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PhD Thesis

“BIG DATA ANALYTICS TOOLS FOR IMPROVING THE DECISION-MAKING PROCESS IN AGRIFOOD SUPPLY CHAIN”

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ABSTRACT

Introduction: In the interest of ensuring long-term food security and safety in the face of changing circumstances, it is interesting and necessary to understand and to take into consideration the environmental, social and economic aspects of food and beverage production in relation to the consumers' demand. Besides, due to the globalization, the problems of long supply chains, information asymmetry, counterfeiting, difficulty for tracing and tracking back the origin of the products and numerous related issues have been raised such as consumers' well-being and healthcare costs. Emerging technologies drive to achieve new socio-economic approaches as they enable government and individual agricultural producers to collect and analyze an ever-increasing amount of environmental, agronomic, logistic data, and they give the possibility to the consumers and quality control authorities to get access to all necessary information in a short notice and easily.

Aim: The object of the research essentially concerns the study of the ways for improving the production process through reducing the information asymmetry, making it available for interested parties in a reasonable time, analyzing the data about production processes considering the environmental impact of production in terms of ecology, economy, food safety and food quality and build the opportunity for stakeholders to make informed decisions, as well as simplifying the control of the quality, counterfeiting and fraud. Therefore, the aim of this work is to study current supply chains, to identify their weaknesses and necessities, to investigate the emerging technologies, their characteristics and the impacts on supply chains, and to provide with the useful recommendations the industry, governments and policymakers.

Research methods: In order to meet the aim, this work includes the empirical analysis as a first step of the research methodology. It creates an overview of the state of the art of a specific topic by synthesis of different previous researches and based on their results. To answer the research questions, numerous academic articles have been identified, selected and studied. The supply chains, their weaknesses and necessities for the modernization and effectiveness; the emerging technologies and BDA tools, with particular interest in BCT and its different types, main characteristics and nature; and their adaptation and benefit for each other are reviewed. The databases like Scopus, Web of Science, Google Scholar, Science Direct, Wiley Online, and Emerald were used and the cross-referencing has been done as well in order to identify the comprehensive literature for capturing relevant points of research questions.

The following step of the methodology is the case study research. It is a popular method of qualitative analysis on the basis of real occasions. It makes the opportunity to study a complex phenomenon in natural surroundings and to elaborate theories from practical circumstances. The case study provided in this work gives insight into the issue related traditional supply chains, particularly wine supply chain, and compares it with the Blockchain based wine supply chain. As for conceptual framework, there are identified actors involved in the case, described the relationship between them, and made more precise picture than the one could be obtained from general empirical analysis. Thus, the data source is the literature like academic articles, reports, and projects that make it credible.

Last but not least, for simplicity and simultaneously for better visualization of the results of case study, an Agent-Based Modeling and Simulation (ABMS) using the programme

GAMA is designed. It translates the results into solutions in a way to be simpler for reader to understand the complex phenomenon and find solutions for wide range of challenges. The ABMs and the software GAMA are used as supportive tools for describing the case in a very clear manner and making the impression for readers that they participated in the research. This makes clear as the phenomenon itself as well as the context it takes place in.

Results: Current agrifood supply chains deal with number of inefficiencies. Despite the high level of digitization in this field, there is still a problem of "paper documents", as well as tracking the product that on the one hand increases the risk of counterfeiting and on the other hand makes difficult to call back falsified or harmful product from market in time. In many cases this causes people to get sick. In addition, there are often problems with access to or reliability of information. On the other hand, the work demonstrated the capabilities of BCT to eliminate these problems and to modernize the agrifood supply chain. It provides a transparent system that collects, stores and transmits data in a secure way and that is maximally protected from any kind of fraud. At the same time, it accumulates the necessary information and delivers it to the interested person in a short notice. Consequently, it simplifies the quality certification process and reduces the economic and healthcare costs associated with identifying falsified or harmful products and removing them from sale.

More likely to achieve aforementioned result if trust-based collaborations are developed and it is promoted by regulations and Local Development Plans (LDPs). Governments can direct all the solutions to the specific circumstances of the local areas and to ensure that the necessity of territory and sector will be met (Kotu et al., 2017). Furthermore, governments play significant role to promote new trends and to encourage the training of labour force regarding to the requirements of modern market. Social capital, in turn, is a crucial factor for economic development (Fischer, 2013; Casieri et al., 2010).

Conclusion: Nowadays more importance is given to healthy products because of their impact on peoples' well-being, therefore, innovations have a leading role in the food industry. It is crucial for the global economic market and social well-being to have the food industry developing over time, where innovations define and create these improvements for the industry.

BDA tools support food safety, judicious use of primary products in accordance with the issues of precision agriculture, identification of the natural potential of agricultural area, and the balance with market demand as well as trustworthiness and transparency of food value chain processes that ensures the quality of the food and simplifies the trace of the production.

In order to transform and modernize a lot of industries and especially the wine supply chain, the BCT has a huge potential. It encourages a transparent system that benefits various stakeholders, particularly, the consumers giving them ability to know all the necessary information about the product. The benefit of this accurate information is ample for manufacturers, suppliers, and retailers as well. Blockchain is a useful tool to ensure a traceability system and to protect the production from any type of fraud.

Finally, these tools allow obtaining healthier foods in a sustainable way, to prevent food-borne illnesses and to increase the profitability of agri-business.

No less importance have the agricultural policies that include collaborative activities between public and private players, farmers, suppliers, consumers and researches, will encourage the progress of agricultural processes.

Implication: This work demonstrates how to lead to more rational decisions and choices on the production, distribution or consumption level, by giving timely all the necessary information to the supply chain actors and consumers. Additionally, this study shows how to promote the value chains that minimize transport and that are auditable and transparent. Therefore, if the results of this work is taken into consideration, it is supposed to reduce the environmental, climatic, social and economic impacts of agricultural production and consumption processes. This will be achieved by influencing on the food security, quality and safety.

This work is useful for policy developers and it may be used to tune financial incentive instruments applied by governments to stimulate agricultural production. Moreover, the results of the study may be beneficial for suppliers, food and beverage producers, distributors, retailers, consumers, audit and quality control agencies in order to investigate modern trends in the agrifood supply chains, to study how to use emerging technologies for improving agriculture, healthcare, economy, environmental and social conditions, and to decide to apply these technologies in their businesses or any kind of action.

KEY WORDS: *Supply chain, Agrifood, Wine, Management, Logistics, Big Data, ICT, Emerging technology, Blockchain, DLT*

Introduzione: Nell'interesse di garantire una sicurezza alimentare a lungo termine di fronte a circostanze mutevoli, è necessario comprendere e considerare gli aspetti ambientali, sociali ed economici del processo di produzione. Inoltre, a causa della globalizzazione, sono stati sollevati i problemi delle lunghe filiere agroalimentari, l'asimmetria informativa, la contraffazione, la difficoltà di tracciare e rintracciare l'origine dei prodotti e le numerose questioni correlate quali il benessere dei consumatori e i costi sanitari. Le tecnologie emergenti guidano verso il raggiungimento di nuovi approcci socioeconomici in quanto consentono al governo e ai singoli produttori agricoli di raccogliere ed analizzare una quantità sempre crescente di dati ambientali, agronomici, logistici e danno la possibilità ai consumatori ed alle autorità di controllo della qualità di accedere a tutte le informazioni necessarie in breve tempo e facilmente.

Obiettivo: L'oggetto della ricerca riguarda lo studio delle modalità di miglioramento del processo produttivo attraverso la riduzione dell'asimmetria informativa, rendendola disponibile alle parti interessate in un tempo ragionevole, analizzando i dati sui processi produttivi, considerando l'impatto ambientale della produzione in termini di ecologia, economia, sicurezza alimentare e qualità di cibo, costruendo delle opportunità per le parti interessate nel prendere decisioni informate, oltre che semplificare il controllo della qualità, della contraffazione e delle frodi. Pertanto, l'obiettivo di questo lavoro è quello di studiare le attuali catene di approvvigionamento, identificare le loro debolezze e necessità, analizzare le tecnologie emergenti, le loro caratteristiche e gli impatti sulle catene di approvvigionamento e fornire utili raccomandazioni all'industria, ai governi e ai policy maker.

Metodologia: Al fine di raggiungere gli obiettivi prefissati, il presente lavoro include un'analisi empirica quale primo passo della metodologia di ricerca. È stata condotta un'analisi dello stato dell'arte dell'oggetto della presente ricerca, la quale ha fornito una sintesi delle diverse ricerche precedenti e dei loro risultati. Inoltre, per rispondere alle domande di ricerca, sono stati individuati, selezionati e studiati numerosi articoli scientifici. Le filiere, le loro debolezze e le necessità di ammodernamento ed efficacia; le tecnologie emergenti e gli strumenti BDA, con particolare interesse per BCT e sue diverse tipologie, principali caratteristiche e natura; e sono stati rivisti sia il loro adattamento che il beneficio reciproco. A tal fine sono stati utilizzati i database come Scopus, Web of Science, Google Scholar, Science Direct, Wiley Online ed Emerald ed inoltre sono stati effettuati anche riferimenti incrociati per identificare la letteratura completa e per catturare i punti rilevanti delle domande di ricerca.

Il passo successivo della metodologia è stata la ricerca di casi di studio. È una metodologia diffusa di analisi qualitativa basata su contesti reali. Offre l'opportunità di studiare un fenomeno complesso in un ambiente naturale e di elaborare teorie a partire da circostanze pratiche. Il caso di studio fornito in questo lavoro fornisce informazioni sulle filiere tradizionali legate al problema, in particolare, la filiera del vino, e la confronta con la filiera del vino basata sulla tecnologia Blockchain. Per quanto riguarda il quadro concettuale, sono stati individuati gli attori coinvolti nel caso, sono stati descritti i rapporti tra di essi ed è stato realizzato un quadro più preciso di quello che si potrebbe ottenere dall'analisi empirica generale. Pertanto, la fonte dei dati è riferita alla letteratura come articoli accademici, report e progetti che lo rendono credibile.

Infine, per semplicità ed al contempo per una migliore visualizzazione dei risultati del caso studio, è stato progettato l'Agent-Based Model and Simulation (ABMS) utilizzando il programma GAMA. Questa metodologia traduce i risultati in soluzioni in modo da rendere più semplice per il lettore la comprensione del fenomeno complesso e per trovare soluzioni per un'ampia gamma di sfide. L'ABMS ed il software GAMA sono stati utilizzati come strumenti di supporto per descrivere il caso in modo più chiaro e per dare l'impressione ai lettori di aver partecipato alla ricerca. Questo rende più chiaro il fenomeno stesso ed il contesto in cui si svolge.

Risultati: Le attuali filiere agroalimentari fanno fronte a numerose inefficienze. Nonostante l'alto livello di digitalizzazione in questo settore, c'è ancora un problema di "documenti cartacei", così come la tracciabilità del prodotto che, da un lato, aumenta il rischio di contraffazione e, dall'altro, rende difficile ritirare prontamente dal mercato prodotti falsi o dannosi. In molti casi questo fa ammalare le persone. Inoltre, ci sono spesso problemi con l'accesso o l'affidabilità delle informazioni. D'altro canto, il lavoro ha dimostrato le capacità di BCT di eliminare questi problemi e di ammodernare la filiera agroalimentare. Ancora, ciò fornisce un sistema trasparente che raccoglie, archivia e trasmette i dati in modo sicuro e che è protetto al massimo da qualsiasi tipo di frode. Allo stesso tempo, accumula le informazioni necessarie e le consegna alla persona interessata in breve tempo. Di conseguenza, semplifica il processo di certificazione della qualità e riduce i costi economici e sanitari associati all'identificazione di prodotti falsificati o nocivi e alla loro rimozione dalla vendita.

È più probabile che raggiunga il suddetto risultato se venissero sviluppate collaborazioni basate sulla fiducia e se fosse promosso da regolamenti e piani di sviluppo locale. I governi possono indirizzare tutte le soluzioni alle circostanze specifiche delle aree locali e garantire che le necessità del territorio e del settore siano soddisfatte (Kotu et al., 2017). Inoltre, i governi svolgono un ruolo significativo per promuovere le nuove tendenze e per incoraggiare la formazione di forza lavoro rispetto alle esigenze del mercato moderno. Il capitale sociale, a sua volta, è un fattore cruciale per lo sviluppo economico (Fischer, 2013; Casieri et al., 2010).

Conclusione: Attualmente viene data più importanza ai prodotti sani a causa del loro impatto sul benessere delle persone; quindi, le innovazioni hanno un ruolo primario nell'industria alimentare. È fondamentale per il mercato economico globale e per il benessere sociale che l'industria alimentare si sviluppi nel tempo, in cui le innovazioni definiscono e creano questi miglioramenti per l'industria.

Gli Gli strumenti BDA supportano la sicurezza alimentare, l'uso virtuoso dei prodotti primari in conformità con le questioni dell'agricoltura di precisione, l'identificazione del potenziale naturale dell'area agricola e l'equilibrio con la domanda del mercato, nonché l'affidabilità e la trasparenza dei processi della catena del valore alimentare, i quali garantiscono la qualità del cibo e semplificano la tracciabilità della produzione.

Per trasformare e ammodernare le industrie, ed in particolare la filiera del vino, la BCT ha un enorme potenziale. Incoraggia un sistema trasparente che avvantaggia le varie parti interessate, in particolare i consumatori, dando loro la possibilità di conoscere tutte le informazioni necessarie sul prodotto. Il vantaggio di queste informazioni accurate è ampio anche per produttori, fornitori e rivenditori. La Blockchain quindi è uno strumento utile per garantire un sistema di tracciabilità e per proteggere la produzione da qualsiasi tipo di frode.

Infine, questi strumenti consentono di ottenere alimenti più sani in modo sostenibile, di prevenire le malattie di origine alimentare e di aumentare la redditività dell'agribusiness.

Non minore importanza hanno le politiche agricole che prevedono attività collaborative tra attori pubblici e privati, agricoltori, fornitori, consumatori e ricercatori, e favoriranno il progresso dei processi agricoli.

Implicazione: Questo lavoro dimostra come condurre decisioni e scelte più razionali a livello di produzione, distribuzione o consumo, fornendo tempestivamente tutte le informazioni necessarie agli attori della filiera e ai consumatori. Inoltre, questo studio mostra come promuovere le filiere che riducono al minimo i trasporti e che sono verificabili e trasparenti. Pertanto, se si prendono in considerazione i risultati di questo lavoro, si suppone che riducano gli impatti ambientali, climatici, sociali ed economici dei processi di produzione e i consumi agricoli. Ciò sarà ottenuto influenzando la sicurezza alimentare, la qualità e la sicurezza.

Questo lavoro è utile per gli sviluppatori di politiche e può essere utilizzato per mettere a punto gli strumenti di incentivazione finanziaria applicati dai governi per stimolare la produzione agricola. Inoltre, i risultati dello studio possono essere utili per fornitori, produttori di alimenti e bevande, distributori, rivenditori, consumatori, agenzie di audit e controllo qualità al fine di indagare le tendenze moderne nelle filiere agroalimentari, per studiare come utilizzare le tecnologie emergenti per migliorare agricoltura, sanità, economia, condizioni ambientali e sociali, e decidere di applicare queste tecnologie nelle loro attività o qualsiasi tipo di azione.

PAROLE CHIAVE: Filiera, Agroalimentare, Vino, Management, Logistica, Big Data, ICT, Tecnologie emergenti, Blockchain, DLT

1. INTRODUCTION

In the world day by day continues to increase importance of health and wellness issues. The population take more responsibility for their health and environment. Thus, the healthy and environmentally friendly life-style trends have come. Populations requirements have changed considerably (Mollet & Rowland, 2002; Young, 2000). Moreover, economic development has caused profound changes in the way people feed: from a diet predominantly based on products from a rural economy, based on agriculture and livestock, there has been a shift to large-scale industrial productions with innovative products in line with the needs of all consumers. Consequently, in the recent times, besides the scope of improving the food quality and safety, agricultural policies have additionally aimed to reduce negative environmental impacts from agricultural activities.

The national and regional smart specialization strategy takes into account a limited set of investment priorities on the basis of issues identified as follows:

- Aerospace;
- Agrifood;

- Blue Growth (economy of the sea);
- Green Chemistry;
- Design, creativity and made in Italy;
- Power;
- Smart Factory;
- Sustainable mobility;
- Health;
- Smart, Secure and Inclusive Communities;
- Technology for Life Environments;
- Technologies for Cultural Heritage.

The thematic areas identified in the National Strategy for Smart Specialization concern about opportunities for the country comparing to new markets and new possibilities offered or generated by the use of technologies; in particular:

- smart and sustainable industry, energy and environment,
- Health, food, quality of life;
- Digital Agenda, Smart Communities, smart mobility systems;
- Tourism, Cultural Heritage, made in Italy and creative industry;
- Aerospace and defense.

This research forms part of the "Health, nutrition, quality of life" belonging to the topic "Agrifood", and includes interventions at as national as international level.

It is crucial for the global economic market and social well-being to have the food industry developing over time, where innovations define and create these improvements for the industry. Achieving improved and sustainable agricultural production and productivity growth largely depends on the advancement of agricultural research and its effective applications in firms' through the transfer of technology and innovation. Firms that use the right ICTs (Information and Communication Technologies) and BDA (Big Data Analytics) tools into the agriculture value chain have a huge advantage (FAO, 2013). Modern software innovations need to play a crucial part in the overall process. Meaning, a corresponding hardware and software can be complemented towards determining challenges, avoiding those obstacles in short time periods and making overall process of bringing the products to the customer as efficient as possible. Surely, the data gets pretty vast in order to document all steps and details of food chain processes (Yao et. al, 2018) and generates so called "Big Data". In the modern world the data has an effective impact on increasing the productivity of agriculture and farming, and even on maintaining a proper level of security and traceability for the products. Therefore, it has a crucial importance to get and manage the data accurately (Rabah, 2017; Ashutosh, 2012). The ability to keep the data accurate and make the documenting process efficient, encourages trustworthiness of products (Stich et. al, 2016). Therefore, ICTs and BDA tools are vital to the delivery of and access to important services and play a critical role in linking farmers and related businesses to markets, reducing food waste, boosting agriculture productivity, support to international awareness of the product, improve supply chains in the sense of transparency, traceability and reliability, raising profits, reducing the fault and corruption (Irani et. al, 2018; Caro et. al, 2018; Ko et. al, 2018).

The BCT (Blockchain Technology) can be of utmost importance in these processes and it can potentially offer permanence of records and facilitation of shared data between diverse actors in food value chain. The potential BCT hold, is vast as they would be able to shift the paradigm and offer a transparent and trustworthy food chain processes within the food integrity standards.

To be precise, Blockchain generally specifically addresses some of the most problematic aspects of the food system and offers beneficial solutions such as: transparency and accountability, origins and processing of food products, market access for small producers and international labor standards (Caro et. al, 2018; Neisse et. al, 2017; Korneychuk, 2018). The ability to track food from its earliest stages, all the way to the shelves and be able to pinpoint all the participating firms as well as individuals in the process, earns customer confidence. Allowing the consumers to know where the food had been cultivated, how well it had been maintained and what the real current value is, promoted a more informed decision-making behaviors, encourages consumers to purchase the products safely and earns a higher revenue to firms/individuals (Kshetri, 2018). Moreover, it simplifies the quality certification process for authorized parties by giving them higher accessibility to the necessary information (Prashar et al., 2020).

Innovation, structural change, and access to and impact on natural resources and climate change are key drivers of productivity growth and sustainability. Innovations play an outstanding role as they can improve sustainability and climate change adaptation and mitigation. More likely to happen if support is conditional on the adoption of environmentally, climate friendly technologies and BDA tools as BDA combined with emerging technologies represents a significant potential for better-informed policy development. However, first steps for adopting emerging technologies may occur quite confusing and costly (Al-Jaroodi & Mohamed, 2019). Therefore, the government role is crucial in the agricultural innovation system in providing governance, regulations, funds for innovation activities, and incentives for private investment in and adoption of innovation (OECD, 2015). Thus, in order to achieve innovation and transformation of the agricultural sector, the agricultural policies affect on productivity and sustainability outcomes of the market as agricultural producers must respond to these policies.

Investments in the physical and knowledge infrastructure, in the innovative techniques and products, from ICT to transportation facilities, and the control mechanisms are important for overall growth and development. Productive and profitable enterprises may have higher incentives to invest in sustainable practices that yield long-term benefits (OECD, 2015). Hence, knowledge infrastructure is a public good that can enable innovation; it includes ICT infrastructure and emerging technologies (including BCT) as well as specific knowledge infrastructure such as easily accessible databases and institutions. Thus, BDA, ICT tools and BCT drives to achieve new socio-economic approaches as they enable government and individual agricultural producers to have easily accessible an ever-increasing amount of environmental and agronomic data. The access to the right information at the right time gives the firms and individuals the capacity to make informed decisions (Odero et. al, 2017; Osuszek et. al, 2016) that affect their livelihoods and thereby play a major role in ensuring food security.

2. METHODOLOGY

2.1. EMPIRICAL ANALYSIS

The paper includes the empirical analysis as a first step of the research methodology. It creates an overview of the state of the art of a specific topic by synthesis of different previous researches and based on their results (Burgers et al., 2019). The Empirical Analysis distributes the key concepts and advances in the researches on related topics and generates the new knowledge as well (Stone & Rahimifard, 2018; Rousseau et al., 2008; Light & Pillemer, 1986). If used properly, it holds a potential to design the research in a way to address important issues and provide transparent and reproducible answers (Lame, 2019).

Consequently, the research questions are identified first. The purpose is to bring on the light the structure, main issues, necessities and requirements of traditional supply chains; besides to describe the emerging technologies that have a notable effect on supply chain modernization with the main focus on Blockchain Technology, its different types and characteristics with their advantages and disadvantages; additionally, to investigate the impacts that could have these technologies if they are adopted by the industries.

To answer the research questions, numerous academic articles have been identified, selected and studied. The databases like Scopus, Web of Science, Google Scholar, Science Direct, Wiley Online, and Emerald were used and the cross-referencing has been done as well in order to identify the comprehensive literature for capturing relevant points of research questions. Then the double screening has been held, in particular, the articles have been sorted regarding to their title and summary, and subsequently analyzed their whole body. It makes the opportunity to be discussed as much literature as possible.

The research is characterized with interdisciplinary. It means to analyze, synthesize and harmonize miscellaneous disciplines and make them coordinated and coherent unity (Choi & Pak, 2006). Consequently, the boundaries between different disciplines and especially connected ones are alleviated (Burgers et al., 2019). Moreover, it makes possibility to understand a matter in different contexts and to investigate the one action's result on different fields.

The search for the valuable literature has been done in tree main directions as described in the figure 1: the relevant articles, books and reports are studied for investigating (1) the supply chains, their weaknesses and necessities for the modernization and effectiveness; (2) the emerging technologies with particular interest in BCT and its different types, main characteristics and nature; (3) after studying these two topics, the works for exploring how they work together and what is the prospective that they will benefit each other are reviewed.

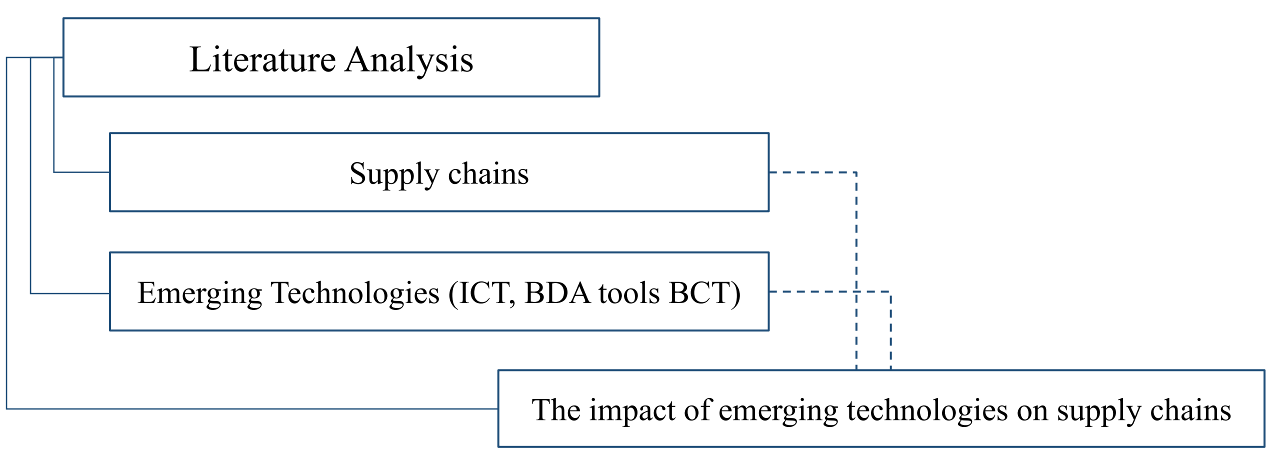


Figure 1. The scheme of literature analysis (Source: own elaboration)

2.2. CASE STUDY

The following step of the methodology is the case study research. It is a popular method of qualitative analysis on the basis of real occasions. It makes the opportunity to study a complex phenomenon in natural surroundings and to elaborate theories from practical circumstances (Recker, 2013). Baxter and Jack (2008) define case study as a methodology that explores the issue through a variety of lenses rather than one lens. Therefore, it allows revealing, describing, explaining, evaluating and understanding the phenomenon from multiple sides and within its real-life context (Harrison et al., 2017). Furthermore, in some researches, it is only the method that can provide the real insight (Rowley, 2002). Baxter and Rideout (2006) proved that case study methodology makes possible to investigate the decision-making process considering the situation within the action takes place.

There are different approaches of case study methodology (Stake, 1995; Yin, 2003; Yin 2006). However, regardless the differences between them, all argue that using this methodology, the topic will be well explored. According to Merriam (2009), it can help to interpret, sort and manage the information in a way that the findings will be clear and easily applicable to the results (Harrison et al., 2017).

Case study methodology is appropriate to use in various instances, including when it is necessary to answer the questions “how”, “what” and “why”; when it is not possible to manipulate with the research object; or when the contextual circumstances are needed to be covered because of their relevance (Yin, 2003).

Because of different research purposes, case study has different types: explanatory, exploratory, descriptive, multiple-case studies, intrinsic, instrumental, and collective (Stake, 1995; Yin, 2003). The case study provided in this work has an instrumental nature. It gives insight into the issue related traditional supply chains and particularly wine supply chain (Stake, 1995). The described case is a single with embedded units. It compares traditional and Blockchain based supply chains and facilitates to understanding differences between them. So, there is shown the wine supply chain in two different conditions, the results are analyzed accordingly (Stake, 1995; Yin, 2003) and the statement is developed. To focus on the statement is important for not to lose the scope and for more credibility to the results. As for conceptual framework, there are identified actors involved in the case, described the relationship between them, and made more precise picture than the one could be obtained from general empirical analysis (Miles & Huberman, 1994). Thus, the data source is the literature like academic articles, reports, and projects that make it credible (Patton, 1990).

2.3. AGENT-BASED MODEL AND SIMULATION IN THE SOFTWARE GAMA

Due to the digitalization, new ways of the studying and solving the problems have been developed. Increasing computer power has resulted to born Agent-Based Models (ABMs) built with computer programing languages. ABMs are computer simulations that are composed by different kinds of agents. These agents are situated in specific environment and circumstances and they are given the ability to make decisions and act autonomously (Sabz Ali Pour et al., 2018). Furthermore, they have the certain predefined rules how to interact with each other in particular situations. These software make the possible for agents to behave unforeseeably and give them ability to evolve and interact. In this way, computer simulations capture the complex matters, generate new knowledge and explain the dynamics of the real world (Crooks & Heppenstall, 2012; Crooks et al., 2018). Dynamic occurs when the agents interact with each other and these interactions are defined based on their cognitive nature (Schieritz & Grobler, 2003; Sabz Ali Pour et al., 2018).

A very early beginning of ABMs can be found in 1970s. In that time, the models mostly were mathematical or statistical and instead of computers, there were used graphs (Hagerstrand, 1967; Schelling, 1971). Most of the models of those times were developed on the basis of aggregation (Wilson, 1974; Batty, 1976; Birkin et al., 1996). So that, they could not analyze individual behaviors and their impact, only the macro-level predictions. In 1996, Epstein and Axtell showed how these models could go beyond limits and create entire artificial system. Later, the models have been more developed. The additional features like ODD (Overview, Design concepts, and Details), the basis of empirical analysis or agents' attributes, made ABMs more transparent, replicable and adapted to the different fields of application (Grimm et al., 2006; Crooks et al., 2018). Though, nowadays, ABMs represent the tool for simulating the processes and create new insight and knowledge. In supply chain optimization processes and logistics agent-based models appeared from the middle of 1990s and the objective was to solve different problems of businesses, for instance, information delivery (Niazi, 2008).

Computer programming made its contribution to becoming ABMs significant tool for studding complicated systems enriching them with the ability to analyze the cases with a complex nature. The simulations software became popular tactical tool for analyzing the business processes, planning the strategies and managing the activities. There are list of the modeling and simulation platforms. According to Taillandier et al. (2019a) each of them are useful and more suitable for different cases. Some researches need to describe the cases and to design the simple models with little data, while others keen on deeper context analysis. On the other hand, the platforms with complex architecture usually require experts in computer science.

Indeed, based on the research interests and objectives, researchers use different platforms. StarLogo is a simple to use. It has a block programming architecture and makes possible the visualization of 3D illustrations. It does not require high mathematical and programming competences but it has limited possibility to build different models (Resnick, 1996; Klopfer, 2020). Similarly, Modelling4all develops very simple models and it is used mostly for teaching (Kahn & Noble, 2009). Modelling4all is based on the software NetLogo. This platform uses Logo dialect as a language and it is extended to be adapted to agents (Keramydas et al., 2016) but it still suffers with noteworthy limitations. As a that result, NetLogo is rarely used for descriptive models. Repast (Recursive Porous Agent Simulation), instead, uses three different ways of modelling. Simple cases can be described with ReLogo and graphical modeling languages, while complex phenomenon need Java and it makes difficult for non-computer scientists to use (North et al. 2013). Similarly, AnyLogic uses graphical modeling language and in case of the extension of simulation, it is assisted by Java. In the platform JADE (The JAVA Agent DEvelopment Framework) agents communicate by the agent communication language (ACL) and they work collectively (Jiao et al., 2006). It offers many powerful tools in order to build multi-agent models that requires programming skills. Cormas (for Common-Pool Resources and Multi-Agent Systems) with the modelling methodology ComMod (Companion-Modeling) has initially created for natural and common-pool resources management. Later it has been extended for supporting participatory modeling for interactive simulations but the main focus remained exploring the natural and social dynamics (Bommel et al., 2016). Swarm is a platform to simulate complex adaptive system (CAS) with the special interest on information flows (Xu et al., 2010; Kwasnicki, 1999). ExtendSim is the potent software for simulating and analyzing the large and complex tasks. It is a modular application constructed with library-based iconic blocks using c-based language, ModL (Kopytov & Muravjovs). FlexSim is suitable software for manufacturing and supply chain. It includes 3-D processing and visualization technology. Additionally, by artificial intelligence and data handling techniques it provides high level simulation (Zhu et al., 2014). However, FlexSim does not support Agent-Based Modeling. Similarly to FlexSim, SeSAm (Shell for Simulated Agent System) has nice visual output and it enables scientists to construct models by visual programming but beginners are not able to use the full power of the software (Klügl et al., 2006). SimEvents has the hybrid nature and it includes as time-driven as well as event-driven components. It is effective for studying task timing and resource usage, for investigating supply chain, forecasting and capacity building to make better decisions (Harahap et al., 2016; Zhang et al., 2017b). Simio is an object-oriented software that can build 3-D models based on intelligent objects and does not require programming if the objects are borrowed from similar models (Kharin, 2018; Mujica &

Piera, 2011). Simul8 is a java-based simulation tool mainly used in operational management. Its reach language provides the possibility for accurate visualization of processes (Bouras et al., 2010).

The simulation software GAMA is an open-source modelling and simulation platform. GAMA is established in 2007 and it is developing continuously by improving its features for satisfying the various and growing needs of its users. Thus, to deal with different data formats, and to increase the effectiveness and usefulness of the Software. The interface has been improved in terms of better view of the data, navigation bar, editor, etc. as well. Developers of GAMA tried to combine the advantages of already existing platforms and eliminate their limitations. Thus, their objective is to make possible to build models easily and quickly like NetLogo does, and to provide as rich simulations as Repast and CORMAS do. Consequently, the modeling language GAML (GAma Modeling Language) has been developed. It is simple to use and, simultaneously, it is powerful tool for data management, for comprehensive visualization and for including big amount of agents (Taillandier et al., 2019b). The other added value is the capacity to model spatial phenomenon. GAMA supports to build large-scale models with extensive visualization that gives the possibility to analyze the simulation results (Grignard & Drogoul, 2017). This is among the main features for agent-based simulation platforms. So, one of the advantages of software GAMA is that it makes possible very easily to build even a complex model and simultaneously to visualize the result. Consequently, it is attainable to check the simulation step-by-step instead of creating the entire model and seeing only the final result. Therefore, it is easier to quickly identify the impact of the changes on the simulation and to use a test-and-try method (Taillandier et al., 2019a).

Moreover, this work requires the possibility to export the simulation results in the different stages of experiment since the aim of the simulation is an academic research and the visualization of its results in the work. For this purpose, the remarkable feature of the platform GAMA is its possibility to accurately export the data in the different formats.

In the table 1, there are summarized the software/platforms described in the previous paragraphs including the characteristics such as: if it is possible to have free access to the software or with payment (under the caption "Access"), how complex tasks can be solved with the software (under the caption "Complexity of the study"), how complex is the modelling and analyzing process using the specific software (under the caption "Complexity of the model"), if there is a need for computer scientist for running the program, and how understandable and nice is visual output (under the caption "Graphical output").

Platform	Access	Complexity of the study	Complexity of the model	Advanced programming skills needed	Graphical output
GAMA	Open	As simple as well as complex	Simple	No	Good
JADE	Open	Complex	Complex	Yes	Good
Repast	Open	As simple as well as complex	Simple till the development of complex model is needed	Needed if necessary to use Java	Good
Modelling4all	Open	Simple	Simple	No	Good
StarLogo	Private (there is also open	Simple	Simple	No	Good

	course version)				
NetLogo	Open	Simple	Simple	No	Weak
Anylogic	Open only with limited features	As simple as well as complex	Simple till the development of complex model is needed	Needed if necessary to use Java	Good
Cormas	Open	As simple as well as complex	Simple till the development of complex model is needed	Needed if the model is complex	Good
Swarm	Open	Complex	Complex	Yes	Weak
ExtendSim	Private	Complex	Complex	Yes	Good
FlexSim	Open	Complex	Complex	Yes	Good
SeSAm	Open	Complex	Complex	Yes	Good
SimEvents	Private	As simple as well as complex	Complex	Yes	Good
Simio	Private	Complex	Simple if the objects can be borrowed	Needed if necessary to create objects	Good
Simul8	Open	Complex	Complex	Yes	Good

Table 1. Comparison of modeling and simulation platforms (Source: own elaboration)

The majority of described software are perfectly applicable for business models and supply chains. Some of them are open source while others private as described in the table 1, few of them have a complex infrastructure and it is difficult to use by non-computer scientists, and most of them have good graphical output so they are useful for visualization of the processes. However, majority of these platforms are perfect for the cases where the individual firms or people are agents and the research question is their interaction forms with each other and its effect on the agents or market or environment. Unlikely, the case described in this work keens to simulate two different supply chains as a whole and the output for the system effectiveness. It generalizes entire industry in a single case. Additionally, it does not include the variety of interaction between agents, neither the environmental conditions are included in the simulation. Therefore, for simplicity and simultaneously for better visualization of the results of case study, an Agent-Based Modeling and Simulation (ABMS) using the programme GAMA is built. It translates the results into solutions in a way to be simpler for reader to understand the complex phenomenon and find solutions for wide range of challenges. The ABMs and the software GAMA are used as supportive tools for describing the case in a very clear manner and making the impression for readers that they participated in the research. This makes clear as the phenomenon itself as well as the context it takes place in (Baxter & Jack, 2008). Additionally, GAMA offers the possibility for the future work, i.e. to analyze the real cases and the models that are more complex as well.

3. LITERATURE REVIEW

3.1. AGRIFOOD SUPPLY CHAIN – STRUCTURE, CHALLENGES, PROSPECTIVE AND CURRENT TRENDS

3.1.1. DEFINITION OF SUPPLY CHAIN

The search for innovative ways of organizing the agrifood supply chain, which are able to contribute to the achievement of shared sustainability objectives, is an extremely topical issue in recent years. The interest in the concept of the Supply Chain has steadily increased since the 1980s, when companies from different sectors, starting from those in the textile and agrifood sectors, have verified the advantages resulting from the construction of collaborative relationships within and outside their own organization (Lummus & Vokurka, 1999). According to Van der Vorst, the supply chain is a sequence of processes (decision-making and executive) and flows of materials, information and money, which occur at different stages of the journey of products and services from the point of production to the point of consumption and cross the borders between the organizations involved (Van der Vorst et al., 2007). A slightly different logic, more focused on the role of active subjects in the supply chain, is that proposed by La Londe & Masters (1994), which identify the Supply Chain as a set of enterprises or identities (Lummus & Alber, 1997) through which the goods destined for the final consumer transit, for example suppliers of raw materials, product assemblers, wholesalers, traders, retailers and transport companies. Similarly, Lambert et al. (1998) define the supply chain as the chain of companies that brings products or services to the market. This chain of companies is often seen in systemic terms as a network of organizations involved, through links with other entities that are upstream and downstream of the supply chain, in the various activities and processes capable of producing value in the form of products or services intended to the consumer (Christopher, 1992).

3.1.2. CHALLENGES IN CURRENT AGRIFOOD SUPPLY CHAINS

The world develops and so do the demands it places on various industries. An important issue is the process of food and beverage production and its perfection. It is caused by the fact that current society continues to place growing importance on health and wellness and address issues surrounding them; taking responsibility for healthy lifestyle. The attitudes and demand for higher quality changed substantially (Molet & Rowland, 2002; Young, 2000).

Besides, millions of smallholder farmers all around the world deal with certain limitations on a general basis. Precisely, difficulties such as challenging entrance barrier on the market or poor access to financial services. Furthermore, some of the other barriers include unqualified human capital resulted by low level of education and training, agricultural research, related data, and problematic physical capital as well (FAO, 2018). Nevertheless, the climate has a big impact on agricultural activities and ignorance of weather conditions may result in many difficulties related to farms (Tenzin et al., 2017). There is also a gap between supply and demand in a long and short-term period of time. Meaning, farmers are not able to change the standard activities immediately which correspond to the changes in consumer preferences (Teng, et al., 2010). So, nowadays farmers need to make more and more complex decisions about the land use, what to produce and in which manner, how to choose suppliers, and how to segment consumers (Rossi et al., 2012), how to reduce the risk of bankruptcy and at the same time maintain their livelihoods well and care about the society (Krantz, 2001).

Meanwhile, due to the globalization supply chains got longer complicating They contain more participants from suppliers to final consumers. A numerous transparency and efficiency issues in agricultural supply chains ultimately put farmers and consumers at a disadvantage. It caused the complexity of finding a bottleneck through supply chain and provoked the simplicity of falsification of products (Esteki et al., 2019; Saberi et al., 2019; Mylrea & Gourisetti, 2018). Difficulties in tracing the product timely may result spreading the contaminated goods on the market and problem of identifying affected items. As a result, producer may become forced to re-call greater amount of products and may be under the risk of losing the reputation as well (Kshetri & Loukoianova, 2019). Therefore, the information about each stage of supply chain acquires greater importance.

Nowadays, the main obstacles that arise usually are the lack of information, its falsification or unreliability (Shahid et al., 2020; Tian, 2017). Ultimately, absence of necessary information or its inaccessibility may cause a negative impact on product quality and reliability, subsequently, on the health of consumers (Aiello et al., 2015). At such times the emerging technologies, a corresponding software and hardware play a crucial role avoiding the obstacles in short time periods and making overall process of bringing the products to the customer, as efficient as possible (Galvez et al., 2018). They allow the information to be accessible and controlled in a short notice of time. This is happening through the digitization of data and the acceleration of industry and society (Beaman et al., 2012).

From a process point of view, companies still suffer with a lack of integration and organization of services, especially regarded to certification processes. The necessity of these companies concerns the simplification of the control and certification procedures and the reduction in the hours/person employed for this activity.

A further critical element that can be found within the organic supply chain is represented by the problem deriving from the conflict of interest generated by the controlled-controller relationship that has led over the last few years to a loss of reputation by consumers towards the certification system and the organic supply chain as a whole The proposal then intends to intervene on the aspects linked to the possible human error in the processes of application of the certification schemes and their control, at the same time reducing the steps and procedures by directing the company and the certifier towards a process automation.

So, traceability becomes the crucial factor in agrifood supply chain, in terms of the ability to trace and follow the history of final product in the supply chain, and possessing necessary information on all stages of production process, warehousing, distribution and trade (Aung & Chang, 2014). It will minimize possible human error reducing the steps and procedures by directing the company and the certifier towards a process automation. The blockchain, in this sense, is opening a world of opportunities that will offer a huge sustainable competitive advantage.

3.1.3. THE ROLE OF COLLABORATION FOR SUSTAINABLE AGRIFOOD AND LOCAL AREAS

Agri-food and rural areas are facing different idiosyncratic and covariate shocks that lead to deep crisis. Therefore, similarly to many other sectors, the focus has moved from the individual activities of firms to the networks of collaboration (Kühne et al., 2015). Agriculture sector needs to blend intensive, specialized production systems to traditional one while trying to reach a competitive advantage in a global marketplace and decreasing environmental impacts.

The changes taking place in the agri-food system require the development of partnerships increasingly oriented to the consolidation and growth of internal and external supply chains and territorial relations. There are many forms of integration that involve, at different levels, the stakeholders of the agri-food system aiming at strenghtening partnership and increasing the contractual force and the market power of the stakeholders (Cantarelli, 2016; Alho, 2015).

Therefore, the actors' networks, rural and agro-food districts, and cooperatives conducting economic and social interactions, represent key forces to promote green and innovative local development in rural areas thus reducing the informative gap (Barati et al., 2017; Contò et al., 2016). Indeed, according to Carrillo et al. (2014), strengthening the knowledge economy through stimulating entrepreneurship and enabling social dialogue gets increasing importance. In addition, nested markets create more and more strong strategies for local development processes and policies, by creating new chances for families' livelihood in rural areas (Schneider et al., 2016). Bojar and Drelichowski (2008) show networking organizations of the agri-food SME in Spain, Greece, Bulgaria, Czech Republic, Lithuania and Poland that experience coopetition and cooperation approach, help to meet needs of consumers for safe and healthy food.

Kotu et al. (2017) demonstrate good rural infrastructure, rural road networks, and multiple information/knowledge sharing can boost adoption of sustainable intensification practices (SIPs) thus increasing income of farmers. Therefore, the instruments of territorial and transnational integration assume great importance in the CAP. Among these instruments, the Local Action Groups (LAGs) represent the main form of territorial integration supported by the CAP in order to enhance rural areas and encourage instruments of territorial and transnational cooperation between farms and other rural development actors (Chmieliński et al., 2018). The core seems to be also acquirement of better acknowledge in policy-making initiatives and opportunities (Huttunen, 2012). Many of these initiatives are encouraged by public policies and aimed at taking full advantage from the measures, the remainders try to meet specific requirements of territory and sector. In Italy, finally, following the law of orientation for the agricultural sector, the Agri-food Districts of Quality and Rural Districts have spread, aimed at improving the territorial governance processes for the development of farms, supply chains and rural areas, in particular areas with a strong vocation and agricultural production specialization (Contò et al., 2012; Zecca et al., 2014).

Furthermore, by investigating the EU project 'CAPIRE: Assessing the multiple Impacts of the Common Agricultural Policies on Rural Economies' Viaggi et al. (2011) highlight the crucial role played by the Local Participatory Networks (LPN) in reaching good results in sustainable and economic development of rural economies. On the other hand, the agriculture that adopts latest technologies gives a major power to farmers since Smart grid technologies can be useful tools for increasing the sustainable energy supply from agricultural residue and waste and for delivering benefits agricultural systems of input (Odara et al., 2015).

Furthermore, several scholars (Fischer, 2013; Casieri et al., 2010) highlight social capital is a crucial factor for starting and maintaining economic development in poor rural areas. Moreover, close cooperation, agro-food agreements, collaborative relationships between public or private players, researchers and business-people help actors of rural systems to match demand and supply in an effective way and they are functional to perform activities with greeter results than when acting in isolation.

Adopting participatory multi-actor approach, involving consumers and knowledge exchange are perceived by stakeholder as most relevant in order to enable a shift towards more sustainable systems and chains (Sacchi et al., 2018).

The following figure (figure 2) assumes that the level of trust between buyers and suppliers (and vice versa) is determined by three interrelated factors: (1) the effective communication and adequate sharing; (2) the existence of positive past cooperation activities and (3) the existence of private and personal bonds that seems to be important when dealing with farmers. Above all, it appears significant to adopt vertical supply or value chain integration from farmers, food processors and grocery retailers in a durable way functional to develop and maintain sustainable relationships in rural areas (Fisher, 2013).

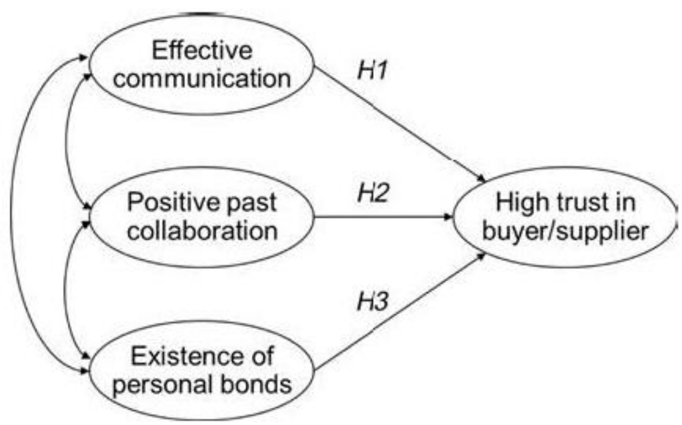


Figure 2. Assumed relationships among trust-affecting factors (Source: Fischer, 2013)

Trust-based collaborations are promoted by Local Development Plans (LDPs) in order to build virtuous and continuous development mechanisms. Both Horizon 2020 framework and Common Agricultural Policy 2014-2020 stress the role of innovations: new Rural

Development policies define new network tools as the European Innovation Partnership (EIP), the Operational Groups (OGs), and technological clusters designed for encouraging innovation processes (Nazzaro & Marotta 2016).

Integrated environmental research and networking of the agricultural economy in rural areas is a trend already started for two decades when processes began to move towards the disappearance of the old rural organisation (Luostarinen, 1998).

Currently, in various French and Brittany regions, rural networks of farmers organise exchange groups to help newcomers and facilitate knowledge exchange on new tools and practices. The EU TRADEIT project (www.tradeitnetwork.eu) was born as a collaboration among researchers, food networks, traditional SMEs, clusters, technology providers, food associations and entrepreneurial networks with the aim to promote, smart use of IT for traditional food producers, relationship building, sustainable technology for food production and so on (EIP-AGRI, 2015). Besides, Weaver (2008) argues that increasing use of innovative technologies has opened new opportunities on the one hand, yet it has resulted the need of strategic reorientation that should be supported by collaborative activities in the supply chain.

Finally, the manner to accomplish this approach can be built going through the currently fragmented marketplace based on power and competition via research and trust-based networks towards an integrated, consistent and entirely sustainable supply system (Fisher, 2013).

3.1.4. CURRENT TRENDS IN AGRICULTURAL PRACTICES

3.1.4.1. ICTS AND BDA TOOLS IN AGRIFOOD SUPPLY CHAINS

Emerging technologies revolutionize the ways people live, interact with each other and do the business (Schwab, 2017). Digitization has heavily affected agriculture as well. According to Stratigea (2009), Information and Communication Technologies (ICTs) contribute real-time systems that enables effective collaboration making easier the interaction and communication process between relevant stakeholders like policy makers, decision makers, farmers, researchers. In addition, the development of technology-driven agriculture and adoption of precision agriculture technologies (PAT) managing the in-field heterogeneity, gives the opportunity to the companies to design the agricultural value chain in detail (El Bilali & Allahyari, 2018; Stafford, 2000) and to face the challenges that agriculture and food industry meet. Consumers want high-quality food at low prices - with the utmost respect for animal and environmental protection. To achieve this, it is necessary to improve production and management processes (Banhazi et al., 2012). With technically supported methods for the individualization of field management and livestock farming plants and animals in an agricultural enterprise receive exactly the treatment they need (Berckmans, 2014). Specifically, there occurs the targeted management of agricultural land - using intelligent electronics. Examples include sensor-assisted soil assessment, automated animal observation on pasture or targeted control of agricultural machinery. Modern methods of differentiated management allow a site-specific work within a parcel (Morimoto & Wadamori, 2018; Jordan et al., 2016).

technology-driven agriculture can provide environmental and economic benefits through the reduction or targeted introduction of agricultural inputs including water, pesticides and nutrients (van Evert et al., 2017). So, accurate applications of nutrients can bring significant environmental and economic benefits. The goal is to apply only the nutrients that the plants need and can use (Zavala-Yoe et al., 2017). In addition, it may be necessary to manage the application in environmentally sensitive areas (Luck et al., 2010). Application rates will vary in the field depending on soil type, fertility levels and environmental sensitivity. Some areas may require reduced rates because of their environmental sensitivity (Fu et al., 2018). Specific pesticide applications can provide economic and environmental benefits. For instance, the use of light bar guidance systems cheap and fast leads environmental benefits for pesticide applications (Balafoutis et al., 2017). These affordable lights bar guidance systems provide a simple method of getting equipment through a field to avoid overlap when pesticides are sprayed.

Sensors, drones and robots make it possible to collect exactly the information that is required for a tailor-made farm (Elijah et al., 2018). With the help of sensors and satellite control, different soil characteristics and yield capabilities within the field can be electronically determined in a so-called field record file and individually responded to in real time (Faccilongo et al., 2016; Zhao & Yang, 2018). Seed, fertilizers and pesticides can be used in a targeted and reduced way and fuel consumption can be reduced thanks to the satellite-controlled safe tracking of agricultural machinery and intelligent sensors (Zhang et al., 2017b). Sensors determine also wind conditions and solar radiation in order to automatically control the irrigation system based on the measured values or to trigger the order for a required fertilizer (Yan, 2017).

Aerial images of drones provide valuable information about the field, such as soil quality, accompanying flora and diseases on plants (Smith & Chan, 2017). The data are available at short notice and appropriate measures can be taken (Parra et al., 2017). An agricultural company can measure its land, calculate the density of cultivation and control the growth and development of its plants and animals. The drones give the farmer an extra pair of eyes - much like satellites that monitor fields and pastures, and control agricultural machines with GPS signals (Fernandez, 2016).

Farming data play an outstanding role as its appropriate use can improve the production process and logistics, and at the same time sustainability, climate change adaptation and mitigation (Kamilaris et al., 2017). However, the benefits of a data-driven agriculture can only be used if the necessary measures can be derived from the data. Surely, the data gets vast (Yao et al., 2018) and farmers not always are able to analyze very large amounts of data without significant assistance. More likely to happen if support is conditional on the adoption of BDA (Big Data Analytics) tools like machine learning or data mining (Ghosh, 2016; Van & Ryan, 2018; Rajeswari et al., 2018). Then, FMIS (Farm Management Information System) and DSS (Decision Support Systems) can be the basis for successful information exploitation. After having all necessary information, using FMIS and DSS, it is possible to analyze and make them available in a useful form to the agricultural entrepreneur to improve the decision-making process and the farming system as a whole (Zaza et al., 2018; Paraforos et al., 2016). Meaning, farmers will be offered with choices that solve the problems regarding to production process and environmental impact (figure 3).

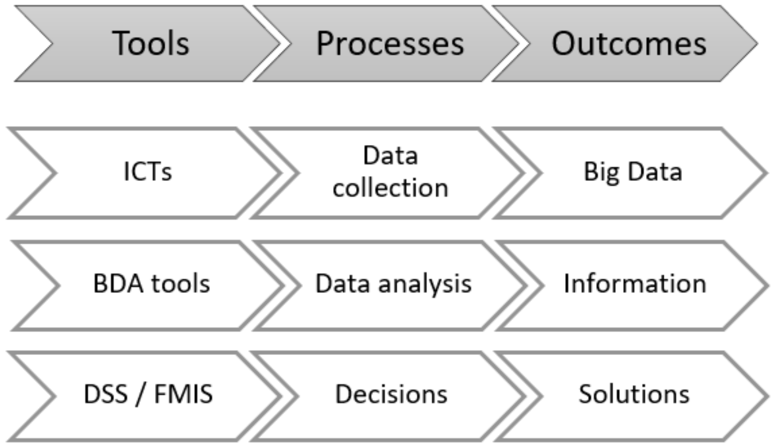


Figure 3. Data towards innovative solutions (Source: own elaboration)

With the other words, ICTs provide farmers with enormous amount of data. The skills to analyze them exceed to human brain capacity. So, there is a need of specific tools for BDA that transform this enormous data into the useful information. Then, DSS can provide particular choices for individual cases taking into account as productivity as environmental impact.

On the other hand, adoption of emerging technologies is quite costly and requires high initial investments. Not all smallholders are able to pay such a high price in machineries (Yigezu et al., 2018). Therefore, there is a need of the investments aimed at the modernization and digitization of the companies and the processing of agricultural products. It will increase commercial value of the products and support to improvement of the supply chains, aggregating and strengthening the production phase, increasing the competitiveness of the producers (Bazzani & Canavari, 2013; Carbone, 2017). Indeed, many Italian regions use the measures useful for the development of technological and sustainable innovations for the improvement of products and production processes and for the promotion of food products (Frascarelli, 2012; La Sala et al., 2017a; La Sala et al., 2017b).

3.1.4.2. BLOCKCHAIN TECHNOLOGY OUTBREAK IN AGRIFOOD SUPPLY CHAINS

Agriculture is experiencing several environmental, economic and social issues that push and motivate a transition towards sustainable paths within of the global economic system (El Bilali et al., 2020; Lin et al, 2020; Jabir & Falib, 2020). Therefore, over the last decade, there was an exponential increasing in promoting smart systems and in identifying ingenious solutions for all the sectors (Ciruela-Lorenzo et al., 2020; Jennath et al., 2019). On the other hand, BCT has been found as revolutionizing technology for number of different fields of economy. One of the industry, where BCT is a very promising, is agriculture.

The adoption of ICT in agriculture sector can certainly strengthen the large-scale transformation, decrease production costs, and increase investments growth (Gorshkova & Kusmartseva, 2020) as well as together to blockchain technology promote sustainable e-agriculture (Demestichas et al., 2020; Song et al., 2020). Therefore, BCT can play a fundamental role and could have a wide scope of application, taking into account the importance of knowing the origin of an agrifood product for consumers and of the usefulness of this technology to fight against counterfeiting and falsification of products.

Blockchain technology influences several factors in the agricultural sector (climate-environment related data, payments, soil-moisture, demand and sale price, seed quality, products’ convenience to the farmers, equipment, finance, loans etc.) and focuses on 4 key aspects (Dove et al., 2019; Umamaheswari et al., 2019; Tian, 2016):

(1) Consensus and distributed trust among farmers regarding crucial rights;

(2) Security in terms of safety of the data;

(3) Provenance that makes sure transactions and avoid fraudulent data;

(4) Trust among actors that are part of a ledger within buyer-seller relationships.

Definitely, BCT collects several advantages and generates an exclusive level of credibility but some limits persist and have to be dealt with: regulations, relationships among actors, data ownership, scalability, etc. (Demestichas et al., 2020). Every business of the agrifood supply chain manages its own data-recording systems; so, a unique tracking system for info appears tricky due to the mismatch among software or data structures (Khan et al., 2020). In addition, it is necessary to highlight that the costs of skilled human resources and of developing, adopting and maintaining blockchain technology can be considered high than other systems (FAO & ITC, 2019).

A recent work (Lin et al., 2020) investigates the BCT in the light of COVID-19 pandemic and of weaknesses and needs emerged in the agro-food chain: the necessity both of real-time accurate information reflecting the purchase choices and of effective coordination between actors to reply with fast and adequate responses; the urgency of efficient processes for reducing times in bureaucracy-based procedures. The figure below (figure 4) illustrates an improved BCT based supply chain system that can be arranged in COVID-19 era to improve the allocation of resources when dealing with unforeseen events.

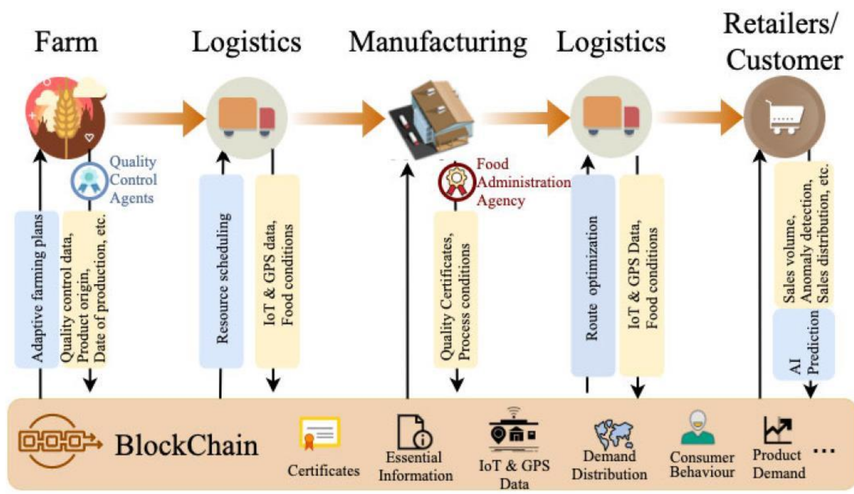


Figure 4: BCT in the COVID-19 pandemic economy (Source: Lin et al., 2020)

Another recent research (Yang et al.,2020) proposes to implement a consortium BCT based machinery scheduling system to join the advantages of the BCT to the intelligent distributed scheduling of agricultural machinery: in this way, it is possible to overcome single point crash, high costs, and waste of resources. On the other hand, Khan et al. (2020) suggest to combine IoT (Internet of Thinks) with BCT, implementing IoT–Blockchain-enabled intelligent system taking farmers as participants and allowing them to create personnel files and duty record files for each section (see figure 5).

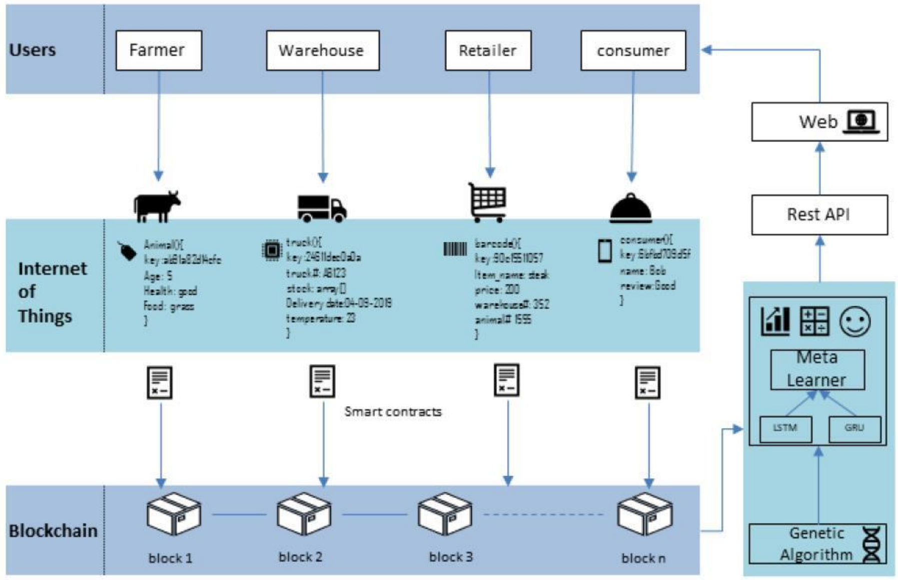


Figure 5: The IoT–Blockchain-enabled intelligent system (Source: Khan et al., 2020)

In order to combine BCT to risk issues, FAO proposes an interesting scheme, FARMS (Financial and Agricultural Risk Management for Smallholders), which provides, through the BCT, easy access to formal financial risk management, while increasing farmers' financial literacy.

To underline the fundamental role that this technology could have in the future, Italian Ministry of Economic Development launched on June 18, 2020 a public consultation to collect proposals collected in the report "Proposals for the Italian Strategy on technologies based on distributed registers and blockchain". The report reaffirms the importance of implementing a digital infrastructure based on Blockchain technologies to promote the development of an ecosystem for the exchange of product information in order to increase its transparency and strengthen guarantees, of origin and food safety, involving all the actors in the supply chain and the final consumer. The BCT is proposed as a transparent traceability and communication system aimed at fighting counterfeiting in the various production sectors and the spread of so-called Italian sounding, representing together with smart contracts and legalization, valid tools for the promotion of Made in Italy above all in the agro-food sector.

In line with above mentioned framework, the European Green Deal by European Commission and the "Farm to Fork" strategy for a fair, healthy and environmentally-friendly food system aim to address in a systemic way the challenges related to the sustainability of food systems, recognizing the connections that link the health of individuals, companies and environment. This strategy is developed around six macro-objectives, which concern the sustainability of food production phases, the food security, the promotion of sustainable food consumption, the reduction of food losses and waste and the fight against fraud in food supply chains.

3.2. THE BLOCKCHAIN TECHNOLOGY – BIRTH, HYPE, NATURE AND CHARACTERISTICS

3.2.1. BRIEF HISTORY OF BLOCKCHAIN TECHNOLOGY

The basic idea behind the blockchain technology was born in 1991, when Haber and Stornetta (1991) in their work described how to sign documents digitally in a way to be easily shown that none of the documents signed in the collection had been modified. The authors in their work "How to time-stamp a digital document", proposed two solutions in order to certify when a document was created or last modified: the hash function and the digital signature. Since, these solutions time-stamp the actual bits of the document, changing even one character in this document causes the difference in hash value. So that, it is easy to show that the signed documents are modified. This system was first used for digital currency in 2008 by an anonymous programmer which presented himself with the pseudonym Satoshi Nakamoto in the initial paper "Bitcoin: A Peer to Peer Electronic Cash System" describing the Bitcoin digital currency solution as the technological basis for the Bitcoin cryptocurrency, with the purpose to ensure the integrity of the registered transactions by trusting them with a shared consensus mechanism.

Blockchain (Prathyusha et al., 2018; Pilkington, 2016) is a peer-to-peer distributed database of transactions (ledger) secured by cryptography. Transactions are registered in a continuously growing list (chain) of records (blocks) which are append-only (you may only write a new block at the end of the structure) and immutable (or at least very hard to change). The blockchain can be updated only via agreement among peers (consensus). From an economic point of view, Blockchain can be defined as a platform where nodes exchange values using transactions without the need for a central trusted authority. Thus, it increases processing speed and reduces costs.

A well-known example of peer-to-peer system was Napster (Ku, 2017), which introduced a file sharing system and revolutionized the traditional music industry by making a closer connection between artists and consumers.

Blockchain is implemented through a distributed peer-to-peer network (A peer-to-peer network is a set of computers exchanging their computational resources with the other nodes at the same level of importance) that is possibly accessible from the Internet. A network of computers that work together to keep the blockchain secure, correct and consistent. From an economic point of view, it can be defined as a platform where nodes exchange values using transactions (A transaction consists in the transfer of some asset from a subject to another) without the need for a central trusted authority. This is perhaps the most important and powerful concept of blockchain technology: a decentralized consensus mechanism with no unique authority governing it, so increasing processing speed and reducing costs.

With the other words, “Blockchain is a distributed ledger maintaining a continuously growing list of data records that are confirmed by all of the participating nodes” (Raikwar et al., 2019). Blockchain technology is a digital ledger of records, called "transactions", secured with a hash function, authenticated, and maintained through a distributed network of nodes using a consensus protocol (Condos et al., 2016). Nodes are all participants involved in the blockchain, each one has a copy of the blockchain and equal authority to accept or not the new blocks (Smith et al., 2016). The new blocks are added on the blockchain if all nodes achieve consensus on the transaction. An indestructible chain is forming since once the new line (block) is added on the blockchain and proved from all nodes applying the hash function, it is not possible to be changed even a little detail in the older data by any single participant (Caseau & Soudoplatoff, 2016; Hon et al., 2016). Therefore, as any distributed ledger technology (DLT), blockchain enables parties who do not trust or even do not know each other, to interact on a peer-to-peer basis without any need of third party authorities, and to exchange the data in a secure way. In the blockchain, parties trust each other on the basis of a consensus mechanism – set of the rules that should be followed by each of the nodes to verify and validate the transaction and to add the block on a chain (Nascimento et al., 2019).

Therefore, BCT is a decentralized digital database that allows the secure recording and sharing of all information regarding transactions, registered by different actors involved in the production and distribution processes. The main characteristics of Blockchain technology mainly are the immutability transparency and traceability of transactions, as well as security based on cryptographic techniques (Caro et al., 2018; Zhao et al., 2019; Kamble et al., 2020; Malik et al., 2018; Gourisetti et al., 2020). Regardless these features, BCT remained under shadow for several years, in 2014 it began to emerge and currently it gained massive attention globally. This attention is shifting to different areas of uses other than money as well. Indeed, at present, BCT is among the popular topics for academic research and application in practice. Only in the first three quarters of 2016, 1.4 billion dollars were invested by startups (Kennedy, 2016).

With the term blockchain we refer to both its data structure (a chain of data blocks), its consensus algorithm, and the entire suite of technologies behind. Being it a shared ledger among distributed peer-to-peer systems its objective is to maintain and demonstrate ownership of the assets registered in its transactions (stored in the blocks of the chain). Proving ownership implies identifying the owner, the object being owned, and mapping the owner to the object.

Instead of one single central ledger, the blockchain offers a set of independent ledgers which document ownership in the final version on which the majority node agrees. In the distributed peer-to-peer system each node maintains one copy of the shared ledger and, following the blockchain’s consensus algorithm, all nodes reach one consistent version of the shared ledger (which in turn demonstrates the state of ownership registered in the blockchain's transactions).

Cryptography (Katz et al., 1996) is used for identifying (recognizing), authenticating (verifying identity), and authorizing subjects claiming assets' ownership. This leads to the blockchain's ability to truthfully manage ownership and to ensure that only the lawful owner can transfer his or her property rights to others.

Recently, BCT has attracted increasing attention in the context of new applications. Using the BCT in various areas made necessary to diversify the its types (Okada et al., 2017). Each field have different requirements and restrictions. For instance, for some areas the transparency nature of Blockchain Technology may occur challenging (Fabiano, 2018; Hebert & Di Cerbo, 2019; Chaudhry & Yousaf, 2019 Desai et al., 2019). For this reason, rises the necessity of protecting the information from accessibility for everyone. Additionally, in some cases, it is impossible to run the system in totally decentralized and uncontrolled way. Some fields have legal requirements that knows each party in the network (EU, 2018); business sector mostly has the necessity to have the system more strictly controlled, with the restriction to modify or even read the blockchain state for several users (Sheldon, 2019; Terzi et al., 2019). So that, it becomes important to identify each node in the network. As a consequence, there are Public or Private / Permissioneless and Permissioned Blockchain Technologies, described in the following paragraph.

On the other hand, in some cases, the main requirement for the system is to minimize the latency or reduce operational cost. In this case, the consensus protocol plays a crucial role (Malik et al., 2019). It determines the scalability of BCT, since the computational power and consequently the time for confirming the transaction depend on the quantity of transactions in each block and the interval between blocks (Gemeliarana & Sari, 2018). Besides, individual businesses independently determine if it is comfortable for their work to include the smart contracts. According to the necessities of various industries, the different features of BCT have been evolved and diverse types of BCT have been developed. Consequently, the architecture of the blockchain technology differs from each other.

3.2.2. CHARACTERISTICS OF BLOCKCHAIN TECHNOLOGY

3.2.2.1. BLOCKCHAIN DATA STRUCTURE AND IMMUTABILITY

The first block of the cain is called the “Genesis block”. Each block stores the following information:

- **Index**: the position of the block in the chain (the genesis block has index 0).
- **Timestamp**: the time when the block was created (used for keeping the blockchain in the correct order).
- **Hash**: a numeric value that uniquely identifies the block’s data (the digital fingerprint of data) and has the following properties:

- Fixed length (typically 256 bits);
- Easy to compute;
- Not reversible (you cannot get the original data from hash);
- If data changes, hash changes (in particular, small change in data leads to big change in hash).

- **Previous hash**: the hash reference of the previous block in the chain.

- **Data**: the data (transactions) stored in the current block (in a cryptocurrency it would include money transactions). Changing the data will change the hash, which will so become invalid. Subsequent blocks will also be invalid, leading to a cascading invalidation of blocks in the chain.

- **Nonce**: the number of iterations needed to find a valid hash, i.e. a hash with a required predefined number of leading zeroes, called *difficulty* (3 in the example shown in Figure 6).

Figure 6. A hash value (with difficulty 3)

The hash of the current block comes from the combination of its index, timestamp, data and nonce and the previous block's hash. Mining is the process of finding a valid hash for the block. A new block being added to the blockchain needs to meet the following requirements:

- Block index = latest block index + 1;
- Block previous hash = latest block hash;
- Block hash meets difficulty requirement (no. of leading zeroes);
- Block hash is correctly calculated.

Because other peers on the network are simultaneously trying to add blocks to the blockchain, new blocks need to be validated before becoming part of the chain (peers ask each other to find who has the most up-to-date blockchain version).

If a block is modified, it and its subsequent blocks become invalid and are rejected by the peers on the network. Earlier blocks will be harder to alter because there are more subsequent blocks to re-mine. The only way to mutate a block would be to mine the block again, and all the blocks after. Since new blocks are always being added, it's nearly impossible to mutate the blockchain.

3.2.2.2. PUBLIC AND PRIVATE BLOCKCHAINS

Blockchain Technology, with its classical definition, provides complete decentralization and uncontrollability of the system (Yao et al., 2020). However, over time, the necessity of permissioned BCTs has been raised. These kinds of BCTs make a possibility to predefine the nodes involved in the system (Falazi et al., 2020). It does not mean full centralization of a system. In this case, nodes need the acceptance for joining the network. After that, the system continues to work in a decentralized manner. This function supports to better authorization and authentication processes. It eliminates the problem of privacy and reduces the latency in transaction processes (Malik et al., 2019).

Now blockchains can be categorized in three types: public (permissionless), consortium (permissioned) and private (permissioned) blockchains. Canadian programmer Buterin Vitalik (2015) describes them in his article "On Public and Private blockchains", their characteristics (table 2), advantages and disadvantages (table 3).

	To read	To send transaction	To participate in consensus process	The mechanism	Other characteristics
Public "fully decentralized"	anyone	anyone	anyone	PoW (Proof of Work), PoS (Proof of Stake)	Secured by cryptoeconomics; The degree of influence is proportionated to the quantity of economic resources
Consortium "partially decentralized"	Anyone / pre-defined nodes	pre-defined nodes	pre-defined nodes	The majority have to sign every block	
Private "fully private"	Anyone / restricted	centralized	centralized		Likely applications include database management, auditing, etc internal to a single company

Table 2. Characteristics of public, consortium and private blockchains (Sourse: Buterin, 2015; Zheng et al., 2017)

	Advantages	Disadvantages
Public "fully decentralized"	Protects users from developers' influence; Trust of the system (blockchain) Censorship resistance Network effect; Immutability nearly impossible to tamper	Can be reduced the block time till 15 seconds (Ethereum) instead of 2 hours (Bitcoin), but still it is more than in the cases of private or consortium blockchains
Consortium "partially decentralized"	Easy changes, revert transaction, modify balances; The validators are known;	Immutability could be tampered

	Cheap transactions; Nodes can be trusted to be very well-connected;	
Private “fully private”	Easy changes, revert transaction, modify balances; The validators are known; Cheap transactions; Nodes can be trusted to be very well-connected; Greater level of privacy if read permissions are restricted.	Immutability could be tampered In some cases, in order to work efficiently the BC, some heterogeneous assets from different industries need to be on the same database, that’s difficult to happen in private BCs.

Table 3. Advantages and disadvantages of public, consortium and private blockchains (Sourse: Buterin, 2015; Zheng et al., 2017)

Seemingly, Public Blockchian is “fully decentralized”, anyone can read and send transactions; Consortium Blockchain is “partially decentralized”, anyone or pre-defined nodes can read and only pre-defined nodes can send transactions; while Private Blockchain is “fully private” meaning that read permissions can be both restricted or public while the writing is centralized (Buterin, 2015; Zheng et al., 2017).

All three types of blockchain technology have its advantages and disadvantages. The users should choose the one that fits better to the requirements of specific field of application.

3.3. BLOCKCHAIN TECHNOLOGY AND AGRIFOOD SUPPLY CHAIN

Blockchain Technology (BCT), the first decentralized technology originally developed for mining of cryptocurrency, has a potential to solve the problem of data reliability, transparency and traceability, thus to guarantee the trustworthiness of information. It represents a protocol providing the infrastructure that ensures the immutability of the information over time (Caro et al., 2018). Because of this property, BCT has been applied in various different areas. The benefit for food and beverage supply chain is noteworthy.

Blockchain innovation is surrounding by fast growing industrial ambience. The hype about the blockchain derives from being it a tool for achieving and maintaining integrity in distributed peer-to-peer systems, with the capability of reshaping whole existing industries by disintermediation. Instead of one single central ledger, the blockchain offers a set of independent ledgers. In this system each node maintains one copy of the shared ledger and, following the blockchain's consensus algorithm, all nodes reach one consistent version of the shared ledger.

Taking into consideration all these characteristics of blockchain, it is foundation need for industries to simplify tracking the products along supply chain, certification process and establishment of new relationships. In fact, currently the attention is focusing on the food traceability since there is an increasing need of certification of origin and quality of product, in particular a quantitative and qualitative model of information shared along the supply chain. One way to provide reliable information is through a decentralized system that is trusted by all participants in the production and delivery process (Zhang & Zhao, 2018). Also this system should ensure data immutability. The reliability can be considered achieved, if the data is available to all participants and if they have the opportunity to verify that the data has not been falsified since its inception (Zhang & Jacobsen, 2018). Besides, if there is a system that can ensure the reliability of the data, it will also be able to deliver the information securely to the recipient (Reyna et al., 2018). Thanks to Blockchain technology, all the players in the supply chain would no longer need to use "paper documents" or rely on central or third-party entities for the certification of the various information and documents produced during the various stages of the supply chain.

3.3.1. TRACKING PRODUCTION THROUGH BLOCKCHAINS

Production tracking seems to be one of the most suitable application areas for the development of blockchains outside the classic world of virtual currencies, in particular the farm production chain. There are several examples in this area. IBM demonstrated the use of blockchain as a fresh food tracking system for Walmart (Zhao et al., 2016; Hackett, 2017), tracing the movements of each individual product from harvesting to packaging, from cold storage to sorting centres.

In Italy, Barilla has adopted a similar process (Morabito, 2017; Petek & Zajec, 2018) to follow the growth of basil plants used for pesto. It starts with sowing and continues with delivery to haulers up to the factory where the basil is transformed into pesto. Again, everything is under control and not a single batch can go unnoticed by the company. The aim is to strengthen the image of quality of the raw material along the entire chain and the anti-counterfeiting control.

Barilla’s project started with an experiment involving a single basil producer with a “farm to table” tracing. The producer has already included in the blockchain all the data relating to cultivation, from irrigation to pesticides to ensure effective sustainability; then at the time of mowing, each individual batch will be followed up to delivery. If the test is successful, the project can be extended to all products in the group, starting with wheat, tomatoes and milk.

Great Eggspectations! is the call for ideas launched by Seeds&Chips in partnership with Coop and Ibm, to use blockchain criteria in the egg chain (Seeds&Chips, 2019). The production and supply chain of eggs is one of the most vital in the global food system, but also one of the most vulnerable. Recent threats throughout Europe have raised the need for both businesses and consumers to identify new principles of accountability and transparency throughout the production and distribution chain.

The blockchain, in this sense, is opening a world of opportunities that will offer a huge sustainable competitive advantage in every sector and supply chain. The Call involves Seeds&Chips, Coop and Ibm, respectively the ecosystem on the FoodTech for excellence, the largest large-scale retail and innovation leader for the business world. The initiative is based on a common path towards a more transparent and authentic egg chain, so as to have access to secure information on what they buy and what they put on the table. The aim of the Call is to identify the best solutions with blockchain technology in various areas: monitoring the distribution chain; agriculture; traceability; retail innovation; big data and precision monitoring.

The interest in Blockchain technology is stronger in the case of Protected Geographical Indication (PGI), Protected Designation of Origin (PDO) and organic products since the detailed information about steps passed by the product gets crucial importance.

3.3.2. BLOCKCHAIN APPLICATION IN AGRIFOOD SUPPLY CHAINS

BCT can play a fundamental role and could have a wide scope of application, taking into account the importance of knowing the origin of an agrifood product for consumers and of the usefulness of this technology to fight against counterfeiting and falsification of products. Indeed, BCT in the agricultural sector is being adopted for optimizing the processes in the supply chain, improving the traceability, enhancing food safety, reducing times and cost of transaction, food fraud, and inefficient processes. In addition, blockchain can improve the profits of farmers and promote ethical issues, like fair-trade, animal welfare, and reduce environmental impacts (Fernandez et al., 2020; Katsikouli et al., 2020; Lin et al., 2020; Caballero & Rivera, 2019; Bermeo-Almeida et al., 2018). Therefore, the implementation of the BCT certainly improves the traceability, the ability to tracing and tracking the food in all the steps (EC, 2002). It can avoid a diffuse use of pesticides and fertilizers, which can cause the presence of residues dangerous for human health (Mirabelli & Solina, 2020). Additionally, BCT gives the ability to suppliers, farmers, producers, retailers and governments to identify and confine contaminated elements and follow its road along supply chain.

It is noteworthy, that thanks to abovementioned characteristics, BCT significantly reduces the time of re-call if the hazardous product appears in the retail shops. Subsequently, it reduces the inefficiencies along supply chain and therefore, the risk of undesirable results

(Kadariya et al., 2014; Scharff 2012). Precisely detecting maleficent goods in time promotes re-calling back the products before it spreads in consumers and only the ones which are affected, so reduces health risk, financial loss and damaging reputation (Pouliot & Sumner, 2013; Kshetri & Loukoianova, 2019).

3.3.3. BLOCKCHAIN APPLICATION IN WINE SUPPLY CHAIN

The interest in the investigation of wine supply chain is linked to the system of classification of wines at EU and Italian national level. Additionally, it is one of the most sensitive products with the features such as provenience and quality. Indeed, the world of wine has always been associated with traditions related to the territory and production methods, but also to sales and distribution systems. In the recent years, there has been an increasing awareness on the side of wine producers. They, in order to face the increasing global international competition, have favored more and more the inclusion of production criteria aimed in particular at obtaining high quality products and the sustainability of processes, factors appreciated by end consumers (Fiore et al., 2017). In particular, in terms of marketing strategies, companies must adopt effective communication strategies to inform end-customers about the uniqueness of each bottle and its added value, in order to create an unconditional relationship of trust with the customer, both intermediate or final. In fact, there is an increasing tendency for consumers to seek information on the products they want to buy, and almost all of them are also prepared to incur higher costs, if this means achieving transparency in the production processes and guaranteed quality (Fiore et al., 2019; Contò et al, 2016; Fiore et al, 2016).

The Blockchain solutions can certainly ensure the traceability, transaction history, provenience and quality standards of each bottle in a safe and immutable way. In addition, the importance of introducing BCT into the wine supply chain derives from the wine classification system on EU and national level. In fact, there are two main categories of wines: with designation of origin (PGI and PDO) and wines without this denomination (varietal wines). The country produces 295 recognized quality agrifood products. The difference is between wine products that maintain a close correlation with the cultivation territory and that have to follow a regulated winemaking procedures, and wines not linked to determinate areas and production processes.

In addition, adopting BCT can affect not only the traceability of the entire production process, but in particular can result in (Valmori, 2018):

- consumer's feedback by means of the use of simple apps;
- customizing reading system for customers and launching strong commercial message;
- reliability of information that, not being centralized, is globally available, thus allowing to protect the image of each winery that can, therefore, protect its product from fakes on the market (fight against counterfeiting);
- automated mechanisms that allow to eliminate intermediaries, reduce waste and increase production efficiency.

3.3.4. THE NEEDS FOR BLOCKCHAIN TECHNOLOGY

Since 2000, combat malnutrition has become a global concern and one of the priorities worldwide (under SDG 2 - Sustainable Development Goals). However, it is still important issue. There is a high ratio of illness and death because of taking contaminated products (WHO 2020). Besides, taking care on the population health is costly. It hits to country's economy and environment in terms of wasted resources and their impact on the environment (Scharff 2015). Increasing importance is given to food safety and integrity that ensure handling, preparing and storing food in ways that prevent foodborne illnesses, as well as the fairness and authenticity of food in the value chains both materially and digitally. It is crucial for the global economic market and social well-being to have the food industry developing over time, where innovations define and create these improvements for the industry.

Besides, globalization has dramatically affected on how the people and companies interact with each other and do their businesses. Counterfeiting activities and fake products are growing in open market (Ting et al., 2015). This problem puts every day a strain on, not only the relationship of trust between business and consumer, but all the relationships that make up the supply chain. A numerous transparency and efficiency issues in agricultural supply chains ultimately put farmers and consumers at a disadvantage. Despite the fact that agrifood supply chains are already digitalized (cloud computing, artificial intelligence, internet of things), there are a lot of remarkable inefficiencies in the farming operations, distribution and selling. Globally, the cost of food fraud is US$40 billion every year (PWC, 2017), the operational costs of supply chains are more than half of the total cost and 7% of the world trade costs are only the documentations (Niforos, 2017). For instance, in June of 2015, after central food laboratory of Kolkata (India) found illegal level of lead in Maggi products, the company had to recall over 38,000 tons of noodles from the market spending over $70 million with lost sales of over $277 million (Jayakrishnan, 2018). The company's market share reduced from 80% to 60%; In 2013, in Europe was the "horse meat scandal" when the product advertised as prepared from beef meat contained undeclared horse meat (Anandh, 2013); and many other examples.

Therefore, traceability becomes the crucial factor in agrifood supply chain, in terms of the ability to trace and follow the history of final product in the supply chain, and possessing necessary information on all stages of production process, warehousing, distribution and trade (Aung & Chang, 2014).

Additionally, consumers demand desired products in a shorter notice. Therefore, the companies need to meet consumers' needs, to perform efficiently and at the same time keep competitiveness and profit.

The innovations need to play a crucial part in the overall processes of food quality and human health improvement, nature protection, and biodiversity safety. Since there is increased problem of information asymmetry and miscommunication among stakeholders caused by longer supply chains (Barratt, 2004), it is crucial to note that, the informational transparency of these processes is required in order to ensure trustworthiness of the products, as well as the effectiveness of all the elements that play part in the process (Hua et. al, 2018). Consequently, the low transparency state and not stably trustworthiness of the agricultural chains systems, poses a severe threat to safety, food quality and sustainability at times (Guo et. al, 2018; Saberi et. al, 2019).

The elements having the highest impact how the system works are strongly related to the information - data, its analysis, its exchange between actors, and in general, its availability in time as well as reliability. Agricultural data contains all kinds of information such as industrial data, storage, transportation, customer behaviors, etc. This data with emerged technologies can change the way companies do the businesses (Chen et al., 2019; You, 2019; Cayirci & Rong, 2018). By using resources in a more efficient manner, it has become a foundation for new business models that create new similar opportunities in making industries more transparent, time effective, traceable, trustful and sustainable.

3.3.5. THE BENEFITS OF BLOCKCHAIN TECHNOLOGY

The blockchain technology can be of utmost importance and could potentially offer permanence of records and facilitation of shared data between diverse actors in food supply chain. Digitalization of the industries has already built new models of relationship between actors of supply chains. In this regard, blockchain is an emerging technology and it is already transforming the ways, stakeholders interact with each other (Queiroz & Wamba, 2019).

Blockchain technology can benefit all actors, by minimizing the food contamination risks, and giving them the ability to know accurately the origin of the products (Yoo & Won, 2018). Indeed, Blockchain technology through decentralization, trustworthiness and collective maintenance ensures a reliable register of well-systemized information (Karikari et al., 2019). It creates accurate fixed data that is locked in time, for all needs and purposes (Lyons & Kahn, 2018). Blockchain technology provides a transformative information and communications, and has the potential to organize the dynamic structure of the data. Moreover, its highly resilient architecture and distributed nature make it an effective platform to deliver more accurate, and appropriate data sets for more productive analysis on a real time basis (Niforos-IFC, 2017). When the transaction occurs across supply chain, all network members get informed instantly and they do not need to wait for relevant documentations or actual actions to arrive in a traditional way. The potential blockchain technologies hold is vast, as they would be able to shift the paradigm and offer a transparent and trustworthy food chain processes, to simplify tracking and tracing the products a recall process if necessary within the food integrity standards.

A recall progress in BCT, that means to have the ability of tracing product ownership, also helps to define if along supply chain, there is passed and used the correct information about product. Before purchasing a product, consumers can be able to verify all the data and consult the certified documentation: not only the origin and provenance, but also the information about transportation conditions - if the frozen food was transported safely at the right temperature, for instance. Theoretically, those who have the access to the network, can track and trace all the relevant information regarding the product. That makes easier for manufacturers, on the one hand, to identify the weak points or causality of faulty; for regulators, on the other hand, to verify if the product meets the standards. Consequently, BCT is recognized as a significant tool to solve the problems related to faulty, fraud and adulteration (Ge et al., 2017). It is a digital distributed ledger that providing immutable permanent transactions and distributed data access, ensures opportunity to record, track, and monitor the assets in a reliable way (Niforos-IFC, 2017).

Blockchain technology makes it easier to trace contaminated products to their source quickly, allowing faulty items to be removed from stores to minimize both illness and financial losses. Blockchain is a digitally ledger containing a reliable and trustworthy information on the origin and provenance of food products. It improves the food standards through transparency and detailed information recorded in the system. This information includes the data about quality (freshness, safety, geographic indications), safety (health, risk management) and sustainability (organic, Fairtrade) of products (Tripoli & Schmidhuber, 2018). Due to the high efficiency potential that comes with the blockchain technology, the food industry workers are able to easily determine products that should be removed from shelves in a matter of minutes instead of the days, it would traditionally require for the same task. Thus, the economic advantage in addition to lower health risks for the customers and higher quality food presentation in stores. Therefore, BCT enables businesses and regulators to trace and pinpoint contaminated or fraudulent products quicker and less wastefully.

Last but not least, from the microeconomic point of view, innovations play an outstanding role for suppliers' success in this field. Consequently, according to the academic data reviewed above, the implementation of software innovations regarding consumer preferences and demands, are crucial and can assist in trustworthiness and transparency of food value chain processes. This could mean higher competitiveness on the market for the firms that have adopted the innovative software approach, while it would mean trustworthy and good quality end products for the customers.

3.3.6. THE CHALLENGES OF BLOCKCHAIN APPLICATION IN SUPPLY CHAINS

From different prospective, some of the benefits can become the limitations for application of Blockchain technology and may lead to unwanted consequences. The main technical limitations and open issues regarding Blockchain application described by Drescher (2017), Hughes *et al*. (2019), Casino *et al*. (2019) can be summerized as follows:

Lack of privacy - On the one hand, there is a transparency – the crucial element for BCT to clarify ownership or verify transaction and without it BCT could not meet its purpose. On the other hand, there is a privacy problem. Since every single transaction, every detail of the information about the product and actions of involved parties should be registered and stored on the distributed ledger. This may cause unwillingness to adopt BCT;

The security model - User identification, user and transaction authorization are based on the cryptography that uses public and private keys. Even though this kind of cryptography is considered as one of the strongest method, still, once the private key is given to another person voluntary or by robbery, there is no other method to protect security. Additionally, it is not secured from quantum attack and for future the quantum-safe blockchain platform will be needed. Moreover, if the key of wallet is lost or forgotten, rises the problem of using owned coins.

Limited scalability - Blockchain ensures possibility for every node to add new transaction data and simultaneously to protect the history of transactions. It requires the complex structure of the system. Indeed, hush function is needed to be calculated for each block that results low processing speed and subsequently limited scalability. Moreover, when the BCT grows (for Bitcoin example, 1 additional block in every 10 min results 1MB growth) nodes need more resources. It reduces the capacity of the system. Rises the synchronization difficulty for new nodes as well;

High costs – Computing the hush function is not only time consuming but expensive in terms of electricity and money as well, considering the difficulty of hush function. This limitation is linked to the issue of *sustainability* of BCT as well;

Hidden centrality – It is said that Blockchain is fully decentralized and each node has the same rights in the network. Still, there is a huge disparity in terms of hardware capability. So, the ones who have the powerful hardware, can calculate the hush value faster than others can. In such cases, the remaining group may act with conspiracy and the hidden centrality may take place. It will result violation of integrity. Indeed, the main problem in blockchains is getting and preserving integrity in a purely distributed peer-to-peer system made of an undetermined number of peers with unknown reliability and trustworthiness;

Lack of flexibility – Blockchain has a complex structure, which consists of number of pre-defined rules such as Blockchain algorithm or cryptographic method. These make Blockchain inflexible to changes;

Attacks – Peer to Peer (P2P) networks are rarely resistant to cyber threats since it is based on the trust between participants of the network and communication. The list of different kind of attacks is increasing over time as the mitigation ways for each one. Based mostly on the researches of Reyna *et al*. (2018), Vokerla *et al*. (2019) and Karame *et al*. (2012) they can be characterized as follows:

- *Double-spend attack* - it means to spend the same coin twice. It is a particular issue found in distributed peer-to-peer systems em (the term derives from the metaphor of counterfeiting money), a violation of the integrity of distributed peer-to-peer systems which arises when a digital asset's ownership can be claimed by more than one subject, being only one subject the legal owner. For correctly managing the single ownership of assets, it is necessary to uniquely describe ownership, protect it from unauthorized access, store ownership transfer's data and distribute them in an untrustworthy environment, leading to a system of distributed ledgers which must eventually agree on the "real" unique official version. When the fast payment has to be done, the transaction confirmation related problem rises. Thus, for the example of Bitcoin, for the transaction containing block the depth of 5-6 level is necessary in order to confirm this transaction. It takes from 21 to 487 minutes[1]. That's a big number for fast payments and meanwhile the risk of double-spend attacks is growing.
- *51% attack* – BCT often faces the challenge of critical size. While discussing the abilities of Blockchain technology, it is assumed that the majority of the nodes are honest. Thus, it is crucially important to reach the number of nodes, which will be difficult to be affected by 51% attack.

[1] https://www.blockchain.com/charts/avg-confirmation-time

- *Race attack* – it appears when the maleficent node sends transaction to the merchant directly and this last one accepts for fast payment. Meanwhile the conflicting transaction of coin spending to himself/herself is sent for the rest of nodes. Presumably, the last transaction will be accepted and added to blockchain. It is possible to reduce the risk of race attack by blocking direct contact by merchants but it is impossible to eliminate the risk at all.
- *Finney attack* – it is another kind of Double-spend attack. It occurs when attacker pre-mines the transaction and spend the same coin before releasing the block to negate that transaction.
- *Block Withholding Attack* – it is built on Finney and Race attacks. In this case, maleficent node creates the valid block but does not transmit. Meanwhile, publishes the transaction with the content of payment. After the merchant accepts this transaction, attacker transmits the block created previously. More likely to be accepted the block by the network. As a result, transaction accepted by merchant will be eliminated.
- *Eclipse attack* – in this case, the client is connected solely with the nodes that are controlled by attacker. Recently, Alangot *et al*. (2020) proposed a protocol that is able to detect the attack with high probability as authors insist.
- *Denial of Service (DoS) attack* – this cyber-attack implies making temporarily unavailable the machine or network for pre-defined set of nodes. Distributed DoS (DDoS) eliminates the possibility to fight against attack by blocking one source. Still, according to Akamai (2016), Kona Site Defender reduces the risk by absorbing DDoS traffic.
- *Sybil attack* – in this case attacker creates number of fake peers that can influence on the performance of the system. It can cause 51% attack as well. For protecting

blockchain from this kind of attack the PoW is used in which the ability for creating the block should be proportional. Thus, node should own the computer power for calculating. It complicates and makes expensive the work for an attacker. Recently, Biryukov and Feher (2020) proposed a new protocol that leverages node reputation in order to enhance Sybil-resistance of consensus protocols.

- *Routing attack* – it means attacking via the internet routing infrastructure itself. This attack is too hard to conclude as it requires intercepting a lot of connections (Apostolaki *et al.*, 2017). However, authors suggest short- and long-term measures for avoiding Routing attacks.
- Besides the above discussed attacks, to name a few, there are more variations such as *Vector76 attack*, *Blockchain reorganization attack*, *Brute-Force attack*, *Bribery attack*, *Tampering*, *Botnets* etc. that can affect Blockchain networks.

Besides, the *legal* aspects have to be discussed. It is not guaranteed that the transaction performed in the Blockchain will be legally accepted. Additionally, adopting blockchain technology requires fundamental changes in the system – the ways parties interact with each other or the method transactions are registered. It may require the change of whole business model as well. This poses the problem of technological barriers. These open questions and lack of *users' knowledge of technology* causes unwillingness to use Blockchain.

Another challenge for Blockchain adoption is the overall circumstances in the industry. In order to reach its maximum benefits, BCT needs the whole industry, banking system, governmental structures to use this technology. Moreover, may occur the problem of *interoperability* between different BCTs. Besides, application of the most of novelties requires beginning investment and consists the risk before trying (Hughes *et al*., 2019).

While application BCT, the question of *suitability* may arise. Not every business need this technology. If only one writer is supposed to be, BCT does not give any additional benefit to that business by providing distributed database or if there is no need to store transactions history, same, BCT does not benefit business with immutable ledger (Casino *et al.*, 2019). Consequently, the field suitability should be validated before adopting the technology.

3.3.7. FUTURE PROSPECTIVE OF BLOCKCHAIN TECHNOLOGY

The limitations discussed in the paragraph above can be overcome with time and work on it – changing the structure and algorithm of Blockchain, give more education to users, write down new/adapted regulations, etc.

Despite the attacks described above, the concept of BCT is strongly associated with safety and security. According to Lacity (2018), the blockchain itself is resilient enough towards attacks on the network, to continue operating normally even in a case of attacked nodes with a high percentage.

The main tool for verifying ownership (so, avoiding double-spend attack) is given by transactions, which provide the following information: the identifiers of the accounts who transfer and receive ownership; the (amount of the) assets to be transferred; the time at which the transaction occurs; a system's reward for executing the transaction; a proof that the originating account agrees with the transfer of his/her ownership. The proof of how subjects acquired and handed off ownership is given by the complete history of transaction data; so, any transaction not being part of that history cannot be trusted on and does not represent any ownership transfer. For obtaining identical results when aggregating transactions, it is mandatory to preserve the order in which transaction data are added to the history (figure 7). In order to maintain integrity, only those transaction being formally/semantically correct and authorized get added to the blockchain.

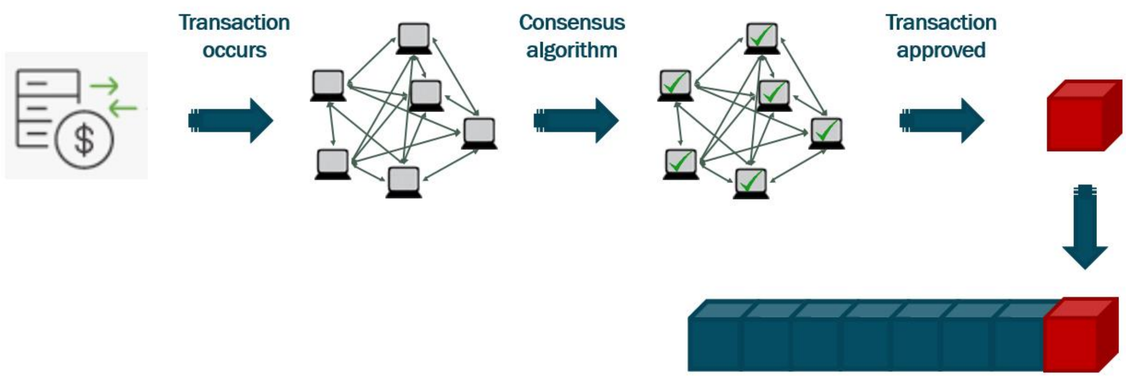


Figure 7. Adding transaction to the Blockchain (Source: own elaboration)

In order to combat with privacy issue, the tighter access control can be developed, data in the BCT can be encrypted or stored outside the chain (so called off-chain solution). In this case, the data related to technical operations such as timestamp or proofs of integrity, can be remained on the blockchain platform, while the sensitive data like personal or competitive information will be stored in another database with restricted access (Lazarovich, 2015). They can be linked to each other and the hash function can be used in order to assure immutability of this data (Houlding, 2017). This is also the solution when system deals with Big Data and storing that huge amount of data in the ledger generates the problem of memory, time or money related issues for the next transactions. Encrypting the transactions or splitting the information and distribution through the network can be another solution for solving the privacy issues (Valenta & Rowan, 2015; Kosba et al., 2016). This will limit the nodes to obtain all the data.

The establishment of unique Blockchain standards can be helpful for the problem of interoperability. So, all the players will have the similar standards and crossing their Blockchain systems will not be the problem anymore.

Involvement of the governments, policymakers and investors is essential for elaborating the common standards, rules, policies and for future development of this technology[2][3].

As for the issue of the technological barriers and legal aspects, these are the essential components of all stages of development.

Consequently, the better study of this technology, refinement of its certain functions and simultaneously consideration of its capabilities in the regulations may be a way to overcome described limitations. Thus, with the time and working on it all above-mentioned limitations can be conquered – changing the structure and algorithm of Blockchain, giving more education to users, writing down new/adapted regulations, establishing the unique standard, etc.

[2] https://www.r3.com/
[3] https://www.iiconsortium.org/

4. MODELS ELABORATED IN THE LINE OF THEORETICAL BACKGROUND

4.1. MODEL 1: SUCCESSFUL ECOSYSTEM FOR AGRICULTURE SECTOR

The data are becoming the capital of agricultural suppliers. They help to optimize offers and develop tailor-made products and services (Tripathy *et al.*, 2014). By sharing the data, knowledge and experience as well, additionally with targeted policies and relevant investment in the field, successful and sustainable agriculture sector will be developed (Rickard, 2015; Barakabitze *et al.*, 2015). So, for successful agriculture, it is essential that the relationship among actors be maintained, as agriculture is complex, individual processes depend on each other and a good return is associated with perfectly organized and efficient work steps (Tesdell, 2016; de Olde *et al.*, 2017; Baker *et al.*, 2016). Therefore, the future-oriented aids, described in the previous sections, require a legal basis and relevant investment too (Barnes et al., 2019; Koutsos & Menexes, 2019; Yigezu et al., 2018). So, a farm success is seen at the center of a triangle between technology, collaboration and knowledge, strengthened by regulations and funds (figure 8). Here, the government have a remarkable potential to foster innovations by making targeted policies and investments. On the other hand, government can play an important role to promote the technological advances and increase awareness of its importance in the country as a whole (FuJun *et al.*, 2018; Seeman *et al.*, 2007). In this way it is more prospective that more bodies will be involved in the process of sustainable development and will make investments for financial or environmental interests.

Regarding to these necessities, Zhao *et al.* (2014) offer the model of innovation collaborations (figure 8). The model shows collaboration scheme where government regulates the policies and makes investment in research and private firms. These two are exchanging the knowledge and funds. At the end, the system results high innovative outputs instead of just cost leadership position.

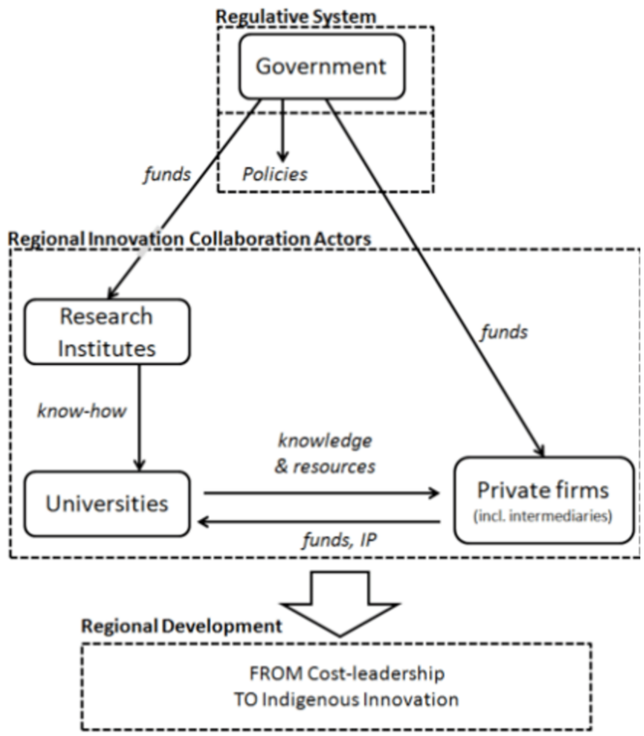


Figure 8. Conceptual model of regional innovation collaborations (Source: Zhao *et al.*, 2014).

Based on the idea of this model, reconstructed the "successful ecosystem for agriculture sector" model (figure 9) has been developed, giving remarkable importance to the adoption of information technologies. Similarly to the model of Zhao, the ecosystem is described where government plays a crucial role by creating targeted policies, funding research activities, producer companies of information technologies and their adopter farms, so, making contribution in the development of emerging technologies. Research institutes and universities, on the other hand, provide knowledge that together with technologies and thanks to the collaboration of the actors and information/knowledge sharing, is a basis of farmers' success.

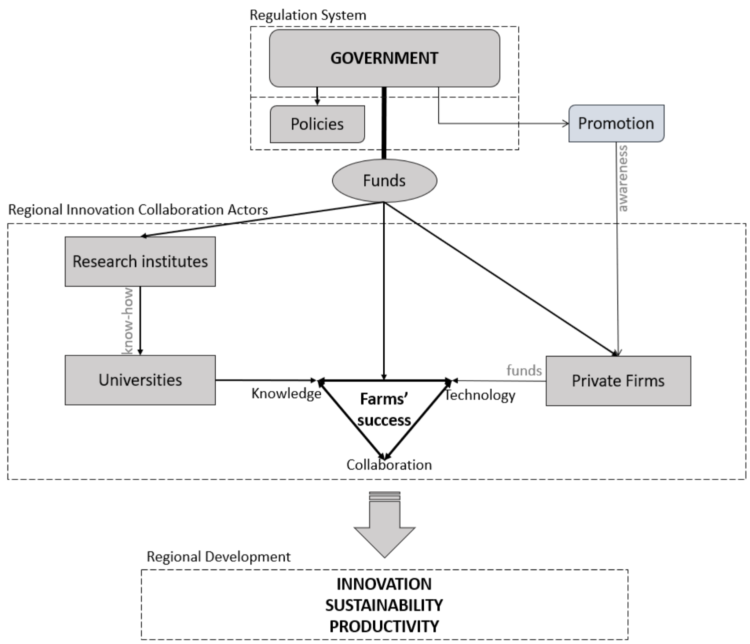


Figure 9. model of successful ecosystem for agriculture sector (Source: our processing)

In Addition of Zhao's (2014) thoughts, this model considers that the <u>promotion</u> of emerging technologies, their adoption in agricultural practices and their role regarding to sustainability issues can play remarkable role to increase awareness in profitability of their adoption in the sense of environmental and financial benefits (Mah & Yeo, 2014; Dong, 2007). This may cause increased interest of farms and private companies as investors.

The ecosystem that functions as described in the model, if all actors and stakeholders collaborate with each other, will result high innovation, productivity and sustainability in agricultural processes. Thus, instead of limiting with cost-leadership strategy, the farms will have an opportunity to move the focus towards indigenous innovations as it happened in the case of Zhao *et al.* (2014).

4.2. MODEL 2: SUPPLY CHAIN TRACKING SYSTEM BY BLOCKCHAIN TECHNOLOGY

Carrying out a comparative analysis of supply chain efficiency ex ante and ex post the IT technology introduction, La Sala et al. (2017c) argue the importance of efficient use and sharing of information and introduce the scheme of the IT system adopted (figure 10). The scheme shows that the interaction between different stakeholders (supplier companies, farmers, processing companies, distribution company, retailer stores) of the industry is much more simplified using advanced technologies.

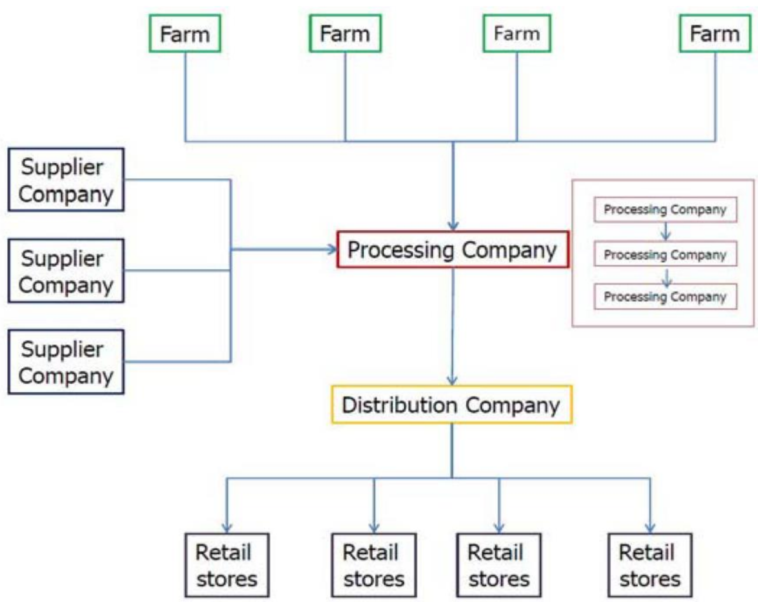


Figure 10. Scheme of the IT system adopted

Started from this scheme, the model is proposed where authenticity of all information is proved by Blockchain technology. It is supposed, that all supplier companies and farmers use Blockchain for registering the transactions. So, all the activities carried out by each stakeholder are registered on the blockchain: after the activity has been done, the information is declared, then proved and protected by hush. Thus, the information provided by supplier companies and farmers are trustful as falsification is almost impossible. Subsequently, processing companies get trustworthy information about input such as the geographical indications, weather conditions, soil management, seeds' nutrients etc. Then similarly they register techniques and technologies of processing and add new block to a chain (or make new Genesis block for specific product as it is shown on the figure 11). Next, distribution company describes the transportation conditions, safety, temperature, vehicle, delivery and adds new block. After that, retail stores register some other information like delivery details, storage, safety and additional block is constructed. Finally, as consumers as regulatory authorities can track all steps passed by specific product simply by scanning its QR code.

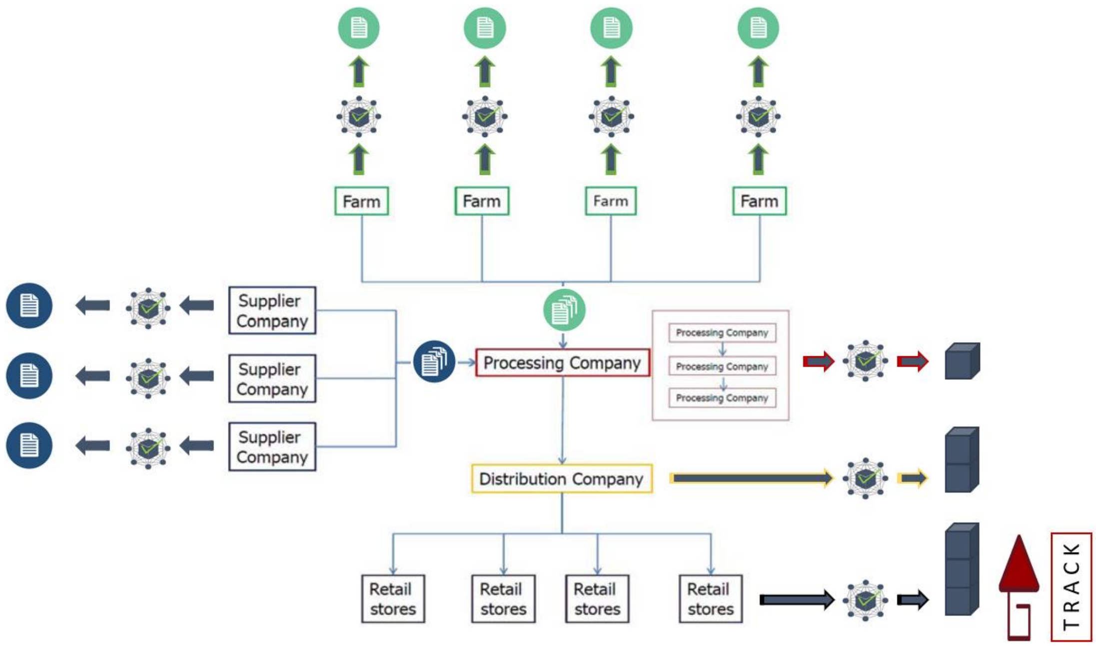


Figure 11. Supply chain tracking system by Blockchain technology

In order to focalize on the wine supply chain and make more visible and understandable the concept in the practice how the blockchain technology ensures the traceability and transparency of the supply chain, the scheme of tracking and tracing back the wine bottle till row materials, is provided (figure 12). The information about grape growing comes registered on the blockchain, the farmer registers every detail about the treatments during cultivation and harvest phases. Once the information is saved in the Blockchain, it's almost impossible to change. Then the data of transformation in bulk wine phase comes registered and another block is added. After that comes the vinification analysis, production process, distribution and retail. Finally, when the consumer finds the product in the shop, simply by scanning it QR code he/she will be able to see all this information about transportation details for instance or sanitation certifications and what is the most important, to trust it.

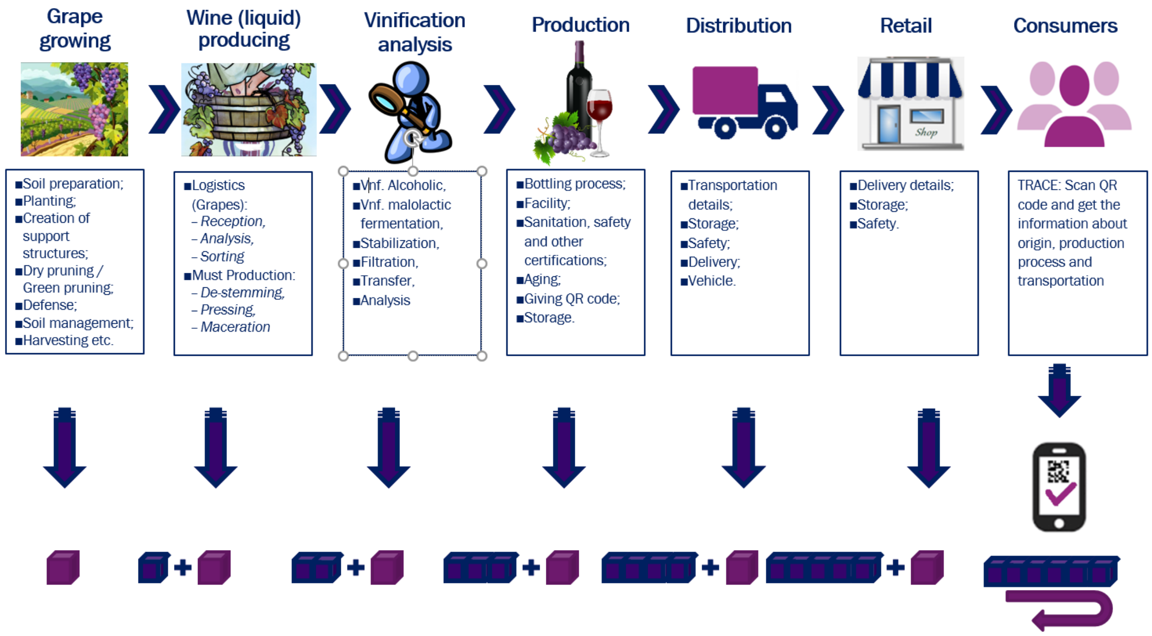


Figure 12. The scheme of tracking and tracing back the wine bottle till row materials (Source: own elaboration)

4.3. THE MODEL (3) AND SIMULATION "WINE ROAD"

Based on the literature review and on the study of ABMs and the programme GAMA, the model and simulation of wine supply chain has been designed. The simple wine supply chain is described. It demonstrates the sequence of the processes and information exchange along supply chain on the example of one producer company for simplicity. The case can be generalized and applicate on the whole industry since the architecture is similar for every producer.

The objects of the model "Wine Roads" are as follows:

Vineyards – On the initial picture of the model (figure 13), plantations of grape-bearing vines are shown reflecting with the grape image. Every time when the program lunches, the grapes are allocated randomly. So, the experiments are every time different from each other.

Grape is the fundamental material for wine and its quality determines the value of the final product. Therefore, the geographical and climate conditions as well as how they are treated is crucially important.

Farmers – Farmers/grape growers are responsible for the treatment of the grape, as well as for harvest and delivery. Besides, they should record all related information.

During coding the simulation, the farmer who collects low-quality grape is identified in the beginning and it is highlighted with the orange color, differently from other green ones (figure 13). On the map, each farmer "owns" the territory where they are allocated. So, the grapes go to the nearest farm, the algorithm computes and chooses the shortest paths. Because they are allocated randomly, every time the simulation runs, different amount of low and high-quality grapes are collected by the farmers.

Processor – All the collected grapes go to the processor company. In order to keep the model as simple as possible, it is considered that the processor company produces the bulk wine and bottles it as well. So, it is responsible for receiving the grapes, production of bulk wine, storage, processing, analyzing, bottling, packing and shipping of final product. By the scenario of the simulation, for this company it is not clear in the beginning which grape has high or low quality. It produces the wine with "first in first out" principle. So, it consumes firstly the grape that received first.

Processor company should record the information such as receiving the grape, their variety, identity of suppliers (farmers/grape growers) as well as the details of transformation from grape to wine including of making the juice, the results of chemical analysis, bottling, packaging, as well as internal business processes.

Distributor – Distributor is responsible for receiving final products, to store, to manage and to pack off them. It may need re-packing as well if required. Similarly to other actors, distributor records all the information.

Wholesaler – Wholesaler receives the bulk quantity of final product from distributor. It collects the goods, stores and distributes to retail shops. It gets the financial risk as well and records the data related to the goods.

Retailer – Retailer buys goods from wholesaler, gets the pallets and cartons, then sells to consumers by units. It has similar responsibilities as distributor. In order to be maintained the whole "road" of the final product and simplicity of tracking in case of unsatisfying good, it is crucially important to record all the information by all actors.

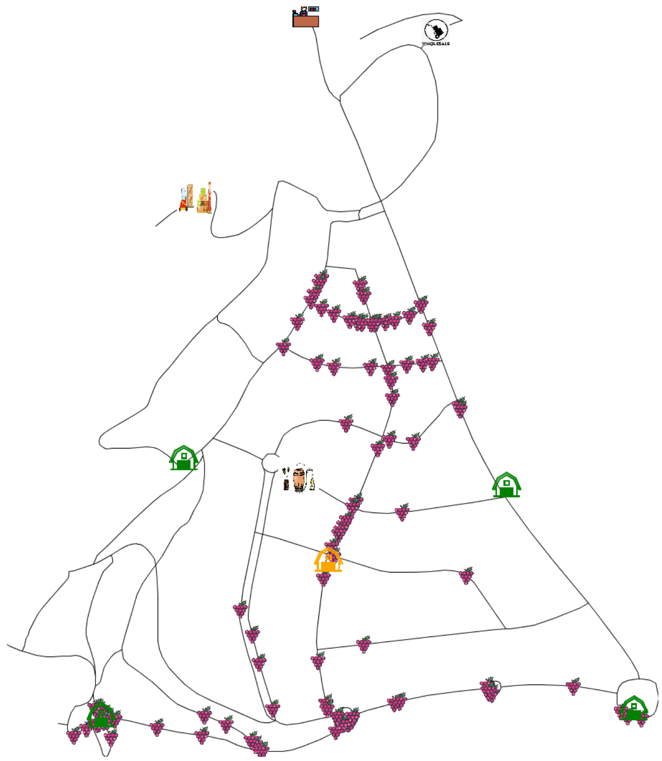


Figure 13: The model “Wine Roads”: initial condition (Source: own elaboration through simulation)

The idea is that in the case of Blockchain-based supply chain, all the information from each actor should be recorded (or linked) on the distributed ledger. Differently to the traditional supply chain, when the supplier is identified, the containers of material and of the bulk wine should be codified, the final product should have the unique identity number (QR code); the pallets and cartons should be codified as well and they should be linked to each other in a way that the information line is not interrupted for tracking back the product.

The simulation examines traditional and blockchain-based supply chains. The architecture is same for each model:

> Grapes are allocated randomly on the map (figure 13).

> Farmers collect the grape and provide the processor with it (figure 15a).

> The processor company produces the final product. The wine quality chart on the figure 14 demonstrates in details the information about production process. With the red line, the availability of the grapes is shown. When the processor company starts to produce the wine, quantity of available grapes decreases and increases the quantity of produced wines. With the orange line the low-quality wine is expressed and with the green line the high quality wine. The gray area shows the accumulative quantity of all produced wines.

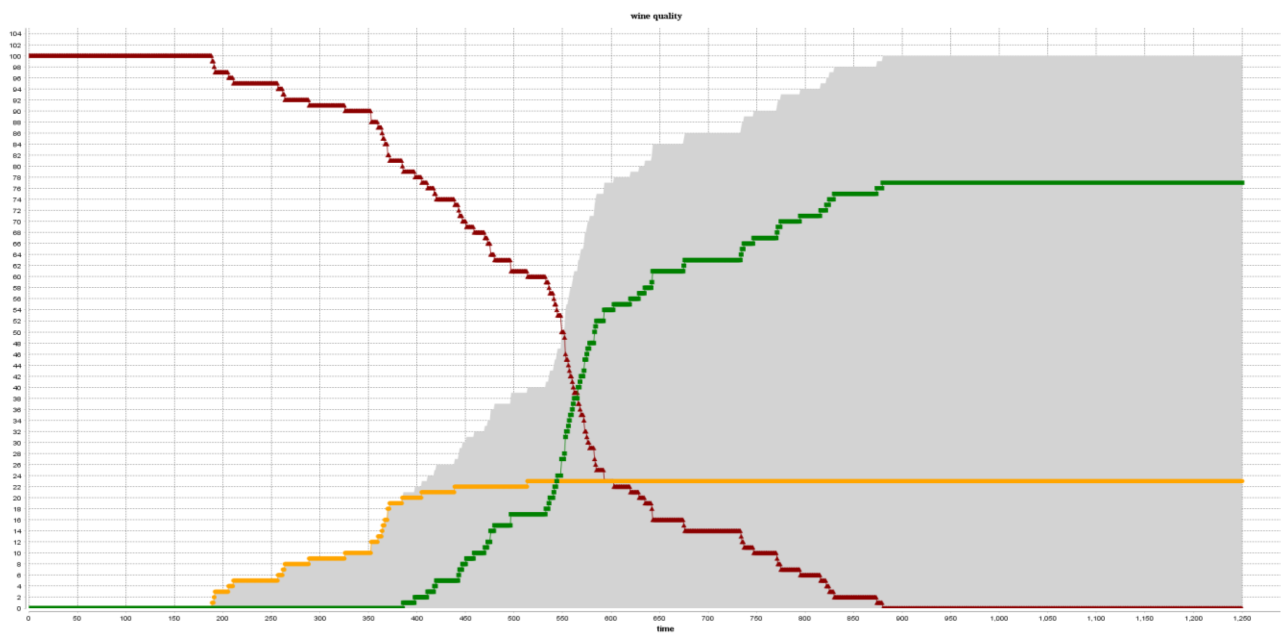
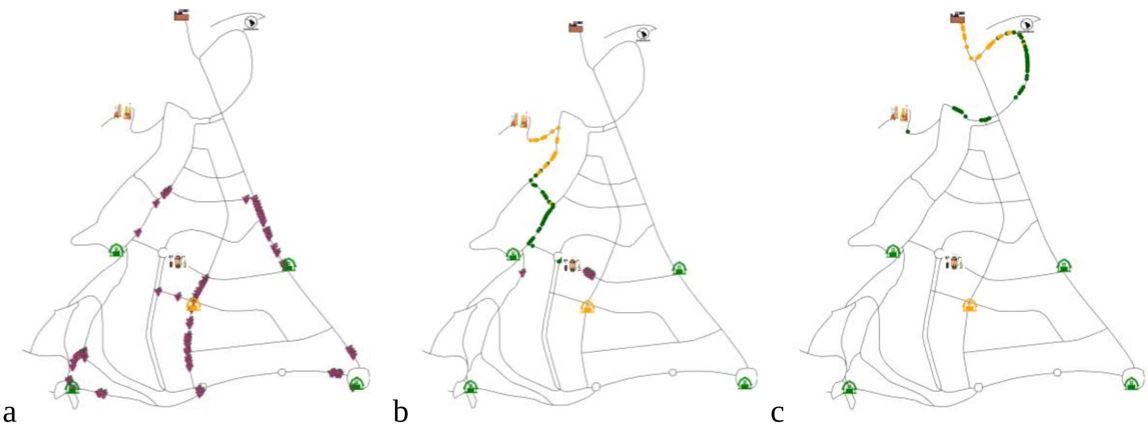


Figure 14. The wine quality chart (Source: own elaboration through simulation)

Processor company does not know which grape has high or low quality. On the figure 15b, the low quality wine is shown with the orange color circles, while the high quality with the green color circles. Processor company starts producing the wine with the first received grapes (in the model, one symbol of the grape represents the material for producing one bottle of wine). Then it dispatches to distributor.

> Distributor sells them to wholesaler and from wholesaler buys retailer (figure 15c).



a b c

Figure 15: The path from vineyard to retailer (Source: own elaboration through simulation)

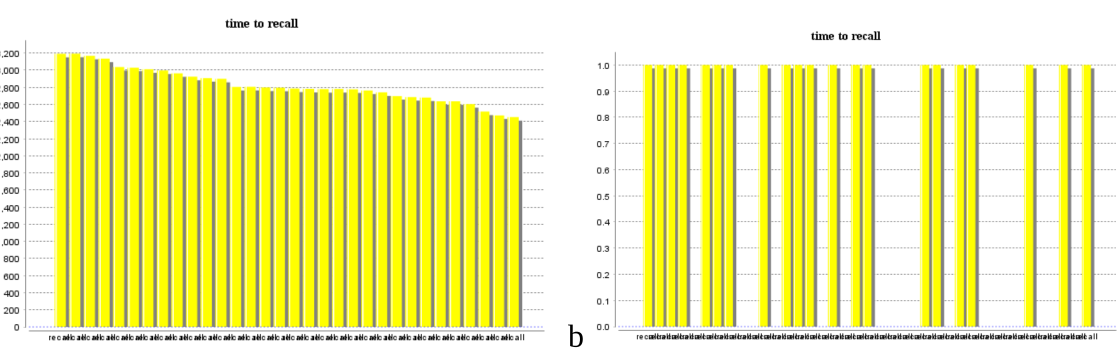
In the event that the low-quality wine is founded by consumer, retailer returns back the unsatisfying product. In order to avoid returning back all the wine supplied by this processor company, the provenience of the used grape should be investigated. So, the product high-quality products will not be re-called from the market. The figure 16 shows the passes from retailer to producer trough wholesaler and distributor, and then processor company finds the farmer who had provided with the low-quality grape.

Figure 16: Tracking back the low-quality wine (Source: own elaboration through simulation)

In the simulation, there are two scenarios of the supply chain – one is the traditional and second blockchain-based. The proportion of the time to re-call the low quality wine for each item in blockchain-based and traditional supply chains is about 1:300 000 calculated based on the work of Hackett R. (2017).

On the figure 17, there are shown the results for both simulations. The charts express the time units needed to identify and to re-call the low-quality products from retail shop.

a



b

Figure 17: Time to re-call: a – traditional supply chain; b – blockchain-based supply chain (Source: own elaboration through simulation)

It is evident, that the time for re-call is considerably low in the case of Blobkhain-based supply chains. Considering the literature (Kshetri & Loukoianova, 2019; Pouliot & Sumner, 2013), it should be caused because of complexity of the traditional ways of tracing the products and simplicity that offers BCT for this issue. In the traditional scenario, traceability is limited since the data is isolated on the organizational level. What the Blockchain does, is that it gathers the information in the shared ledger that gives the opportunity to track and trace the product over multiple tiers (Westerkamp et al., 2020). As a result, in the case of re-call, BCT eliminates uncertainty, it is clear which particular product is damaged or counterfeited, consequently, targeted actions can be performed in order to avoid large-scale destructive outcomes.

As for the re-call case in traditional supply chain, there is necessity of human involvement in tracing the products (FAO, 2001). Ellie Collier (2019) publishes the procedures for product re-call. It includes 10 steps: (1) Decide if the Food Needs to be Recalled; (2) Create a Food Recall Team; (3) Gather Information on the Food Safety Incident; (4) Notify the Relevant Authorities; (5) Set Apart Affected Products in your Control; (6) Notify Consumers; (7) Monitor Progress; (8) Control Recalled Products; (9) Dispose of Recalled Products; (10) Fix the Cause of the Recall. The most time-consuming step is the information gathering. It intends to gain different kind of information, including (a) production records, (b) sales records, (c) employees, (d) suppliers, (e) complaints, (f) audit, (g) sample analysis, from various internal and external sources. The information is scattered among different actors, there is no shared database. It is not impossible but it may take weeks or months to determine which particular products, on which phase of supply chain and where have been contaminated (Guo et al., 2018).

If the contaminated or forged product come out on the market, solution lies on timely detecting and preventing of spreading them. If not detected and identified timely hazardous products on the market, it will result raised health problems or even death for the people, higher healthcare costs for governments, increased costs (meaning higher quantity of lost, re-called goods and the cost of re-call) and lost reputation for producers (Kadariya et al., 2014; Scharff, 2012; Kshetri & Loukoianova, 2019; Pouliot & Sumner, 2013).

Thus, case study illustrates how effective blockchain diffusion can be in the wine supply chain in terms of information sharing and time and costs of tracking back the products. The benefits of BCT implementation is agrifood supply chain is obvious. This technology has the ability to register all the data immutably and securely transfer it. Moreover, it reduces the time to accumulate necessary information and provide with it the interested party. Therefore, it simplifies recall process as well and, consequently, minimizes the risk of fraud, illness and related costs.

5. RESULTS AND DISCUSSION

The research has been carried out with the different directions through different methodologies. Therefore, the multiple results have been obtained. However, the literature analysis has been a base and starting point of each methodology.

5.1. LITERATURE

Investigating the relevant literature regarding agrifood supply chains and application of emerging technologies, the following questions can be answered: what are the main challenges of current agrifood supply chains and why the need for emerging technologies has been raised; what are the main benefits that the BCT can bring to agrifood sector; what are the limitations of this technology and how to overcome. The answers on these questions are summarized in the figure 18

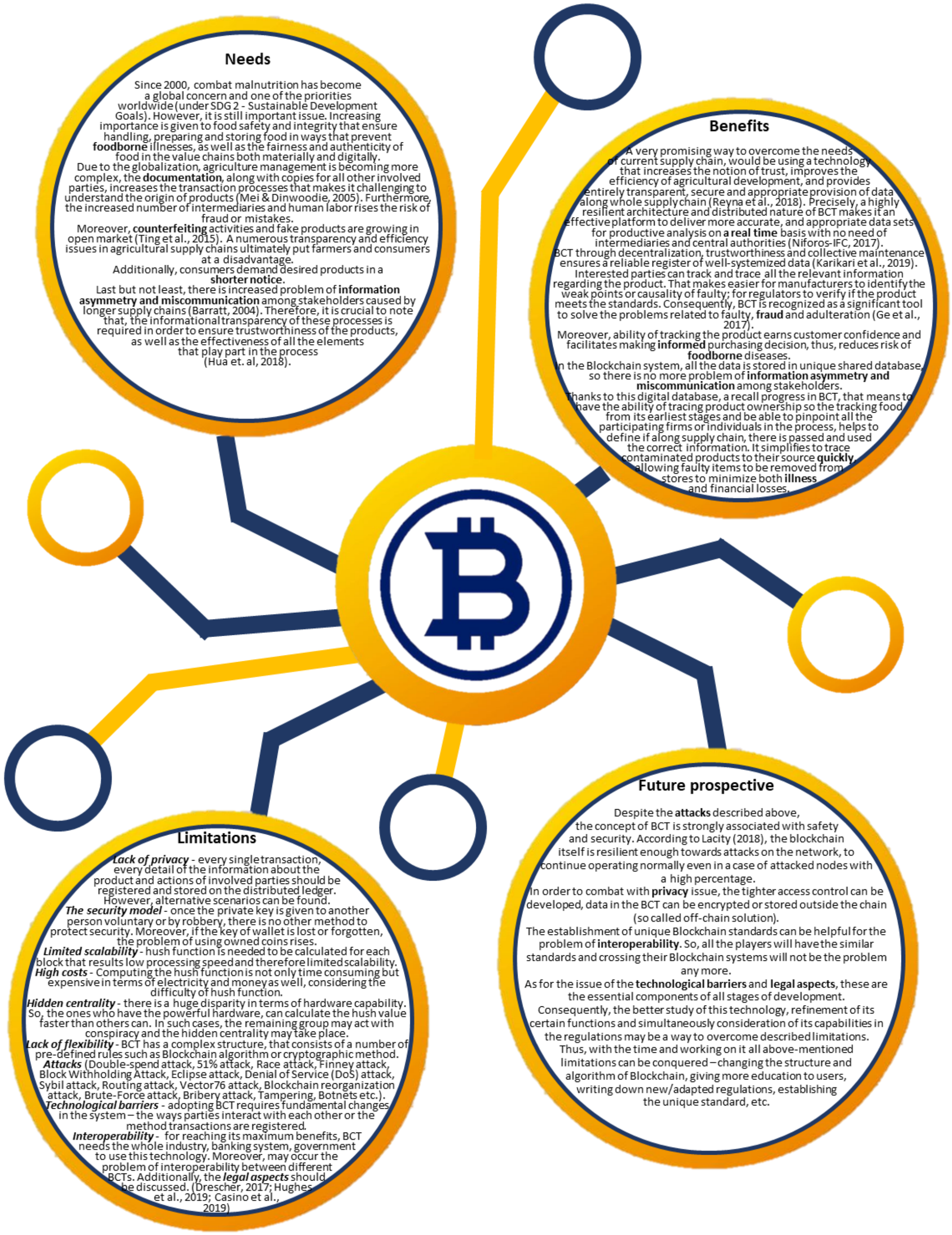


Figure 18. Blockchian integration in agrifood supply chain (Source: own elaboration through simulation)

Subsequently, current agrifood supply chains deal with number of inefficiencies. Despite the high level of digitization in this field, there is still a problem of "paper documents", as well as tracking the product that on the one hand increases the risk of counterfeiting and on the other hand makes difficult to call back falsified or harmful product from market in time. In many cases this causes people to get sick. In addition, there are often problems with access to or reliability of information. On the other hand, the figure demonstrated the capabilities of BCT to eliminate these problems and to modernize the agrifood supply chain. It provides a transparent system that collects, stores and transmits data in a secure way and that is maximally protected from any kind of fraud. At the same time, it accumulates the necessary information and delivers it to the interested person in a short notice. Consequently, it reduces the economic and healthcare costs associated with identifying falsified or harmful products and removing them from sale.

Therefore, the main areas where the Blockchain Technology has a potential to revolutionize the processes can be defined: BCT ensures to achieve improved and sustainable agricultural production by giving an opportunity to society make more informed decisions, and minimize foodborne diseases. Moreover, it reduces the food waste and operational costs as well. These results are discussed in the following subsections.

5.1.1. BIG DATA VALIDATION

Big data has an effective impact on increasing the productivity of agriculture and farming, and even on maintaining a proper level of security and traceability for the products; one of the main issues that will appear with the increase of the use of big data, and the increase of resources that would contribute in adding to this data, will be the validity of the data and which of this data would be proper or qualified to be used in the required big data analysis (Rabah, 2017; Ashutosh, 2012).

The usage of invalid, misinterpreted, or unrelated data while performing the big data analysis can result in less accurate outputs, expectations, or system behavior, which will affect the total productivity of the agricultural system under analysis (Stubbs, 2016).

A very promising way to solve these issues, would be using a technology that increases the notion of trust, improves the efficiency of agriculture sustainability development, and provides entirely transparent, secure and appropriate provision of data from farms, passing by agricultural technology providers, working staff, financial sectors, to the end of chain represented in processing and handling (Reyna et al., 2018). All these requirements can be found in blockchain technology (BCT) (Laurence, 2017), as it provides a transformative Information and Communications, and has the potential to organize the dynamic structure of Big data. Moreover, its highly resilient architecture and distributed nature make it an effective platform to deliver more accurate, and appropriate Big data sets for more productive analysis (Niforos, 2017).

Moreover, blockchain can benefit consumers, by minimizing the food contamination risks, and giving them the ability to know accurately the origin of the products (Yoo & Won, 2018).

5.1.2. REDUCED PAPER-WORK AND TRANSACTION COSTS

In today's constantly transforming world, agriculture management, as almost all other fields, is becoming more complex. Product and material flows are not as easy as before. A more frequent need for intermediaries causes the supply chains to get longer (Mylrea & Gourisetti, 2018). Hence, the documentation, along with copies for all other involved parties, increases the transaction processes which makes it challenging to understand the origin of products (Mei & Dinwoodie, 2005). A numerous transparency and efficiency issues in agricultural supply chains ultimately put farmers and consumers at a disadvantage. So, traceability becomes the crucial factor in agrifood supply chain, in terms of the ability to trace and follow the history of final product in the supply chain, and possessing necessary information on all stages of production process, warehousing, distribution and trade (Aung & Chang, 2014). Consequently, a simpler and a more time efficient system for all these processes in needed. Because the new system would increase the efficiency of production process and would reduce fraud, DLTs (Distributed Ledger Technologies) and particularly BCT (Blockchain technology) have been recognized as a significant tool to solve these problems (Ge, et al., 2017; Casado-Vara et. al, 2019) and reduce the transaction costs as well (Costa, et al., 2012).

Blockchain technology (BCT) can substantially reduce the costs in supply chain and increase the efficiency of the operations especially if there is a need for contracts (Chen et. al, 2018). BCT allows to remove paperwork, create “smart contracts” and have a unique system of records (Accenture, 2018). Smart contracts are a type of computer programs that allow users to create the contract by posting a transaction to the blockchain and by building complex if-then statements; the contracts can self-verify if the conditions meet the agreements done by nodes (Laurence, 2017). The advantage compared to physical contracts, is that smart contracts do not depend on centralized authorities, they do not need to settle or clear the transactions manually that are time consuming, costly and contain high risk of error or fraud (Mohanta et. al, 2018; De Souza et. al, 2018). So, smart contracts provide the real-time performance of the contractual obligations and, at the same time, huge savings in transaction fees and legal costs.

5.1.3. REDUCED FOOD WASTE

Another field that blockchain has a promising effect on is the food waste, especially knowing that one third of the food produced in the world for human consumption (about 1.3 billion metric tons) gets lost or wasted, total value of these products is about 1 trillion dollars that would be sufficient to feed 300 million people (FAO, 2011). On the other hand, according to the United Nations, one in nine people today — or 815 million globally — lack access to the food necessary to lead a healthy lifestyle. A staggering 98% of these, live in developing countries and 75% live in rural areas that depend on agriculture for their livelihood (UN, 2018). Growing population density and lack of resources cause the global hunger issues to worsen overtime which is why many communities across globe attempt to bring positive change in diverse forms.

In addition, Natural Resources Defense Council counted the finances that is needed to remove the unconsumed products from the market and only in America $218 billion dollars per year are spent for production, transportation and removal of unused food (NRDC, 2012).

Additionally, not all the products are wasted because consumers throw them away, but majorly, they are wasted because consumers can't get them on time (Irani et. al, 2018). So, there is a huge problem of inefficient distribution. Through advances in blockchain technology we have an opportunity to incorporate higher accuracy into the system, putting an end to a process that allow viable produce to go to waste (Meng & Qian, 2018). In addition, blockchain's internal algorithms allow for expiration dated to be calculated which plays an important part in ensured longevity of food storage (Nelson, 2018).

So, with enhanced transparency and accountability, a decentralized supply chain can be endorsed and it would have a great impact on global infrastructure, making its systems more accurate (Guo et. al, 2018).

5.1.4. MINIMIZE FOODBORNE DISEASES

All over the world the issue of foodborne diseases is present to different extents. According to World Health Organization (WHO), an estimated 600 million (that is 1/10 of world population) fall ill because of eating contaminated food and 420,000 people die every year (WHO, 2017). Foodborne diseases are extremely costly in economic terms, and environmentally, in terms of wasted resources. The estimates of foodborne diseases in the US alone are roughly US$55 billion annually (Scharff 2015).

Therefore, increasing importance has to be given to food safety and integrity that ensure handling, preparing and storing food in ways that prevent foodborne illnesses, as well as the fairness and authenticity of food in the value chains both materially and digitally. There should digitally be a reliable and trustworthy information on the origin and provenance of food products. It will also improve the food and sustainability standards as well, through transparency and detailed information recorded in the system. Therefore, BCT enables businesses and regulators to trace and pinpoint contaminated or fraudulent products quicker and less wastefully.

Currently, developing the blockchain technology in the food and beverage industry has become more common. For instance, IBM carried out successful pilot project with Walmart how BCT can solve food safety problems and trace contaminated products to their source. The results showed that tracking a package of mangos from the supermarket to the farm where they were grown, took six days, 18 hours and 26 minutes with traditional methods, while with the BCT it took 2.2 seconds to identify the exact origin and the path the fruit followed to the retail shelves (Wass, 2017).

As a result, Blockchain technology makes it easier to trace contaminated products to their source quickly, allowing faulty items to be removed from stores to minimize both illness and financial losses.

5.2. LITERATURE AND MODEL 1

Nowadays, the main trend that can be outlined is the increasing demand for safe and quality products allied to the environmental impact of agri-food sector that is linked to the performance of supply chains. This trend leads to search for trust-based and alternative food networks and to identify visionary leadership with more effective collaborations between key stakeholders in both the public and the private sectors (Blom-Zandstra et al., 2016) aimed at improving production process and contemporary at promoting sustainable impact (Bazzani & Canavari, 2013). Indeed, strengthening of the partnership enhances stakeholders providing them the contractual force and the market power (Cantarelli, 2016; Alho, 2015) resulted by the ability to meet consumers' needs (Bojar & Drelichowski, 2008). Literally, strong network of key actors of agri-food supply and close collaborative relationships between public or private players, provide the industry with the ability to match demand and supply in an effective way. Additionally, stakeholders reach the higher performance and greeter results when acting collaboratively rather than in isolation (Sacchi et al., 2018).

More likely to achieve aforementioned result if trust-based collaborations are promoted by regulations and Local Development Plans (LDPs). Governments can direct all the solutions to the specific circumstances of the local areas and to ensure that the necessity of territory and sector will be met (Kotu et al., 2017). Furthermore, governments play significant role to promote new trends and to encourage the training of labour force regarding to the requirements of modern market. Social capital, in turn, is a crucial factor for economic development (Fischer, 2013; Casieri et al., 2010).

Moreover, in order to be able to keep agricultural operations up to date and as effective as possible, farmers in both upstream and downstream sectors require data regarding agricultural issues, latest market developments and diverse farming methods (Kamilaris *et al.,* 2017). Knowledge became the key strategic element for competitiveness. In the era of information economy, the Information and Communication Technologies (ICTs) combined with data management are powerful tools (Ghosh, 2016; Van & Ryan, 2018). They gain information from the huge amount of data generated by the Precision Agriculture

Technologies (PAT), such as environmental sensors, Unmanned Aerial Vehicles (UAVs), satellite images, etc. and analyse it (Rajeswari *et al.*, 2018). The agricultural working environment has recently been heavily affected by technological advancements, such as the use of electronic systems and data transmission. More precisely, being able to retrieve satellite imagery would allow stakeholders to monitor the territory and to plan how to use the landscape in order to avoid undesired results (FAO, 2015). Because climate change heavily influences agriculture and country operations, easily accessible digital tools get monitor forest cover, land use patterns and data changes over time, have growing potential for wide use. Consequently, the PATs gives the opportunity to gain vast amount of data about agricultural practices, analyse them, share between stakeholders and make strong network of the key actors in agriculture sector. However, it is not easy for all smallholders to adopt of emerging technologies, since they are quite costly and requires high initial investments (Yigezu *et al.*, 2018). Therefore, the financial contribution of public and private sectors become crucially important.

5.3. LITERATURE AND MODEL 2

In the current agrifood market, there is the increasing need to certify the origin and quality of products using a new traceability model capable of setting a quantitative and qualitative model of information shared along the supply chain. In this way, the problems related to food safety would be solved, at the same time ensuring the maximum transparency for final consumers and regulatory authorities. This requirement is even more important in the organic farming sector where the control and certification of all stages of the supply chain become important to guarantee compliance with the certification schemes that the correct agronomic and processing practices related to organic farming are done.

The agriculture sector benefits from digital innovations. However, there are the issues of current agrifood supply chains. They still deal "paper documents". Tracking and tracing the product is still challenging. This reflect in the risk of counterfeiting or in the difficulty to recall the product from retail stores. This latter may cause the spread of illness in the population related to alimentation. The study showed the features of BCT that can be a solution for identified problems along supply chains.

Blockchain technology would allow agrifood information to be shared in a reliable and secure environment, also guaranteeing its immutability. All the players in the supply chain would no longer need to use "paper documents" or rely on central or third-party entities for the certification of the various information and documents produced during the different stages of the supply chain. Before buying a product, consumers will be able to verify all the data and consult the certified documentation: not only the origin, but also, for example, if the frozen food has been transported safely at the right temperature.

5.4. LITERATURE, CASE STUDY AND WINE ROADS

Compiling, in the literature review, the BCT is portrayed, its characteristics and different aspects for its implementation in agrifood supply chain are described. It is evident that, thanks to its nature, BCT has the ability to minimize disorganization and inefficiencies along supply chain that may cause disastrous results (Kadariya et al., 2014; Scharff, 2012). BCT considerably diminish the time necessary for identifying falsified or contaminated products and for removing from the trade all and only that products, also for tracing the producer and its suppliers.

Using a case study methodology, there is described a simplified model of wine supply chain in this work. It describes all major activities that happens in real time in the industry. These activities are as following: grape growing; wine production, its bottling and packaging; distribution, wholesale and retail selling of final products. Also, the model includes the act of returning back the hazardous product by final consumer, then identifying similar products and their origin tracking.

Through ABMs and GAMA, the whole process, from grape growing to returning back hazardous item, is clearly visualized. Additionally, GAMA graphically displays the units of time required to perform these actions. Thank to this graph, the difference between traditional and blockchain-based supply chains is abundantly clear.

It is important to note that delays in the removal of hazardous products from sale may lead to widespread their consumption, deteriorating consumer health, economic pressures on the healthcare system as well as on the manufacturer, and damage to the manufacturer's reputation (Pouliot & Sumner, 2013; Kshetri & Loukoianova, 2019).

CONCLUSION AND RECOMMENDATIONS

Nowadays more importance is given to healthy products because of their impact on peoples’ well-being, therefore, innovations have a leading role in the food industry. It is crucial for the global economic market and social well-being to have the food industry developing over time, where innovations define and create these improvements for the industry. From the microeconomic point of view, innovations play an outstanding role for suppliers' success in this field. Consequently, according to the academic data reviewed in this work, the implementation of software innovations regarding consumer preferences and demands, are crucial and can assist in trustworthiness and transparency of food value chain processes. This could mean higher competitiveness on the market for the firms that have adopted the innovative software approach, while it would mean trustworthy and good quality end products for the customers.

BDA tools suggest reliable traceability, as well as security for food products and plays a vital role in increasing efficiency productivity of agrifood supply chain (Contò et al., 2015; Ma et al., 2018). Big Data contains all kinds of information (Lynch, 2008) such as industrial data, storage, transportation, customer behaviors and etc. BDA with emerged technologies have changed the way companies do the businesses (Chen et al., 2019; You, 2019; Cayirci & Rong, 2018). Modern businesses pay more attention on the using resources in aa efficient manner, it has become a foundation to create new similar opportunities in making industries more transparent, time effective, traceable, trustful and sustainable. Subsequently, the need for third party involvement gets reduced, together with documentations, upscale internal operations of the companies and streamline business processes, that result higher profit and satisfaction of customers (Tripoli & Schmidhuber, 2018).

Therefore, BDA tools support food safety, judicious use of primary products in accordance with the issues of precision agriculture, identification of the natural potential of agricultural area, and the balance with market demand as well as trustworthiness and transparency of food value chain processes that ensures the quality of the food and simplifies the trace of the production. Finally, these tools allow obtaining healthier foods in a sustainable way, to prevent food-borne illnesses and to increase the profitability of agri-business.

Yet, there are constant security and privacy issues that exist when it comes to collecting and storing a big amount of data (Behera & Rasool, 2019; Jadon & Mishra, 2019). It is important to emphasize that the validity of all the data for big data analysis can be questionable and often poses as a challenge to producers. The usage of faulty, misinterpreted, or unrelated data while performing the big data analysis can result in less accurate outcomes, expectations, or system behavior, which will affect the total productivity of the agricultural system (Estes, 2016).

The solution to this challenge would be having basic techniques integrated that would work solely towards acquiring reliable data, would improve the efficiency of sustainable agriculture development, and provide transparent, secure and appropriate provision of data from farms, passing by agricultural technology providers, working staff, financial sectors, to the end of chain represented in processing and handling entities (Abe et al, 2017; Noyes, 2014).

In fact, the vital result of this research has found that it is beneficial to optimize the agrifood chain by affecting the management and decision-making processes of firms. The planned software innovations that meet the needs of agricultural industry. Additionally, due to the high efficiency potential that comes with the blockchain software, the food industry workers will be able to easily determine products that should be removed from shelves in a matter of minutes instead of the days, it would traditionally require for the same task. Thus, the economic advantage in addition to lower health risks for the customers and higher quality food presentation in stores.

Indeed, in order to transform and modernize a lot of industries and especially the wine supply chain, the BCT has a huge potential. It encourages a transparent system that benefits various stakeholders, particularly, the consumers giving them ability to know all the necessary information about the product. The benefit of this accurate information is ample for manufacturers, suppliers, and retailers as well. Blockchain is a useful tool to ensure a traceability system and to protect the production from any type of fraud. Therefore, the ability to trace and track the product from supplier to consumer, so called "from farm to fork", makes significant difference for consumers' health conditions and even between life or death, consequently, for the affected businesses' success.

Moreover, in the current agrifood market, the need to certify the origin and quality of products, especially organic ones, is getting increasingly important, using a new traceability model capable of setting a quantitative and qualitative model of the information shared along the supply chain. All problems related to food safety would be solved in this way, while ensuring maximum transparency as a guarantee for the final consumer and enhancing quality agrifood work.

BCT considerably simplifies information sharing between actors along supply chain, reduces the need of paperwork and digitizes the processes that gives the possibility to trace and track the product in a significantly short time and with low costs. Therefore, blockchain technology improves the monitoring of production process and reduces the work intensity necessary to guarantee the quality and certification processes. A further effect on the production processes and transformation is giving the ability to all the players in the supply chain to participate in a shared manner in the construction of quality processes. The implementation of the technology and related management model guarantee the nodes mapping of the supply chain where the gap takes place. Through this mapping it will be possible to provide the data for better control and for improvement of the processes. The monitoring will allow to identify any inefficiencies in the supply chain and the consequent intervention for their minimization. There will be an intensification of information exchanges between operators and consumers which will determine an increase in awareness of the final consumer about the organic product and the value of the supply chain processes.

It can be concluded that the advances for sustainable agricultural production and overall process efficiency, largely depend on the advancement of agricultural research and on the implementation of effective strategies as well as on relevant policies that would be used in firms through innovation and technology transfer. Innovations such as the Internet of Things, Cloud Computing, Big Data, Blockchain are revolutionizing agriculture. Having access to supporting technology and establishing effective trust-based communication between farmers, researchers and policy makers are crucial for the overall process efficiency (Tesdell, 2016). Collaboration is main driving force for economic growth in the last century (Weaver, 2008) as it enhances innovation capacities of the network members (Kühne *et al.*, 2015). These circumstances underline a need for the effective agricultural policies that would lead the technological innovation and collaboration and information/knowledge exchange between key stakeholders. The agricultural policies that include collaborative activities between public and private players, farmers, suppliers, consumers and researches, will encourage the progress of agricultural processes. So, a much more effective result could be created is all of three participating parties worked on a unanimous solution for an effective policy that would boost the agricultural productivity (Baker *et al.*, 2016). Thus, the solution would be used towards improving the challenges with increased food production, effects of climate change and environmental factors. It needs to be emphasized that the increase in investments in agricultural research and interest in development of emerging technologies, helps BDA tools to progress in a refreshing way. Therefore:

- It would be very helpful for the industry if stakeholders had access on the necessary information, for instance, by establishing open data sources containing detailed information about agricultural practices;
- Government can increase the general awareness of the population about the benefits of emerging technologies and promote them in this way;
- Government can support the adoption of emerging technologies by financial aid;
- Establishing the different grants for applicable research projects would have strong impact on the industry: it would increase the scientific knowledge and support the development of the technologies as well; the projects may contain training activities for human capital; and the results of the projects will be useful for the industry.

Hence, policy makers are expected to estimate the impact of agricultural production and consumption on the environment and climate and use the models to generate better evidence for optimization of regional ecosystem services including organization, market dynamics, ecological sustainability relative to tolerance and natural potential of individual agricultural areas.

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ANNEX 1: PUBLICATIONS

1. **Adamashvili** N., State R., Fiore M. "Blockchain-based wine supply chain for whole process advancement". Food reviews international (*Forthcoming*)

2. Salvatore F.P., **Adamashvili** N., Contò F. "Factors Affecting the Consumer Purchasing Behaviour of Functional Food". British Food Journal (*Forthcoming*)

3. **Adamashvili** N., Shervashidze S., Salvatore F.P. (2021) "Does the Development of the Country Drive the Consumer Behavior? A Two-Country Study". International Journal of Business Research and Management 12 (2), 34-49

4. **Adamashvili** N., Zumburidze O. (2021) "Blockchain Technology – Breakthrough for Agri-food Industry". International Scientific Journal Economics and Finances 1 (2021) 304-313

5. **Adamashvili** N., Colantuono F., Contò F., Fiore M. (2020). "Investigating the role of community of practice for sharing knowledge in agriculture sector". Journal for Global Business Advancement 13(2), 162 – 184. DOI: 10.1504/JGBA.2020.110612

6. Delicato C., **Adamashvili** N. (2020) "Comunità di Pratica: Uno strumento per l'Agricoltura Sostenibile", Book chapter in: Ragionando di Sviluppo Locale: Una Lettura "Nuova" di Tematiche "Antiche" Contò F., Fiore M. Editor Franco Angeli, 478-508.

7. **Adamashvili** N., Fiore M., Contò F., La Sala P. (2020) "Ecosystem for Sustainable Agriculture: Collaborative approach as a driver for sustainable agricultural development". Journal European Countryside 12(2), 242-256. DOI: 10.2478/euco-2020-0014

8. **Adamashvili** N., State R., Cassagnes C., Faccilongo N., Sardano R., Contò F. (2020). "Opportunities for blockchain diffusion in the agri-food supply chain: case study in wine sector" (abstract), HAICTA 2020 9th International Conference

on Information and Communication Technologies in Agriculture, Food & Environment. pp 68-69.

9. **Adamashvili** N., Chiara F., Fiore M. (2019). "Food Loss and Waste, a global responsibility?!" Economia agro-alimentare / Food Economy 21(3), 825-846. DOI: 10.3280/ECAG2019-003014

10. Gallo C., Faccilongo N., Contò F., **Adamashvili** N. (2019). "Blockchain: a tool for supply chain certification", Conference proceedings: EFITA-HAICTA-WCCA Congress: digitizing agriculture. 114-119.

11. **Adamashvili** N., Fiore M., Colantuono F., Contò F. (2019). "The Effectiveness of Communities of Practice for Sustainable Agricultural Development" (abstract), 12th Annual Conference of the Euromed Academy of Business: Business Management Theories and Practices in a Dynamic Competitive Environment pp 1590-1592, ISSN 2547-8516.

12. Alaimo L., Fiore M., **Adamashvili** N., Contò F. (2019) "Linkage Between Moderate Wine Consumption and Well-Being: Analysis of Italian Consumers by Regions Over Time" (abstract), 12th Annual Conference of the Euromed Academy of Business: Business Management Theories and Practices in a Dynamic Competitive Environment, pp 1598-1601, , ISSN 2547-8516.

13. **Adamashvili** N., Contò F. (2018). "Distributed Ledger Technology for Agri-Food Supply Chain Management" (abstract) in the international scientific conference Formation of the mechanism of public management of rural development as a priority of the state policy of decentralization, Zhitomir, Ukraina.

14. Zumburidze O., **Adamashvili** N. (2018). "Link Between Country Competitiveness and Technological Progress" (abstract), First Joint R&D International conference - Dynamics and Recent Trends of Vary Industries in EU and Georgia: Involvement of ICTs in Supply Chain Management (JoRDI – 2018), pp 31-33, ISBN 978-9941-28-403-8

15. **Adamashvili** N., Gallo C., Rana R. L., Faccilongo N. (2018). “Blockchain Technology – the Tool for Revolutionize the Agri-food Supply Chain” (abstract), First Joint R&D International conference - Dynamics and Recent Trends of Vary Industries in EU and Georgia: Involvement of ICTs in Supply Chain Management (JoRDI – 2018), pp 23-25, ISBN 978-9941-28-403-8

16. Fiore M., La Sala P., **Adamashvili** N., Contò F. (2018). “ICT-based modern farming and data management as drivers for sustainable agriculture” (abstract), XVI European Rural Development Network Conference (ERDN): CAP 2020+: Experience and ideas for future rural areas and development, pp 20-21.

17. Salvatore F.P., **Adamashvili** N., Chiara F., Contò F. (2018) “The Awareness of the People of Their Nutrition Intake: Comparison of Developed and Developing Countries” (abstract), Global Business Conference 2018 Proceedings: Developing New Value-Creating Paradigms, pp 208-209, ISSN 1848-2252.

18. **Adamashvili** N., Fiore M. (2017). Investigating the role of business marketing techniques in sales process, European Journal of Management Issues 25 (3-4), 135-143, ISSN 2519-8564 (print) ISSN 2523-451X (online), DOI: https://doi.org/10.15421/191717

19. **Adamashvili** N., Salvatore F.P. Sekhniashvili D. (2021). “Malnutrition – Saving or Double Burden for the Economics Sector of the Countries”. Editorial for Special Issue in the International Scientific Journal Economics and Finance”. https://international-scientific-journal-economics-and-finance/special-issue

ANNEX 2: CONFERENCE PARTICIPATIONS

1. Team Capitan, IFAMA 2021 Student Case Competition, Graduate division, in the frame of 2021 IFAMA conference "Innovations Reshaping the Future of Food" 14-15.05.2021

2. Blockchain and Supply Chain Integration: Needs, benefits, challenges and future perspective. IV International Scientific Conference „Economic Sciences for Agribusiness and Rural Economy". MS Teams platform organized by Warsaw University of Life Sciences, 24.05.2021

3. Blockchain Technology – Breakthrough for Agri-food Industry. International Scientific Conference "Science, Education, Innovation: Current Issues and Contemporary Aspects". Tbilisi, Georgia, 12.02.2021

4. Opportunities for blockchain diffusion in the agri-food supply chain: case study in wine sector. HAICTA 2020 9th International conference on ICTs in agriculture, food and environment. Thessaloniki, Greece, 24.09.2020-27.09.2020

5. The Effectiveness of Communities of Practice for Sustainable Agricultural Development; Linkage Between Moderate Wine Consumption and Well-Being: Analysis of Italian Consumers by Regions Over Time, 12th Annual Conference of the Euromed Academy of Business: Business Management Theories and Practices in a Dynamic Competitive Environment, Thessaloniki, Greece, 18.09.2019-20.09.2019;

6. Blockchain: A Tool for Supply Chain Certification, EFITA-HAICTA-WCCA Congress 2019: European Federation for Information Technology in Agriculture, Food and Environment: Digitizing Agriculture, Rhodes, Greece, 27.06.2019-29.06.2019;

7. Protection of supply chain through the use of the blockchain, World congress IFAMA 2019: Food Security 2050 – eCommerce, Agri-food Value Chain

Transformation, Zhejiang University, Hangzhou Shangri-La Hotel, 22.06.2019-27.06.2019;

8. Distributed Ledger Technology for Agri-Food Supply Chain Management, International conference: Formation of the mechanism of public management of rural development as a priority of the state policy of decentralization, Zhytomyr National Agroecological University, 04.12.2018;

9. Link Between Country Competitiveness and Technological Progress; Blockchain Technology – the Tool for Revolutionize the Agri-food Supply Chain, First Joint R&D International conference - Dynamics and Recent Trends of Vary Industries in EU and Georgia: Involvement of ICTs in Supply Chain Management (JoRDI – 2018), Georgian Technical University, 17.10.2018-19.10.2018;

10. ICT-based modern farming and data management as drivers for sustainable agriculture, XVI European Rural Development Network Conference (ERDN), University of Agricultural Sciences and Veterinary Medicine, 17.09.2018-19.09.2018;

11. Involving of technologies in human resource training practices, HR Festival International Conference, Cracow University of Management, 23.04.2018-26.04.2018

ANNEX 3: OTHER SCIENTIFIC ACTIVITIES

1. Internal Tutor - Project: PCTO (Percorsi per le Competenze Trasversali e per l'Orientamento - Paths for Transversal Skills and for Orientation). Teaching activities and exercising 03-11.02.2021

2. Committee member on the exams 2020-2021. Subject "Economia e politica dello sviluppo locale" on the program "Economia aziendale". Professor Mariantonietta Fiore. CFU 7.

3. Committee member on the exams 2020-2021. Subject "Economia e politica dello sviluppo rurale" on the program "Economia aziendale", EAT. Professor Mariantonietta Fiore. CFU 7-8

4. Chair of the plenary session on the International Scientific Conference "Science, Education, Innovation: Current Issues and Contemporary Aspects" 2021. Tbilisi, Georgia.

5. Member of organizational committee of International Scientific and Practical Forum: National Models of the Economic Development: Yesterday, Today, Tomorrow, 2020. Gonio – Batumi, Georgia;

6. Member of organizational committee and Chair of plenary session of First Joint R&D International conference - Dynamics and Recent Trends of Vary Industries in EU and Georgia: Involvement of ICTs in Supply Chain Management (JoRDI – 2018). Georgian Technical University, Tbilisi, Georgia

7. Project collaboration - Student & Researcher. eTomato EU Project (Participation); Research activity at the University of Foggia, Department of Economics

8. Project collaboration - Student & Researcher. SKIN EU Project (Participation); Research activity at the University of Foggia, Department of Economics