit trust. (Williamson, The Economic Institutions of Capitalism, 1985)
In Williamson's perspective of firms originating by the need of contrasting the effects of asset specificity and bounded rationality in contracts, blockchain can eliminate the need of trust enabling crypto-enforced execution of agreed contracts through consensus and transparency.
In this view, blockchain is a mechanism to control opportunism by eliminating the need for trust by using crypto-enforced execution of agreed contracts through consensus and transparency.

[12] Moral hazard is the risk that a party has not entered into a contract in good faith or has provided misleading information about its assets, liabilities, or credit capacity.

We can distinguish two different intrinsic natures of transaction costs: Adverse selection and moral hazard; while the first refers to pre-contracting risks, the second refers to post contracting risk, where a party of the transaction doesn't keep the originally understood expectations of the transaction.
These kind of problems arise because of the asymmetric information about the goods or services traded or about the identity of the parties involved in the transaction, this leads to so-called "Principal-agent problem", Inquiries about strangers could be difficult.

Principal-agent problem occurs when an agent is empowered to make decisions on behalf of a principal, assuming the agent as a self-interested utility maximizer in the absence of threats, sanctions or inducements, moral hazard occurs when the agent takes more risk because someone else bears the costs of those risk, and this is fuelled by informational asymmetry.
For example, this problem can occur in the shareholders – corporate management relationship, some scholars affirm that blockchain, together with smart contracts, offer an innovative solution to address the problem, giving the possibility of a more decentralised governance model, while lowering transaction costs of reaching agreements by enforcing transaction rules (rights and obligations) that bond people through a smart contract consent.

Oliver Hart, a specialist of contract theory that won a Nobel prize for his formulation of a "Principal-agent problem" , while expressing doubts that smart contracts could be a cure-for-all solution, affirmed that in its vision blockchain technologies must focus on their ability to reduce transaction costs of goods and services exchange, "whether it is more capable of making contracts "smart", or being able to circumvent traditional forms of middlemen market transaction fees." (Akram, 2017)
The auto-enforceable code under blockchain and smart contracts can substitute middle men and lower bureaucracy. (Voshmgir, 2017)
In this respect, although Blockchain can track identity of people and assets, it cannot dig up hidden information about them.

An example of the possible benefits of disintermediation is the Airbnb case, that in the past would have been considered a high transaction costs business since people weren't easily willing to share living spaces with strangers, transparency given by the publicly available rating and feedback mechanism allowed people to look for a living and for hosts to look for potential customers without the need for intermediations except from the platform itself.

2.3 Food traceability network benefits

Blockchain technology can lead to benefits for all actors of the production and consumption network, in this paragraph we'll examine how this technology can bring value to the food sector.

- *Contrasting food fraud*

Food fraud is a worldwide problem that can have multiple facets, from products sold under improper label which may cause even health risk, to products whose origin is mislabelled to trick the consumer at the moment of purchase, to the fake claims that unfairly (and illegally) refer to a designation of origin product while it isn't certified and comes from a totally different place or produced with totally different processes and qualitative standards so damaging the real certified producers.

Beef is at high risk of food fraud in most parts of the world.

The principal identified fraud risks for beef meat sector worldwide are:

- Misrepresentation of meat species.
- Illegal slaughtering and poaching.
- Tampering with expiry dates.
- Undeclared or illegal use of veterinary drugs.
- Treatment with bleach to improve appearance.

- Treatment with formalin to extend shelf life.
- Smuggling, illegal imports, tax avoidance.
- Addition of ground offal to ground muscle meat.
- Addition of water and other 'fillers' to increase the weight or volume of product.
- Misrepresentation of origin, variety, organic status, halal status or conditions of animal-raising representing fake claims on quality features.

Some of the frauds related to meat market in last years, reported by *Trello – Food fraud risk information:*

- Wagyu beef has become very popular in the United Arab Emirates and Japan is doubling their exports to that country. Japanese wagyu is pure-bred and competes with meat from Australia, US, Chile and China that is not pure-bred wagyu. Japanese wagyu is double the price of the wagyu from other countries. 27/02/2017
- The US FDA has implemented rules related to the use of antibiotics in animals raised for food. 3/01/2017 This new rule will have large and long-term effects on the raising of livestock in the USA. Fraudulent veterinary declarations and fraudulent practices around antibiotic use are expected to increase.
- Personnel from the United States Department of Agriculture's Food Safety and Inspection Service (FSIS) observed workers at a meat plant switching inspection labels, leading to a recall of over 25 tons of beef. 13/12/2016
- An Irish company has been fined for falsely declaring that imported beef was locally grown. 18/06/2016 Misrepresentation of country of origin is expected to continue to be a common type of fraud in the meat industry,

particularly where locally grown products are more expensive or more sought-after by purchasers.

- Many markets have issues with incorrect labelling and fraudulent or counterfeit products, like for example the abuse of denominations like “Biologic” or “Organic” or the incorrect indication of provenance and denomination of food like in the case of Parmesan in America.
  The actual model for ensuring authenticity of products to protect customers and brand image requires significant investments in time and money in tracking parts, filling documentation and communicating with partners to validate provenance

- *Assuring food safety*

In case of a product recall, this technology consents a quick control of the provenience of the good and can help in case of legal disputes and controls by appointed organisations, this can be of huge importance in the case, for example, of a product problem linked to an animal disease, which need to be timely localized to minimize the risk of spreading.

Furthermore, don’t knowing precisely and timely rapidly where every unit of product in the market come from, there is the possibility that a lot of not problematic products will get back to producer and will likely be thrown away without necessity.

In April 2019, according to U.S. CDC[13], E.coli bacterial infection linked to ground meat infected hundreds of people and led to tens of hospitalized people in eastern U.S, actually in November 2019 “No single supplier, distributor, or brand of ground beef was identified” (Centers for Deseases Control and Prevention, 2019) and probably will never be identified, and this is only one of many foodborne infections like salmonella, listeria, cyclospora and other bacteria causing emergencies worldwide.

[13] *Centre for Diseases Control and Prevention*

An emblematic case study confirming this huge potential benefit is the one concerning Walmart's challenge in mangoes tracing.

This challenge was made basing on the idea that when outbreaks of food-borne disease happens, it usually will take days to find its source; better traceability can be of vital importance both for customer and producers, withdrawing right product from the market and protecting livelihoods of farmers discarding only products coming from affected farms.

So Walmart started to trace mangoes with IBM food trust platform, creating a traceability model basing on Hyperledger Fabric[14].

The test was based on a Proof of concept[15], the project manager bought a pack of sliced mangoes by nearby Walmart store and asked his team to go back to their source, to create a benchmark, and then ran the same query with IBM blockchain platform.

The results were surprising, the time needed to trace mangoes provenance passed from the 7 days with traditional methods to 2.2 seconds with the new one, conscious of significant implications this can have the company passed from being sceptical to being a believer of Blockchain technology and started a project aiming at tracing this way a lot of its products. (Hyperledger global collaboration - Linux foundation, 2019)

For completeness and correctness sake, we have to consider that in the previous, apparently very inefficient traceability system it took a week to trace the mangoes back to the farm, but this is not only related to the system being based on a traditional database rather than on blockchain; it is also related to the change from fragmented, non-integrated and possibly partly manual register to online, distributed, harmonised, and connected one. (Petter Olsen, 2019).

[14] Hyperledger Fabric is a blockchain framework implementation which allows components, such as consensus and membership services, to be plug and play, and leverages container technology to host smart contracts called "chaincode" that comprise the application logic of the system.

[15] Proof of concept (PoC) is a realization of a certain method or idea in order to demonstrate its feasibility, or a demonstration in principle with the aim of verifying that some concept or theory has practical potential. A proof of concept is usually small and may or may not be complete.

Walmart, together with IBM, developed also a pilot project concerning pork meat sales in China

China has an enormous consumption of pork meat and serious issues in farming and slaughtering practices and in food safety and quality.

Chinese government heavily supported Walmart's blockchain based pilot and were enthusiastic about this technology's potential and its ability to give to procurement managers remote information about farm origination, batch numbers, processing data, soil quality and fertilizers, and even shipping details and storage temperatures; all this data can be uploaded on an e-certificate and linked to the product package via a QR Code, improving food safety and public confidence. (Kamath, 2018)

Blockchain traceability will improve transparency between trade partners, making it possible for customers at different levels of the supply chain to have by one source real time information about the product, who made it, how they made it and where the product is.

Streamlining the information flux will lead to a gain in efficiency and save time usually spent in inquiring the chain of custody, and responsibility, of the product using different software and archives promoting integration between actors while eliminating inefficient processes like manual data entry, paper-based records and data and transactions reconciliation, allowing access to information without having to communicate. (Christine Leong, 2018)

In addition to the reduction of costs and risks of non-compliance with the regulations linked to controls by the authorities, blockchains may provide benefits in the data entry process with considerable time savings and de-bureaucratization of the supply chain traceability processes.

Another important aspect is the advantage of being able to obtain from a single source a multitude of data available for economic, technical and managerial analyses (all the transactions will remain in this register and will not be modifiable) from which it will be possible to obtain information for process optimization and the decrease in operational risk deriving from deficient and inefficient systems: indeed

the traceability process is now fragmented and uses different software and document formats that need reconciliation.

Blockchain technology is a tool that aims to lower information costs for companies, institutions and consumers.

While in traditional systems data elements can be overwritten and need documentation and further recording to be proved, in BC systems only the transactions are written, it means there is a structural higher level of immutability, integrity and transparency, enhancing the trust that will not be relying only on food business and brand but also to the higher degree of transparency; moreover, while external processes were necessary to grant robustness of data providing back-up, duplication and other services, these functions are built within the blockchain technology itself .

The main influencing factor in making a trade-off between these systems might be interoperability: in an actual traceability process there is a plethora of database structures, of standards for TRU identification and Electronic Data Interchange, and few standards defining how the recorded data elements should be named and measured. This means that system interoperability (exchange of data between different systems) is a big problem.

Blockchain-based systems are less diverse: they all record transactions rather than static values and this makes Data Interchange between blockchain-based food traceability systems easier than between actual systems.

A transparent company is seen as a good company, especially if we talk about companies that have impact on the environment and have to do with animals and their welfare, society is more and more involved in sustainability issues linked to environmental and animal welfare respect, and also to the safety and impact on their health and wellness of the food they are purchasing and consuming.

Blockchain traceability is synonymous of an excellent business organisation and can be a discriminant for consumers which are interested in provenance and in purchasing National food, no-antibiotics food, no-OGM food and to be sure that other features are certified and immediately consultable.

According to a research driven on 1500 people surveyed, 75% of consumers don't trust that the labels on most food products are complete and accurate. (Label Insight, 2016)

Not only the perception of the brand by people will change but this can be a commercial advance for suppliers serving GDO, which can soon start to require this kind of products that probably won't be provided quickly by many suppliers because blockchain is difficult and slow to elaborate for companies that for example rely to a lot of suppliers or have no advanced technological and organisational structure.

The result will be an interface accessible to the final consumer in which there will be the information that the company will decide to provide and certify through blockchain and likely a "commercial" part in which the company will have the possibility to enter additional information or multimedia material (photo and videos of companies, advertising of products, cooking recipes etc).

According to a Label Insight[16] research conducted in the US population, 94% of respondents say it is important to them that brands and manufacturers they buy from are transparent about what is in their food and how it is made and 83% of respondents say that they will find value in having more in-depth information about the food they're purchasing.

Another important data which emerged from this research is that the 37% of the respondents said they'll be willing to switch brands if another brand shared more detailed product information (Label Insight, 2016)

More in-depth and meat specific analysis of consumer opinions about product related information and labels will be made in Chapter 3.

[16] Label Insight is the US leading provider of SaaS (Software as a Service) data solutions, powering transparency between Consumer Packaged Goods (CPG) brands, retailers and consumers.

2.3.1 Sectorial trends on blockchain

Coordinating many different, sometimes disconnected actors and promoting the digital transformation needed can be complex, mostly if the level of digitization is low, how it is often in small firms of agricultural sector.

Furthermore, managing large amounts of disparate and potentially inconsistent data can be difficult and can require a lot of time.

Blockchain in this sense can become a game changer, enabling actors to eliminate cross-party data validation and reconciliation costs and assuring consistency of data due to its “you see what I see” logic. (Christine Leong, 2018)

To put this IT environment to work we need to create a network of cooperating actors.

In the context of food traceability, blockchain is a response to the growing consumer demand for safety, traceability and transparency and a new perspective of collaboration between companies and certification and control bodies, which are also increasingly interested and involved in projects that envisage the use of this technology.

Indeed, blockchain aims to become a self-certification mechanism in various aspects of the production cycle, which in the specific sector of beef cattle breeding ranges from the origin of livestock, animal welfare conditions during breeding and transport, the responsible use of antibiotics, to the day of slaughter and much more.

This mean we need suppliers, customers and collaborators to enter the network as validator nodes in the company blockchain.

In Italian agricultural environment, some control organisations manifested interest in creating a network with businesses to collaborate for improving sector transparency and changing the ways control are operated: It’s the case of CSQA Choral trust, a blockchain platform created by CSQA[17], as a support for all

[17] CSQA is the Italian leading certification company active in the sectors of agribusiness, consumer goods, catering, technical services and professionals, which demonstrated its interest in blockchain creating a blockchain for food certification called “CSQA choral trust”

companies in the agri-food sector to improve the management of supply chain data and guarantee the safety and quality of food products to consumers, ensuring direct and transparent information (CSQA, 2019), or the pilot projects developed by IZSVE[18] to contrast the spreading of rage, with the development of a system that allows to control, share and stock veterinarian certificates, a tool that provides access to the network to veterinarian clinics, zooprophylactic institutes, the competent ministry, customs and control bodies and lastly animal owners; the project was conducted with success leading not only to grant a precise control on the issue but also to cause a 80% saving on total costs of ownership (TCO) and to increase the value of product.

In the context of food traceability, blockchain can become a solution for the growing consumer demand for safety, traceability and transparency and a new perspective of collaboration between companies and certification and control bodies, which are also increasingly interested and involved in projects that envisage the use of this technology.

This of course creates the need to enter the network for suppliers, customers, collaborators and control bodies as validator nodes in the manufacturer's blockchain: the information that they decide to share and certify will be disseminated[19].

An increase in the use of blockchain by companies is expected from 10% to 40% within 3 years, (Deloitte, 2019) likely blockchain technology certification will pass within a few years from being an added value to the product to being a requirement for the sales to large retailers.

Some food giants, both producers and resellers (Nestlé, Starbucks, Walmart, Carrefour are just some examples) are developing their own blockchain network to have full control on their supply chain.

18 The Istituto Zooprofilattico Sperimentale delle Venezie (IZSVe) is a public law health institution that carries out prevention, research and services in the areas of animal health, food safety and environmental protection.

19 According to what is written in chapter *1.2.2 – Hyperledger Fabric*, different actors will have access only to the information the business chose to share with.

IBM has launched a relevant project, *IBM Food trust*, that aims to create visibility and reliability in the food supply chain. It is a network which connects growers, processors, distributors and retailers through a registration subject to permanent and shared authorization of the food system data; this is just one of the examples of companies that have activated themselves in creating platforms in this purpose: Smart Agri-Food, SAP, Provenance, and TE Food, just to name a few, are developing their alternative solution.

Considering beef supply chain, in Australia blockchain has become an anti-counterfeiting tool for the beef cattle market, against the great demand from part of China's Australian meat and a large rate of counterfeiting, Australian companies have decided to protect themselves by certifying the origin of the meat with the use of this technology, VeChain, Beefledger and AgriDigital are only some of the supply chain tracking solutions emerged in Australia on this purpose. (Fenton, 2019)

The UK’s Food Standards Agency (FSA) completed a blockchain pilot at a cattle slaughterhouse. The pilot project involved the FSA and the slaughterhouse and had a good outcome, the plan of FSA is now to include other locations and also the farmers to see their data as well. (Morris, 2018)

The priority objective is to integrate consumer guarantee systems with innovative technological solutions aimed at increasing the level of transparency in the management of agri-food supply chains and at the same time optimizing the communication flows between the parties, the data management of the multiple actors of the chains and the information to the consumer.

CAPITOLO 3

Blockchain for meat traceability

3.1 The journey of beef traceability

This study born as an attempt to evaluate the potential of traceability and transparency systems based on blockchain technology from a holistic perspective, including the supply chain stakeholders: farmers, butchers, retailers, consumers, government officials and third-party transparency service providers.

We will consider traceability for the entire process of cattle and slaughtering, considering a single animal as a tracing unit, starting with a genesis block[20] which will contain registry information provided by the BDN[21] that are associated with the ear tags of the animal.

It is important to clarify that this analysis is studying the process specifically in Italy, indeed countries could have different registry institutions and legislations for

[20] The genesis block is the first block in any blockchain-based protocol.

[21] "Banca Dati Nazionale" (BDN): is an Italian government institution that manage and grant:
the traceability and traceability of animals and their products, the protection of public health and livestock, the planning of controls on the identification of animals, the provision and control of community aid schemes, consumer information

cattle identification, in Brazil for example, most of the farms still do not track the livestock with any form of unique identification. (Christine Leong, 2018)
The initial step for the company is made at the moment of purchase:

Registry data that have to be entered in blockchain and will form genesis block are actually communicated by the supplier in a specific telematic form, then data is transferred from the document, manually or with the help of an optical reader, to the ERP system.

When data is in the ERP, they can automatically be transferred to blockchain to form the first block, but before the transaction have to be validated by the supplier.
Information contained in genesis block should be:

- Ear tag
- Date of birth
- Country of birth
- Breed

The nodes decide what will be added to the blockchain, and what should not be accepted. There may also be nodes that are not part of the validation process, but simply memorize the record.

For the supplier it will be necessary to enter blockchain as a node and validate the block it will be needed a pc or smartphone application that will consent an easy and fast validation of data for all levels of technical literacy.
Once the genesis block will be validated the tracing of the livestock can start; in this passage, there can be an issue: when the supplier reads and writes the ear tags of the livestock there may be errors, at the time of uploading at buyer's stables many of these errors are identified, others are not.
If an ear tag number is registered in the first block in blockchain erroneously and is discovered to be wrong later when other blocks are added to the chain, it will not be possible to modify data and the chain will become invalid.

To decrease the probability of human errors, we can elaborate some "smart contracts" producing a validation basing on double data checks.

RFID (Radio Frequency Identification Devices) enable to trace items using a physical sensor, attached to the product itself, as it travels through detection gate; although no independent control mechanism or institution regulates the proper and truthful usage of RFID tags, if linked to Blockchain technology they can provide a better traceability solution for the cattle industry.

Food and beverage industry are facing emergent sustainability and food safety pressures, an interesting example of the possible application of blockchain combined with RFID technology is to equip a food supply chain able to track food real-time based on based on Hazard Analysis and Critical Control Points (HACCP) rules, able to record back to supply chain events in the agricultural sector (Staples, 2017)

The information about the process can only be recorded by authorised actor, in this way, unethical supplier and counterfeit products, that can cause serious social harms can be easily detected.

It is possible and desirable that in the future institutions as BDN will start to have their own blockchain system, start using blockchain technology also to control compliance to regulations and will provide directly data in this form, so the moving of data from actual documental form to the BC distributed register would not be necessary anymore.

However, despite the interest many certification and regulation institutions demonstrated in this sense, due to substantial technical and legislative issues still to solve to make this process fully operative and recognized and the high amount of external actors and their decisions involved, in this study we will consider how a pilot project could be implemented at the current state of the art.

Once the livestock have been bought, it will be transferred to company’s owned farm.

In this second transaction the units are moved to a stable that has a specific stable ID.

The stable ID has to be linked to the certifications the stable possess, uploading certificates released by competent institutions in blockchain, in this way, every animal that will move to a stable that has for example a valid CReNBA[22] animal welfare certification, will automatically assume the status of animal growth in respect of welfare standard and keep this title still the end of the process communicating it to the final consumer.

The second block in the blockchain will thus add to the registered data information about the plant of breeding.

More information can be entered about the site of breeding and share with the final consumer to communicate quality standards, for example, consumers may be interested in features linked to animal feeding quality and veterinary provisions.

For these purposes it would be necessary that both feeding stock suppliers and veterinary service providers enter the register as validator nodes.

For feed supply, we will need for example NO OGM certifications from our suppliers, and the validation of the transaction of feed stock from them to us.

Consumers are concerned with the risk of antibiotic resistance due to eating meat from animals that are given high doses of antibiotics in last period of permanence in the farm.

In the case of veterinary service, we might want to demonstrate that our animal was healthy prior to culling and has not been given antibiotics for a period of minimum 60 days before slaughtering or that it hasn't been given antibiotics at all.

To prove this with blockchain we should enter accredited veterinary actions into the register by uploading vet health reports, and program a smart contract that basing on the date of intervention will automatically state if the unit is ok for the standard we chose to assure.

This can make a doubt arise, are blockchain a 100% method of certification? The arbitrary responsibility choice of the veterinary service to enter every intervention cannot be assured with total security by veterinarians, as it is for paper-based

[22] The CReNBA - national reference centre for animal welfare - has created a public standard aimed at monitoring the animal welfare status of beef and dairy cattle farms.

registers, but there is the difference that with the DLTs registers will become unified and distributed, so a control basing on quantity of zoo-prophylactic medicines purchased and those which are been used will become faster and easier.

The transparency in some levels will be still left to operators and institution responsibility, at least in the short term.

Re-using of good certificates to replace missing or bad ones is a common fraud in the sector, this fraud know as falsification of certificates can be prevented by the use of blockchain technology, since the re-use of a certificate would be detected by its duplicated ID because data on certificates cannot be modified. (Petter Olsen, 2019)

Back to operation analysis, we will need thus to include these external actors to enter and validate our information, an interface for suppliers and veterinarians will be needed to consent a quick validation, before passing to next transaction.

When livestock arrives to the slaughterhouse, its ear tag number is registered in slaughterhouse software, and the data is automatically transferred to principal company's ERP, which is communicating with Blockchain, so in the moment of registration of the arrival, data about the age of the animal and its cattle conditions before slaughtering can be automatically assessed.

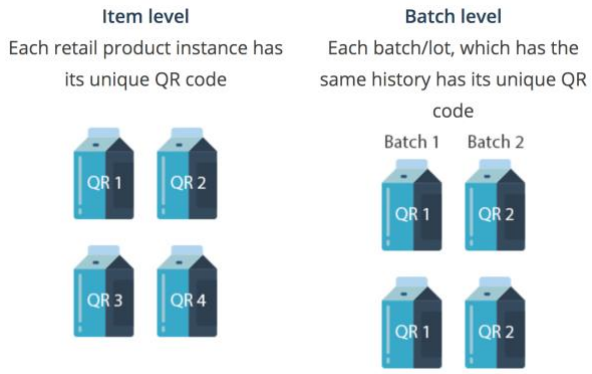
Since the blockchain has to be consultable by consumers, who don't purchase the entire carcass, a system that splits the virtual version of the carcass has to be implemented, if the slaughterhouse owns its Brand, it's likely that the transformation from carcass to ready to buy product will take place in the plant where the slaughter has taken place, we will assume so.

The easier system to address the problem will be to calculate a medium yield to be calculated starting from the weight of the entire carcass passing in this way from a "tracking of unit" model to a "tracking of volumes" one; a smart contract solution can help regulating this aspect, developing a chaincode that will assure no fraud can be purported.

For traceability to be correct and effective, during the process of sectioning and transformation we need to duly keep traceability, indeed the system will, following a dedicated smart contract, print the labels till the total weight will equal that of the estimated yield.

It is clear that a system which prints an arbitrary number of labels per hulk would be incorrect from blockchain certification conceptual perspective and a technical solution has to be found.

There are two opportunities to manage the retail level product identification: Item level and Batch level.



Source [te-food.com]

TE-Food, a major player in blockchain service providing environment, offers four different approaches to address the issue of Blockchain-to-QR code management.

1. The blockchain service provider which has access to blockchain data generates, prints and sends QR Code labels to blockchain managing company.
2. The blockchain service provider generate the serials and sends them to the Blockchain managing company, who will print and apply the label
3. Blockchain managing company generates QR Codes itself according to a predefined convention communicating to the blockchain service provider the used serial interval (the first and the last serial for every production batch).

4. Blockchain service provider gives the blockchain managing company an industrial solution, a printer server communicating serials and managing the label printer. (recommended for large scale productions)
   (TE-FOOD, 2019)

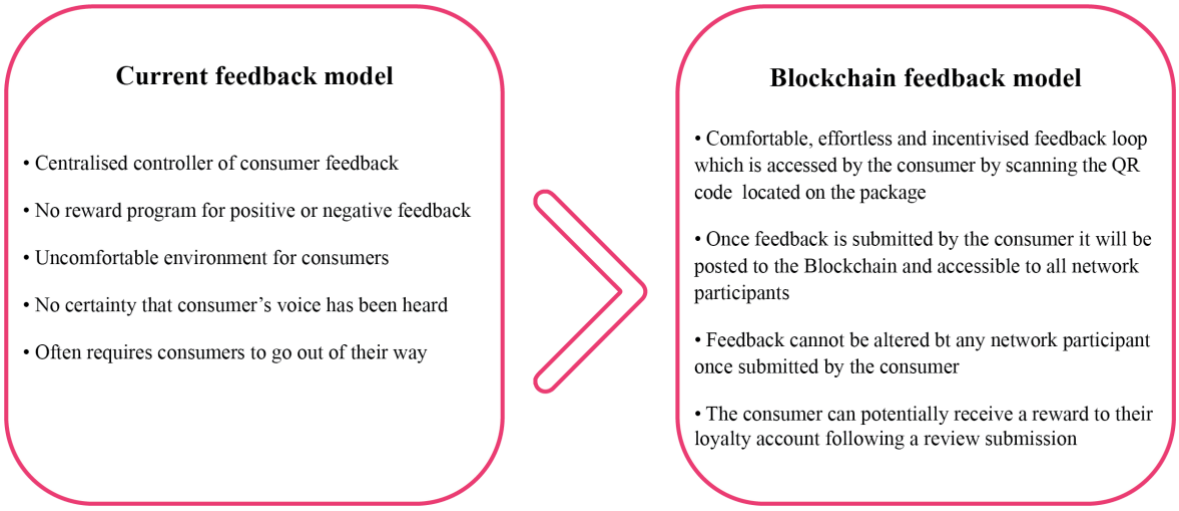
The next step is the generation of a user interface, that make blockchain data accessible by the consumer through a QR Code, readable with a whatsoever smartphone with an internet connection.

The result will be an interface accessible to the final consumer in which there will be the information that the company will decide to provide and certify through blockchain and a "commercial" part in which the company will have the possibility to enter additional information or multimedia material (photo and videos of companies, advertising of products, cooking recipes, a feedback request etc.).

Why Blockchain can be a valid driver for Consumer Engagement?

It reassures and establishes consumer trust in beef market, provides a competitive advantage over competitors on the shop floor and aligns with evolving purchase drivers and hi-tech food service sector.

A positive side-effect can be the implementation of feedback loop through blockchain consumer interface, that presents some strength points respect to traditional feedback mechanism. (Leonowicz C. et al., 2018)



[Source: personal elaboration]

3.2 Consumers' attitude toward meat information and labelling

How information can influence consumer's decision in meat purchasing?
What make supply chain stakeholders and consumers accept blockchain as a transparency and traceability system?

In meat sector, transparency means knowing that animals were humanly treated and for example that they didn't grow up with the usage of hormones, non-responsible use of antibiotics, bad slaughtering conditions or other bad practices and that required safety controls have been done on the meat; traceability instead is defined as the ability to trace back meat from retail to the farm to the animal of origin. (Dickinson, 2002)

The beef Labelling Regulation, introduced and made compulsory by the EU commission in July 2000 for all member states, is actually the most advanced system in EU, requiring to track meat from its origin to packaging on retails, however it presents some issues: no mechanism ensures the credibility of information in the farm-to-abattoir supply chain phase, and it remains difficult to

track meat imported from non EU countries, moreover, there is no assurances against active manipulation and human error.

Considering that customers today are becoming more and more knowledgeable and pretentious toward information that is given to them about food they purchase (Pardo, 2015), a credible traceability and transparency system appears inevitable and necessary, also across borders.

Blockchain can become a response to this issue, its information trustworthiness and security is assured by cryptography and a cloud-based and decentralized protocol, information about assets get recorded and locked into decentralized digital blocks that put together form an online information chain.

According to Gellynk et al., the complexity and the vast number of certification labels can be misleading for consumers and inefficient to solve important production and informational issues for the consumer, for example in the pork industry, hardly attacked for its use of antibiotics and gene feeding, there's no certification in pork meat labels that contains communication about this problems and more generally about livestock and farming conditions, in this sense, self-investigation tools can help the customer to eradicate uncertainty about meat production conditions. (Sander F., 2018)

According to stakeholder theory, the key for a shared and efficient process in a network is to take into account involved stakeholders' opinions and perspectives, this means that in assessing and evaluating the possibility to use Blockchain technology as a traceability and transparency system for meat sector it is fundamental to take into account the various players involved: farmers, butchers, retailers, consumers, government and third-party transparency service providers, in this information system have to configure themselves as an overarching interest group.

A research study conducted by British Food Journal can help the understanding of different actors' perspectives on this topic:

Consumers affirm that they're confused by the multitude of certification labels that are present in the market, the existence of self-investigation tools and a complete

traceability and transparency system enhances their quality perception and can thus influence their purchasing decision, according to the research, consumers struggle to evaluate all labels and eventually base their decision on price rather than on origin or certification. (Sander F., 2018)

Supply chain producers assert that the majority of customers are mainly concerned with price, (contradicting the consumer declared endorsement for improving traceability and transparency system), and that extreme, total traceability and transparency are not needed nor desirable, a compromise between customers' needs of transparency and consequent implications for manufactures is needed.

Some supply chain stakeholders assert that this would be only a window dressing activity since they don't perceive a consumer demand for more sophisticated and improved systems; policy makers and consumer associations seems the most suited to initiate those change.

The supply chain stakeholders' opinions divergence on trust topic, (also into the same category of actors) could be a partial explanation on why current systems have stagnated in their evolution.

By one side, involving some meat companies competing on a cost base without particular concerns for quality will be a hard challenge, since it is unlikely that they would be prone to share information about how their animals have been farmed, slaughtered and processed; although it can be a differentiation driver for companies that want to raise their positioning in the market, since such efforts can increase fair competition creating a transparent marketplace in which consumer understanding of what they are purchasing is enhanced, credibility and reliance are improved and consumer-friendly capability of Blockchain technology that allows people to self-investigate the origin of their products seems to be a great deal in consumers' perception.

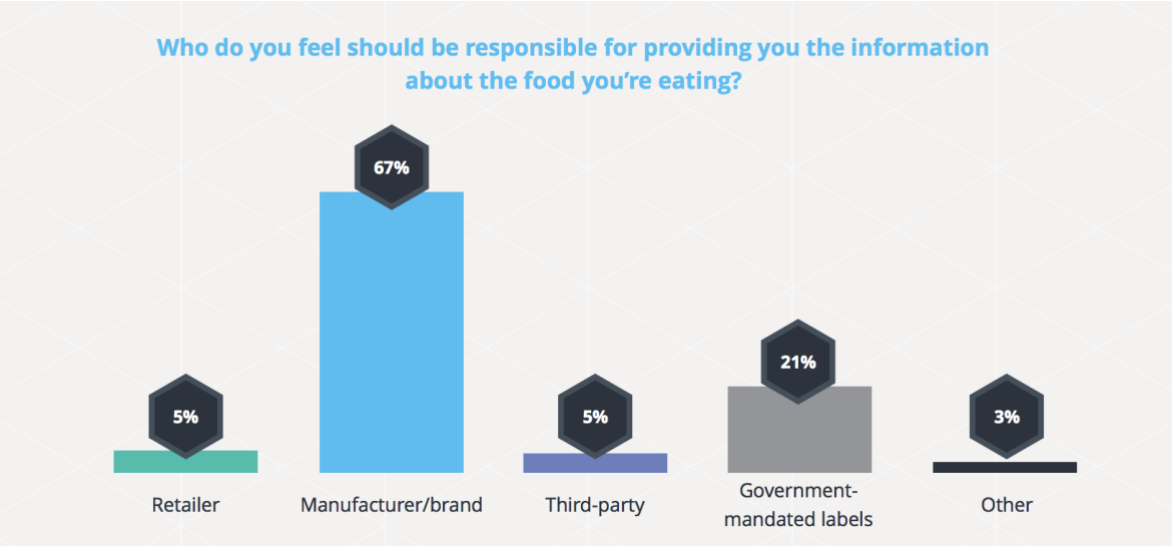
On the other side, little farmers too could have economic, knowledge and technological constraints in the application of blockchain based traceability and transparency systems, moreover, if their role in the supply chain is restricted to the

farming activity, their eventual blockchain data will likely not arrive to the consumers if slaughterhouse and retailers will not enter in the blockchain network too.

But who is responsible to evaluate and eventually facilitate and promote stakeholders' wanted changes along the supply chain?

According to Buchanan and Boddy the responsibility to shift the mentality on the meat supply chain, facilitating and acting as change agents and role models is up to meat supplying firms, due to their helicopter perspective on the supply chain. (Buchanan, 1992)

Also according to Label Insight Food Revolution Study, consumers feel manufacturers to be responsible to provide the information about the food they're eating.



[Source: Label insight – Label Insight Food Revolution Study]

3.3 Blockchain as a traceability and transparency booster

Blockchain tracking in the food sector starts at the producer's place, where, in vary modalities basing on the specific product, it will be packed and assigned an RFID tag to have a univocal identification, and then will enter in the system together with relevant information about the product, the production plant and the production process.

Examples of these information can be: «background environment (e.g., soil, water, air and sunlight quality); plant cropping conditions (e.g., quality of seeds, working practices, variety, item number, production area, growing conditions, planting time, plucking time, staff involved); and application of fertilizers and pesticides. » (C.R.W. De Meijer, 2016)

In agricultural production, an example of data that can be included to the blockchain goes from geolocation of culture field and certifications, nature of composting and treatments prior to planting, sowing process, eventual herbicide treatments, coverage fertilization to control phytosanitary treatments and staff phytosanitary usage license; data on phytosanitary treatments attracted high community attention in recent years due to its link with public health and quality of life, a verification should be done to prove the reliability and consistency of data, analytical methods and IoT analysis, together with blockchain technology, can provide a not tampered and sure way to certify company's behaviour.

When it comes to processing, company can read and enter new data into a product's profile (for example by scanning its tag), information can include processing conditions and product modification, using IoT then the company can track in real time the product in its storage process taking advantage of dynamic storage benefits in storage management.

With the help of temperature and humidity sensors we are able to ensure that the distribution conditions respected the requirements and allows you to continuously monitor remotely delivery status and conditions, as well as certify them to consumers.

At the moment in which retailers receive the products, they can get any information about the supply chain and the process, this enormously improves auditability and simplify traceability inspections, as well as to enable a quick monitoring of freshness, lifetime of products in order to replace them, besides also consumers will be able to get this kind of information too.

With this new system, for certification and auditing authorities and government departments it will be enough to control that data is not tampered before entering in blockchain, so that the real product and the image of it on the blockchain corresponds. This step of control will still be necessary until a process would assure itself the reliability and consistency of data; however, companies using blockchain will be strongly discouraged to tamper data and do food fraud because of the immutability and quick availability of information that will put the system on a high transparency level making it very difficult to act unfairly.

When talking about food traceability we refer to a unit, which could be a single item or a batch, this unit that we want to trace and whose information is recorded in our traceability system is called by the scientific literature *Traceable Resource Unit (TRU).*

There are two levels of traceability, *internal traceability* refers to traceability inside the company and represents the basis for a good overall tracking and *chain traceability*, basing on the transmission of internal traceability data and is the traceability between links and companies.

The three fundamental steps of traceability are:

1. the unique identification of TRUs and their association with an identifier.
2. The documentation of transformations (we consider transformation every process involving a TRU that starting from an input generate an output), movements, property changes etc.
3. Attributes of the TRUs, a set of attributes carried by the traceability system.

The drivers of traceability are:

- Safety regulations: consumer protection
- Security: prevention of criminal actions, brand and product protection
- Regulatory quality (EC labelling, mandatory consumer information)
- Non-regulatory quality and marketing: creation and maintenance of credence attributes (Public quality seals, Organic/Eco labelling)
- Food chain trade and logistics management: food chain uniformity and improved logistic (public and private information standards)
- Plant management: Productivity improvement and cost reduction
- Documentation of sustainability: control on mandatory or voluntary natural resource sustainability programs

Since food safety is a strong driver to implement traceability, analytical methods, thus they're only a small subset of information collected in a traceability system, play a fundamental role in traceability:

Analytical methods analyse a food item sample to control a set of biochemical food item properties. Properties that to some degree can be verified by analytical methods include species, geographical origin (broadly), process status (e.g. fresh or frozen), presence of additives, some aspects of organic production, remaining shelf life, and many others, depending on the type of food item.

Since they do not deal with recorded identifications, they are technically not methods of traceability, but they are method to check, verify and certificate the claims of the traceability system are true and so they are of fundamental importance on traceability and transparency systems.

The level of transparency of a supply chain is in effect the degree of shared access to product-related information as requested by a supply chain's stakeholder without loss, noise, delay, or distortion, its link to analytical method is thus evident. (Hofstede, 2004)

An efficient and good traceability system must be able to provide to stakeholder product information with the less noise, delay, loss and distortion; it is important to remember that in a TS there are a lot of unverified claims, and that «one cannot really have transparency without traceability, but for transparency some other components are needed as well. » (Petter Olsen, 2019)

It is important to ask yourself some questions about blockchain: is blockchain traceability better than traditional one, does it have some advantages? What kind of advantages? It is fundamental to clarify an important point: what do we mean saying traditional traceability system? Are we really arguing the benefits of blockchain technology in a strict sense or rather comparing online vs offline, single-copy centralised vs distributed implementations?

Strictly speaking, the only sure differences between a blockchain based database and another relate to the immutable, inherently consistent nature of the blockchain data structure, while many analyses on the topic rather consider the differences, and so the benefits, between a traditional centralised traceability system and a distributer ledger based system.

Blockchain structurally reckon on distributed ledger technology, the features strictly linked to blockchain are that there is a consensus mechanism to decide how to synchronise the multiple copies, and that there is a signing process which uses public and private keys to ensure identification and to enable encryption. (Petter Olsen, 2019) , but in hybrid and private blockchain implementations, these are only implementation choices, if other implementation choices are made, the underlying data structure would still be a blockchain.

That’s why it is important for companies to understand deeply the sense behind blockchain technology claims without generalising different kinds of distributer ledger and blockchain based traceability systems when it comes to make an investment.

3.3.1 Blockchain and marketing

For agri-food sector blockchain is not merely a form of marketing for product's traceability or quality attributed, it could have some other important application fields, like price and logistics management.
Some of the information that can be collected are for example information about the quality of the supplies, farming staff and environment, growing cycle and weigh scales, processing process, retailer's name, sale price, sale time and sale quantity (Zhang, 2020)
Society wide technology advances often bring business opportunities, blockchain is defined as a "foundational technology", one having the potential to create new foundations for economic and social systems, (Iansiti, 2017) but also new expectations to consumers and can change customer-product relationship.
With blockchain application this relationship will evolve in the expectations on trustworthiness and transparency and will raise the expectations in having tangible and accessible proofs supporting the claims.
Blockchain aims to ensure traceability and transparency for the activities of everyone in the network, ensuring a "can't be evil system" trying to contrast distrust in everyday life business.

According to researchers, in recent times, trust to marketers it's decreasing and has reached historic lows with less than 20 per cent of customers having an high level of trust to brands and the information they provide; (Gallup , 2019) two factors are thought to be the main causes of the mistrust on customer-level marketers, the misinterpretations or lies on products features and the intentional wrongdoing, that led to the customer level management to become the less trusted source of information. (Edelman, 2017)
This led to the raise of the importance of intermediaries, boosted by online commerce growth mining trust by making business easier between far and unknown parties.

According to Seebacher et al. (2017), trust in business environment is the expectation that counterparties behave following 4 principles: (Seebacher & Schüritz, 2017)

Honesty principle requires all stakeholders to behave in a truthful manner without lying through omission or obfuscate through complexity

Consideration principle requires to have good faith in transactions respecting others' interests and concerns.

Accountability principle requires honouring commitments made to stakeholders and owning the blame when it requires without putting it to others.

«*Traceability* is the ability to identify and verify the components and chronology of events in all steps of a process chain» (Skilton & Robinson, 2009)

Transparency requires instead the ready availability of truthful information to stakeholders.

Blockchain technology can become a game changer ensuring the respect of principles of honesty, accountability (BC could make the responsibility assessment quicker and clearer) and naturally traceability and transparency.
Blockchain in this perspective can enhance trust in business and resolve uncertainty at different levels: about who the counterpart is, about asset tracking across the supply chain, about brand promises and when things go wrong.
- *Uncertainty on who the counterpart is:* The proof of identity showed on a protocol level with the application of pseudonyms can eliminate the risk of fake identity declarations.
«Through the infrastructure of a blockchain, the verifying parties do not need to check the validity of the actual data in the provided proof but can rather use the blockchain to check the validity of the attestation and attesting party (such as the government) from which they can determine whether to validate the proof.

Hence, the validation of a proof is based on the verifier's judgement of the reliability of the attesting party». (TYKN, 2019)

Proof of identity is even more important in online commerce and in contrasting fake feedbacks and comments about brands and products.

- *Uncertainty in assets tracking across the supply chain:* transparent and real time monitoring of assets can eliminate uncertainties about assets creation, evolution and position thanks to the ability of distributed ledgers to give a single global network viewpoint.

- *Ensuring that brand promises are kept*: Blockchain can reduce the risk of uncertainty assuring that brand acted as promised providing stakeholders and thus customers with a high level on transparency on operations and certificates assuring the company is acting with integrity and preventing the business to incur on costly scandals.

An example on how much reputational issues due to fake information providing is represented by recent Volkswagen diesel emission scandal, in which Volkswagen admitted that it had cheated tests to make its vehicles appear less polluting than really they were: the company said the scandal has cost the company €30bn. (Independent, 2019)

In this sense, a system in which trust in human beings would be replaced by trust in a fully automated process system capable of assuring reliability to claims, quality standards, environmental and social sustainability engagement by the brand and whatever is in top of mind of customer when making a purchase decision.

Like it was said by (Tapscott, 2016) : «in the past, brands' success depended on dressing. However, today success depends on to what extent a brand undresses.»

Uncertainty when things go wrong: blockchain, together with smart contracts technology, act as an automatic trusted third party, thanks to an "if this then that" logic, it can assure that if for example the assets is not delivered to the customer, the payment for that asset will be automatically rolled back.

Sustainability in supply chains requires the confirmation and verification that processes, products and activities taking place in the process meet certain sustainability criteria and verifications, (Grimm, 2016) supply chain strategy and practices is facing emergent pressures to consider and certify sustainability.
The way to address the problem is improving supply chain security, durability, transparency and process integrity, reaching these goals can be made more feasible, from economical, technological and organisational aspect with the development of applications basing on blockchain technology in order to create Blockchain based traceability and transparency systems covering the whole production and distribution process, moreover, this system can empower network openness, transparency, neutrality, reliability and security for its agents.

Blockchain can configure itself as a powerful tool to improve sustainability networks, «Tracking potential social and environmental conditions that might pose environmental, health and safety concerns is an important application focus for the blockchain» (Adams, 2018) some examples of early application come from China where companies are participating a blockchain for carbon market assets, in order to generate carbon assets efficiently in accordance Carbon Emissions Reduction for the Paris Agreement objectives.
In traditional systems assessing the carbon footprint of each product is hard, with Blockchain based systems the evaluation of the footprint could become easier and more precise, with relevant commercial implications: if carbon tax makes it necessary for large carbon footprint product manufacturers to raise the price, customers will eventually react switching to low carbon footprint products which are not economically penalized and can have a market benefit from the tax.
This kind of market pressure and rearrangement may cause firms to revaluate and restructure their supply chain to reduce carbon emission to meet the demand of buyers. (Sara Saberi, 2019)
Blockchain technology can prevent corruption of individuals and institutions to unfairly seize people assets.

Information about process about green product are often unavailable or difficult to verify, customers are more likely to purchase environmentally friendly products, but how to achieve a such complex task, taking count of the complexity of tracking an item from its source to final purchase place?

We may argue that sustainability is only a world if we lack transparency, that's why while sustainability becomes a more and more important value, we need a technology able to grant transparency and credibility to claims

How would blockchain help in this context? Essentially in two ways:

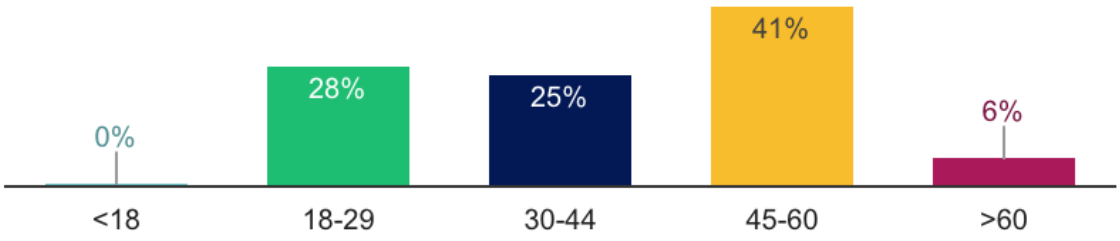
- It would provide the fundamentals for supply chain mapping.
- It would provide the fundamentals to apply low carbon product design, production and transportation.

This system will encourage the participants to figure out a long term solution to reduce the emissions with the direct economic benefits deriving by low-carbon products friendly regulations and the indirect economic benefits of good reputation, by solving the inefficiencies of actual emission trading scheme (Khaqqi, 2018)

3.4 A research on customers' perspective

Methodology

This market research was implemented through a multiple choice survey submitted to 170 US citizens with sex distribution balanced with respect to the census and with age distribution showed by the following image



[Fonte: Surveymonkey.com]

Data comes from a survey composed by 15 questions submitted by respondent via web using *Surveymonkey,com* service provider, and present a 95% confidence level and an 8% error margin, so the sample is quite representative of the studied population and their beliefs.

This survey's aim is to assess people's knowledge about blockchain technology, their trust in meat certification labels, their concerns about meat production issues and finally their interest in a Blockchain based traceability and transparency system.

Blockchain basic knowledge

The questions in this initial phase try to assess people's knowledge about the technology itself and its application in the food traceability sector.

Q1: Do you know how blockchain technology works?
A1: yes (16,18%)
A2: Not completely, but I know what it can be used for (28,32%)
A3: Not completely, and I don’t know what it can be used for (11,56%)
A4: No (43,93%)

More than half of respondents (56%) answered they don’t know what blockchain is or what it can be used for, with an additional 28% saying they know what it can be used for but don’t know how it works, only 16% of respondents say they have a good knowledge of the technology.

Q2: Are you interested in learning more about Blockchain technology and its applications?
A1: Yes (67,63%)
A2: No (32,37%)

Despite a low knowledge rate on the topic, 68% of respondents said they are interested in learning more about blockchain technology and its applications, this means that the collective knowledge of the argument is expected to grow in the next period.

Q3: Did you know blockchain technology can be used for food traceability?
A1: Yes (28,32%)
A2: No (71,68%)

With regard to its use for food traceability, 72% of respondent said they didn’t know blockchain technology can be linked to food traceability.
Summing up, the survey reveals that blockchain technology and thus its potential is still far to be understood by consumers and only a little part of the population know it is linked with food sector traceability and transparency systems,

nevertheless the majority of respondents demonstrated to be interested in knowing more about the topic.

Customer opinion about actual labelling system.

This section tries to assess the interest of people for information contained in the meat packages labels and their trust on it, to understand if there is an informational need or will that can be better satisfied.

Q4: Do you usually read information contained in labels on meat packages?
A1: Yes (69,77%)
A2: No (30,23%)

Q5: Why don't you read information contained in meat packages?
A1: I don't trust it (7,55%)
A2: It's not clear (22,64%)
A3: I'm not interested (50,94%)
A4: Other – please specify (18,87%)

Q6: How do you consider information contained in labels of meat packages?
A1: Reliable and clear (19,30%)
A2: Reliable but not clear (33,92%)
A3: Clear but not reliable (23,98%)
A4: Not reliable nor clear (22,81%)

Only the 30% of respondents declared they don't read information contained in meat packages' labels, more than a half of them said they don't read this kind of information because they are not interested, a 22% said they don't read them because they are not clear and a 7% because they don't trust them.

Despite the majority of respondents declaring they read information contained in labels, only a 19% consider this information clear and reliable, with the remaining 81% feeling they lack on reliability, clarity or both

Blockchain as an information tool

In this section the questions aim to inquire if the use of Blockchain technology has for people consideration a potential to solve the informational gap on meat labelling detected in previous questions.

Q7: Would you trust information about food (concerning for example origin, safety, animal welfare, expiry date, quality certifications etc.) that is certified through blockchain technology?

A1: Yes, more than information certified by traditional methods (36,05%)

A2: Yes, but I equally trust information certified by traditional methods (29,65%)

A3: No, because I don't know enough on how blockchain works (28,49%)

A4: No, I would not trust (5,81%)

Q8: Do you know how to scan a QR code?

A1: Yes (82,74%)

A2: No (17,26%)

Q9: Would you scan a QR Code to get information about the meat at the moment of purchase?

A1: Yes (78,24%)

A2: No (21,76%)

More than a third of respondents (36%) said they will trust information deriving from a blockchain technology more, and an additional 28% declare they would not trust because of their limited knowledge about the technology. Solving this

knowledge gap could potentially make the percentage of people preferring Blockchain certified information increase from one to about two thirds.

Production standards influencing meat purchase

What information about the product are interesting customers the most? An important aspect planning a blockchain based traceability system is represented by the content, the nature of the information.

Implementing such a system can be a complex and costly organisational work, so a focus on what matter the most for customer is fundamental to make the most of this technology and to not waste money.

	1	2	3	4	5	TOTALE	MEDIA PONDERATA
Provenience of the meat	12,05% 20	10,84% 18	35,54% 59	23,49% 39	18,07% 30	166	3,25
Animal welfare	16,07% 27	8,33% 14	26,79% 45	20,83% 35	27,98% 47	168	3,36
Responsible antibiotic use on the animal	11,45% 19	6,63% 11	24,10% 40	25,30% 42	32,53% 54	166	3,61
GMO free	16,87% 28	8,43% 14	26,51% 44	17,47% 29	30,72% 51	166	3,37
Food safety	14,37% 24	2,99% 5	10,78% 18	15,57% 26	56,29% 94	167	3,96
Company's engagement on sustainability issues	13,17% 22	11,38% 19	22,75% 38	18,56% 31	34,13% 57	167	3,49

[Source: Surveymonkey.com]

The feature which scored the highest score thus being more important to respondents is the food safety, rating a weighted average of 3.96 out of 5.

The second aspect in order of perceived importance (3.61/5) is the responsible antibiotic use on the animal, the issue had raised media attention in last times as a consequence of the combination of antibiotic resistance in humans linked to the administration of antibiotic treatments in beef breeding.

Third aspect scoring 3.49/5 is the company's engagement on sustainability issues, attention to this topic has raised in last period due to studies affirming that a big part of carbon dioxide, methane and nitrogen oxide causing greenhouse effect and global warming are produced by intensive breeding.
Fourth and fifth aspects, scoring 3.37/5 and 3.6/5 are the GMO free and the animal welfare certifications while the less considered aspect on the list is the provenience of the meat.
Provenience of the meat could become a major object of interest when certifying niche meat for which the country or the region it comes, or the breed of the animal, represent a superior quality mark themselves and are objects of forgery.
In this case, due to the higher price of the meat, the additional price paid for blockchain certification should impact less on consumer perception, and consumer willing to pay high price for niche meat is most likely passionate or has good purchasing power and therefore will be more elastic regarding the price of the product.

Q12: Would you pay a higher price to have certified information about the meat you purchase, easily accessible through scanning a QR code?
A1: Yes (46,75%)
A2: No (53,25%)

Q13: What additional percentage would you pay for Blockchain meat certification?

	0%	UP TO 5%	UP TO 10%	UP TO 20%	UP TO 30%	TOTALE	MEDIA PONDERATA
☆	28,82% 49	28,82% 49	22,35% 38	12,35% 21	7,65% 13	170	8,44

[Source: Surveymonkey.com]

How much are consumers willing to pay for this service?

Almost a half of respondents (46,75%) said they would pay an additional price for having certified information about the meat they are purchasing easily through scanning a QR code.

However, when we come to quantitative assessing of the demand elasticity, we see that only 28,82% of respondents said they will not pay any additional percentage for blockchain traceability and transparency system implementation; 7,65% of respondents said they would pay up to an additional 30%, that is a very high incremental price, 20% (7,65+12,35%) are willing to pay up to 20%more, almost a half of respondents, 42,35% (20+22,35%) are willing to pay up to 10% more.

The weighted average of the additional price people is willing to pay is 8,4%

Conclusion

We have seen how many different businesses and organizations are interested in blockchain possibilities among various sectors and levels, this is likely to cause a *spillover effect*[23] speeding up the diffusion of knowledge, competences and consideration about blockchain, both for actors and consumers.

Its application however is far from being immediate, the more a business interacts with multiple partners along the supply chain, the harder it will be to involve all the other actors necessary to form and maintain blockchain operations.

The complexities could be of different nature, from lack of technological competences, to unwillingness to share private data, to unwillingness to sustain the costs associated to implement this system.

Permissioned blockchains seems to be the more valued hypothesis to bypass the privacy issue, although some scholars argue that permissioned blockchains are impure versions of the technology that doesn't have some fundamental properties of public ones.

In supply chain context, blockchain can have different levels of data sharing and different objectives, from anti-forgery, to efficiency gain, to internal visibility, to product and process certification.

Benefits on efficiency as speeding up transactions, improving control and reducing manual data entry and audits translates in long term economic benefits opening to a new way to manage transactions in the supply chain and moving towards a process of disintermediation, avoiding slow processes of documentary reconciliation while ensuring authenticity and accuracy of data, which is readily available to interested actors, thus improving the efficiency of the whole system; decentralised solutions indeed have the capability to lower cost of information sharing, processing and shipping.

[23] Spillover effect: the phenomenon (and related mechanisms) for which adopting a behaviour in a certain domain spills over in different domains.

According to Transaction costs economics, contract incompleteness is responsible of costs linked to the enforcement of contracts and to the unforeseen contingencies that could arise; the use of blockchain technology combined to smart contracts influences this costs automating processes and eliminating the impact of bounded rationality, main cause of contract incompleteness, while requiring a level of transparency that discourages opportunistic behaviour.
For what concerns post contracting risks and the associated costs, blockchain is a mechanism to control opportunism by eliminating the need for trust by using crypto-enforced execution of agreed contracts through consensus and transparency.
We saw that combining blockchain and RFID technology it is possible to track and certify all beef meat life cycle before the arrive on the shelf, involving farmers, butchers, shippers, retailers but also veterinarians and certification authorities in a climate of collaboration and efficiency.
The other important benefit is customer oriented and is represented by the improve on company's image linked to the engagement in transparency and the willingness to share data in an immutable way, being reactive to grasp what's important for the consumer and the way to certify it through blockchain technology.
This point has two different points of view:
Consumers affirm that they're confused by the multitude of certification labels that are present in the market, self-investigation tools can help the customer to eradicate uncertainty about meet production conditions and enhance quality perception.
Supply chain producers assert that the majority of customers are mainly concerned with price, (contradicting the consumer declared endorsement for improving traceability and transparency system), and that extreme, total traceability and transparency are not needed nor desirable
By the way, both internal and chain traceability is important when factors affecting consumers' safety and health have to be controlled and certified.

A system of traceability with less noise, delay, loss and distortion that can be provided using blockchain technology is interesting for consumers but also for commercial partners, who constantly look for honesty, accountability, traceability and transparency of partners, in a sort of shift to a “can’t be evil” system aiming to fight distrust in everyday business, providing a trusted and self-investigative source of information about safety regulations, security, regulatory and non-regulatory quality, logistics management and also documentation of sustainability in the process.

From our market research it emerges that both food safety and responsible antibiotic use on the animal are core aspects of the purchasing decisions, followed by the interest for sustainability issues linked to the production process and their management.

The majority of respondents affirmed that they don’t know the technology and its functionalities and even less people affirmed to be aware of its link with food supply chain certification, but a great part of them said they were interested in knowing more.

There is a gap in consumers’ satisfaction about the actual system of sharing data about meat supply chain: 70% of consumers affirm that they usually read information in meat labels while only a 20% of them consider that information clear and reliable.

The demand demonstrated to be partially flexible to price increases, this adds an opportunity to increase marginality to products, together with other benefits like return of image and opportunities to increase market shares and penetrate new markets.

At the state of the art, some questions have still to be given an answer, blockchain could become a widely used technology in many supply chains communicating with each other, however the complexity of such a system requires the development of adequate regulations and well defined sector specific protocols.

To conclude, blockchain systems have to be considered not as solutions looking for a problem, but complex instruments to mediate customers’ specific

informational needs and the ability of companies to disclose information and prove their transparency over the competitors to create value in a new, more open system.

Bibliography

Adams, R. B. (2018). “Blockchain for Good? Digital Ledger Technology and Sustainable Development Goals.”. *Handbook of Sustainability and Social Science Research*, p. 127-140.

Akram, W. (2017). BLOCKCHAIN TECHNOLOGY: CHALLENGES AND FUTURE PROSPECTS. *International Journal of Advanced Research in Computer Science*.

Babbitt, D., & Dietz, J. (2015). *Cryptoeconomic design: A proposed agent-based modeling effort.* Tratto il giorno 9 17, 2019 da Swarmfest 2014: http://www3.nd.edu/~swarm06/SwarmFest2014/Babbitt.pdf

Buchanan, D. a. (1992). *The Expertise of the Change Agent.* London: Prentice Hall.

Buterin, V. (2013). *Ethereum: A Next-Generation Smart Contract and Decentralized Application Platform.* Tratto il giorno 9 24, 2019 da http://ethereum.org/ethereum.html

Buterin, V. (2015). *‘Visions part I: The value of blockchain technology’.* Tratto il giorno 9 30, 2019 da https://blog.ethereum.org/2015/04/13/visions-part-1-the-value-of-blockchain-technology/

By Akash Bhatia, Z. Y. (2019, May). *Stamping Out Counterfeit Goods with Blockchain and IoT.* Tratto da https://www.bcg.com/publications/2019/stamping-out-counterfeit-goods-blockchain-internet-of-things-iot.aspx

C.R.W. De Meijer. (2016). *Blockchain: Can it Be of Help for the Agricultural Industry?* Tratto il giorno 9 22, 2019 da Finextra: https://www.finextra.com/blogposting/13286/blockchain- can-it-be-of-help-for-the-agricultural-industry.

Centers for Deseases Control and Prevention. (2019, Novembre). *Outbreak of E. coli Infections Linked to Ground Beef.* Tratto da https://www.cdc.gov/ecoli/2019/o103-04-19/index.html

Christine Leong, T. V. (2018). *Tracing the supply chain, How Blockchain can enable traceability in the food industry.* Accenture.

Costa, C. F. (2013). “A Review on Agri-Food Supply Chain Traceability by Means of RFID Technology.”. *Food and Bioprocess Technology, 6*(2), p. 353-366.

CSQA. (2019, 02). *"CSQA CHORAL TRUST": THE BLOCKCHAIN CSQA SOLUTION FOR TRACEABILITY IN THE FOOD SECTOR*. Tratto il giorno 10 24, 2019 da https://www.csqa.it/Food-e-Packaging/News/CSQA-Choral-Trust%E2%80%9D-la-soluzione-blockchain-CSQA

David Furlonger, C. U. (2019, Ottobre 15). The Real Business of Blockchain: How Leaders Can Create Value in a New Digital Age. *Harvard Business Review*.

Deloitte. (2019). *Global Blockchain Survey.* Deloitte.

Dickinson, D. a. (2002). Meat traceability: are U.S. consumers willing to pay for it? *Journal of Agricultural and Resource Economics, 27*(2), p. 348-364.

Edelman. (2017). *"Trust Barometer Annual Global Study".* Tratto il giorno 10 30, 2019 da Edelman Trust Barometer Archive: www.edelman.com/insights/intellectual-property/edelman-trust-barometer-archive

Fenton, A. (2019, 07 25). *PROOF OF STEAK: Blockchain and nanotech tackle $2B fake Aussie beef problem.* Tratto da https://micky.com.au/proof-of-steak-blockchain-and-nanotech-tackle-2b-fake-aussie-beef-problem/.

Furlonger, D. U. (2019). The Real Business of Blockchain : How Leaders Can Create Value in a New Digital Age. *Boston : Harvard Business Review Press*.

Gallup . (2019, 11 4). *Confidence in institutions.* Tratto da Gallup: www.gallup.com/poll/1597/confidence-institutions.aspx

Grimm, J. H. (2016). "Exploring Sub-Suppliers' Compliance with Corporate Sustainability Standards.". *Journal of Cleaner Production*(112), p. 1971 - 1984.

Hart, O. (1989). 'An economists perspective on the theory of the firm'. *Columbia Law Review, 89*, p. 1757-74.

Hofstede, G. (2004). *Hide or confide?: the dilemma of transparency.* 'sGravenhage: Reed business information.

Hyperledger global collaboration - Linux foundation. (2019). *How Walmart brought unprecedented transparency to the food supply chain with Hyperledger Fabric.* Tratto da https://www.hyperledger.org/wp-content/uploads/2019/02/Hyperledger_CaseStudy_Walmart_Printable_V4.pdf

Iansiti, M. &. (2017). *The truth about Blockchain.* (Vol. 95). Harvard Business Review.

INDEPENDENT. (2019, 05 02). Volkswagen says cost of diesel emissions scandal has hit €30bn. *Business News*.

International Data Corporation. (2019). *IDC's Worldwide Semiannual Blockchain Spending Guide.* Framingham, Massachussets (US).

Investopedia. (2019, 06 25). *Jake Frankenfield*. Tratto il giorno 11 08, 2019 da Investopedia: https://www.investopedia.com/terms/c/consensus-mechanism-cryptocurrency.asp

Kamath, R. (2018). *Food traceability on blockchain: Walmart's prok and Mango Pilots with IBM.* The Journal of the British Blockchain Association.

Khaqqi, K. N. (2018). “Incorporating Seller/Buyer Reputation-Based System in BlockchainEnabled Emission Trading Application.”. *Applied Energy*(209), p. 8 - 19.

Label Insight. (2016). *How Consumer Demand for Transparency is Shaping the Food Industry.* Tratto il giorno 11 08, 2019 da The 2016 Label Insight Food Revolution Study: https://www.labelinsight.com/hubfs/Label_Insight-Food-Revolution-Study.pdf?hsCtaTracking=fc71fa82-7e0b-4b05-b2b4-de1ade992d33%257C95a8befc-d0cc-4b8b-8102-529d937eb427

Label Insight. (2016). *Label Insight Food Revolution Study.* Tratto da https://www.labelinsight.com/hubfs/Label_Insight-Food-Revolution-Study.pdf?hsCtaTracking=fc71fa82-7e0b-4b05-b2b4-de1ade992d33%257C95a8befc-d0cc-4b8b-8102-529d937eb427

Leonowicz C. et al. (2018). *Beefing Up Blockchain: How Blockchain can Transform the Irish Beef Supply Chain.* Deloitte.

Linux Foundation Project. (2019). *Hyperledger - Open source Blockchain Technologies*. Tratto il giorno 11 17, 2019 da https://www.hyperledger.org/

Morris, N. (2018). *UK Food watchdog completes blockchain pilot.* Tratto da ledgerinsights.com/food-watchdog-fsa-blockchain-pilot/

OECD and European Union Intellectual Property Office . (2019). *Trends in Trade in Counterfeit and Pirated Goods.*

Pardo, M. J.-V. (2015). Misdescription incidents in seafood sector. *Food Control, 62*(11), p. 277-283.

PATUANELLI, S. G. (2019, Gennaio). Proposta di modifica n. 8.0.3 al DDL n. 989. Roma.

Petter Olsen, M. B. (2019). *Applications, limitations, costs, and benefits related to the use of blockchain technology in the food industry.* Nofima.

RJ Krawiek, D. H. (2016). *Blockchain: Opportunities for health care.* Deloitte.

Sander F., S. J. (2018). The acceptance of blockchain technology in meat traceability and transparency. *British Food Journal, 120*(9).

Sara Saberi, M. K. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*.

Saussier, S. (2000). Transaction costs and contractual incompleteness: the case of Électricité de France . *Stéphane Saussier, 42*, p. 189-206.

Schwartz, A. (1992). Legal contract theories and incomplete contracts. . *Contract Economics*, p. 76–109.

Seebacher, S., & Schüritz, R. (2017). *Blockchain Technology as an Enabler of Service Systems: A Structured Literature Review.* ITALY, ROME.

Sinclair Davidson, P. D. (2016, 03). *Economics of Blockchain.* Tratto il giorno 10 13, 2019 da HAL: https://hal.archives-ouvertes.fr/hal-01382002/document

Skilton, P., & Robinson, J. (2009). *Traceability and normal accident theory: How does supply network complexity influence the traceability of adverse events?* J. Supply Chain Manag.

Social Science Research Network (SSRN). (2017, December 5). The Decentralized Autonomous Organization and Governance Issues. *Regulation of Financial Institutions Journal: Social Science Research Network*.

Staples, M. S. (2017). *"Risks and Opportunities for Systems Using Blockchain and Smartcontracts.".* Tratto da Data61: https://research.csiro.au/data61/wp-content/uploads/sites/85/2016/08/BlockchainRisksandOpps-PDF.pdf.

Tapscott, D. &. (2016). *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world.* Penguin.

TE-FOOD. (2019). *How to implement food traceability*. Tratto il giorno 12 03, 2019 da te-food.com: https://www.te-food.com/how_to_implement_food_traceability.html

Tripoli, M. &. (2018). *Emerging Opportunities for the Application of Blockchain in the Agri-food Industry.* FAO, ICTSD.

TYKN. (2019). *Identity Management with Blockchain: The Definitive Guide (2019 Update).* Tratto il giorno 9 21, 2019 da TYKN: https://tykn.tech/identity-management-blockchain/#What_is_Identity_Management

Vishal Gaur, A. G. (2020, May). Building a Transparent Supply Chain. *Harvard Business Review*.

Voshmgir, S. (2017). Disrupting governance with blockchains and smart contracts. *Strategic change*, p. 499-509.

Wiles, N. (2015). *'The radical potential of blockchain technology'.* Tratto il giorno 9 26, 2019 da Youtube: https://www.youtube.com/watch?v=JMT0xwmFKIY

Williamson, O. E. (1985). *The Economic Institutions of Capitalism.* New York.

Williamson, O. E. (1991). Comparative Economic Organization: The Analysis of Discrete Structural Alternatives. *Administrative Science Quarterly*(36), p. 269 - 296.

Zhang, H. F. (2020). Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. *Journal of cleaner production*.