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A Delphi Study on Blockchain Application to Food Traceability

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ABSTRACT

Blockchain has been described as a breakthrough Information and Communication Technology having the potential to ensure safe, immutable and transparent information exchange between actors. This study attempts to foresee whether Blockchain will play an important role in traceability management and how this innovation is expected to change the agri-food sector's future, using a Delphi group discussion with experts. According to our results, blockchain is potentially recognised as a decentralised system able not only to harmonise safety and quality standards but also to reduce bureaucracy. Greater efficiency and reliability of the system would lead to the establishment and coordination of new supply chain relationships.

***Keywords**: Blockchain; Food Traceability; Food Safety; Supply Chain Management;*

1 Introduction

Food supply chain management is in the midst of an important transformation. Due to the conversion of local food systems to industrialised and globalised production, consumers, which are increasingly distant from the production source, *would like to see* accurate and reliable supply chain information (Sarig et al., 2003; Verbeke, 2001). Indeed, lack of transparency, food frauds, food-borne illnesses and unsustainable social and environmental food production have recently been in the spotlight of public concern, leading consumers to demand food safety, animal welfare, fair trade and eco-friendly products (Sander, Semeijn, & Mahr, 2018). Despite this, food labels often do not provide customers with enough information about how and where the product was produced (Bacarella, Altamore, Valdesi, Chironi, & Ingrassia, 2015).

Despite increasingly strict food safety legislation, the public has become more conscious of scandals (Sarig et al., 2003). Therefore, fast recognition and withdrawal of non-secure food distributed all around the world is required to protect consumers' health (Regattieri, Gamberi, & Manzini, 2007). Food frauds are another main issue in food safety that, due to complex supply chains, is growing, and the national food regulatory bodies in developed countries are currently trying to implement new scientific and technological measures; including and enforcement of food control systems, such as real-time monitoring and inspections (Spink & Moyer, 2011; Verbeke, 2001). In line with these developments, supply chain management is more than ever directed toward the connection of supply chains' stakeholders and aims for transparent management (Wagner & Sweeney, 2010). In this context, information systems are developed exponentially also with the improvement of new technologies and techniques (Holsapple & Singh, 2001).

Recently, Blockchain technology has been in the spotlight of public concern as it is commonly recognised as a technology that enables safe and transparent exchanges of information and values among actors (Nakamoto, 2008). Developed as an accounting method for the Bitcoin cryptocurrency, it has recently been described as an Information and Communication system with the great potential of ensuring safe, immutable and transparent information exchange between actors (Nakamoto, 2008), particularly in food supply chain management (Zhao, Fan, & Yan, 2016).

As such, this study tries to foresee whether Blockchain will play an important role in traceability management and how this innovation may be expected to change the future of the agri-food sector. By starting with a broad description of this technology and its current use, in the following sections, a possible future scenario of Blockchain in food traceability is drawn with the help of key informants in several areas of the Italian food industry and the application of the Delphi approach to group discussion (Gordon, 1994; Linstone, Turoff & Helmer, 1975) as a data collection and analysis tool. Then, opportunities and potential challenges are identified, allowing us to suggest potential directions for a future research agenda.

1.1 Background: Blockchain technology

Blockchain (the epitome of the more general concept of distributed ledger technology - DLT) is commonly described as a distributed database: members, having a copy of the same unit, can have the same access to the shared information and transact with other members without the need of a third party. Blockchain is also based on a decentralised system. Thus, decision power is not handled by a particular group or figure, and there is no central organisation in the network, and if a user is lost, the entire system will still run (Davidson, De Filippi, & Potts, 2018). The database is structured in Blocks (containing multiple transactions) that are connected in a network. Participants, also called nodes, control and approve all transactions by creating a network that shares on each node the archive of the whole Blockchain and therefore of all the blocks with all transactions. Each block is also a folder for all transactions and the entire history of each transaction. This information is protected with cryptographed codes. Transactions are available to the network only if they are voluntarily unencoded by the same user. Hence, the concepts of immutability, transparency and governance of the entire process (Nakamoto, 2008).

In food supply chain management, data can be collected and stored in each step of the process from the field to the plate by either the users themselves or by specific sensors connected directly to the ledger. Smart sensors have the potential to convert physical objects into digital information in real-time, allowing the collection of objective data along the entire supply chain. The role of Blockchain in the convergence of these technologies is to record digital data in a way that makes them tamper-resistant. When, at the end of the supply chain, consumers or other operators are given access to the sequence of events in a product's history, for instance, by simply scanning the QR code placed on the product label, they can trust the integrity of this information after its input in the system.

2 Design of the study

Since research in this field is still at its primary stage, a qualitative and explorative analysis was designed according to the Delphi Method, a foresight methodology developed for those situations in which empirical data are insufficient for valid forecasts (Helmer, 1963, 1967). The Delphi Method has been applied in many study areas across the globe (Linstone, Turoff, & Helmer, 1975), including the food industry (Su & Canavari, 2018; Camanzi, Hammoudi, & Malorgio, 2019; Archontakis & Anastasiadis, 2019). Even though researchers tailored focused variations for each situation, this study followed the classical method, which is based on the administration of open-ended questionnaires, individually submitted to a panel of experts to realise an asynchronous and mediated discussion group. The individual interview develops in several (typically two) rounds. After each round, anonymous opinions of each participant are combined and shared among the group. Feedback enables experts to revise their answers in subsequent rounds in order to reach an overall consensus on the topic, which will be considered the most correct and plausible foresight (Helmer, 1963).

2.1 Data source

The main data source for the Delphi method is typically a panel of experts; in this case, 35 experts were invited, but only 22 accepted to collaborate. Experts were recruited based on the inherence of their career and knowledge of the topic (Adler & Ziglio, 1996; Su & Canavari, 2018), according to two different profiles: 1) Practitioners involved in the agri-food sector; 2) Experts specialised in Blockchain promotion and management.

Most of the experts' sample belonged to the first profile, balanced by various professional figures deriving from different supply chain areas (Table 1). In some cases, some of the interviewees belonged to both profiles.

Table 1.
Composition of the panel of experts taking part in the analysis

Experts (N=22)			
First Profile		**Second Profile**	
Supply chain Managers	3	Blockchain Managers	2
Agronomists	2	Consultant in Performance Management	1
Quality Managers	2	Food Science and Innovation Manager	1
Retailer Management	1	Smart Sensors and Equipment Suppliers	2
Marketing Managers	2		
Export Managers	2		
Public Affair Manager	1		
Supply Chain Certifier	1		
Agricultural Journalist	1		
Cooperative Director	1		

2.2 Procedure

The research procedure is summarised in Figure 1.

Initial literature allowed to conceptualise the problem, design the study and define the research instruments (Skulmoski, Hartman, & Krahn, 2007). Some experts of Blockchain technology were contacted to gather more detailed explanations and suggestions about the topic. This background study was useful to prepare an introduction to Blockchain technology that was sent to all the panellists before the first interview. This first introduction was considered fundamental to fill and inform possible knowledge gaps among experts.

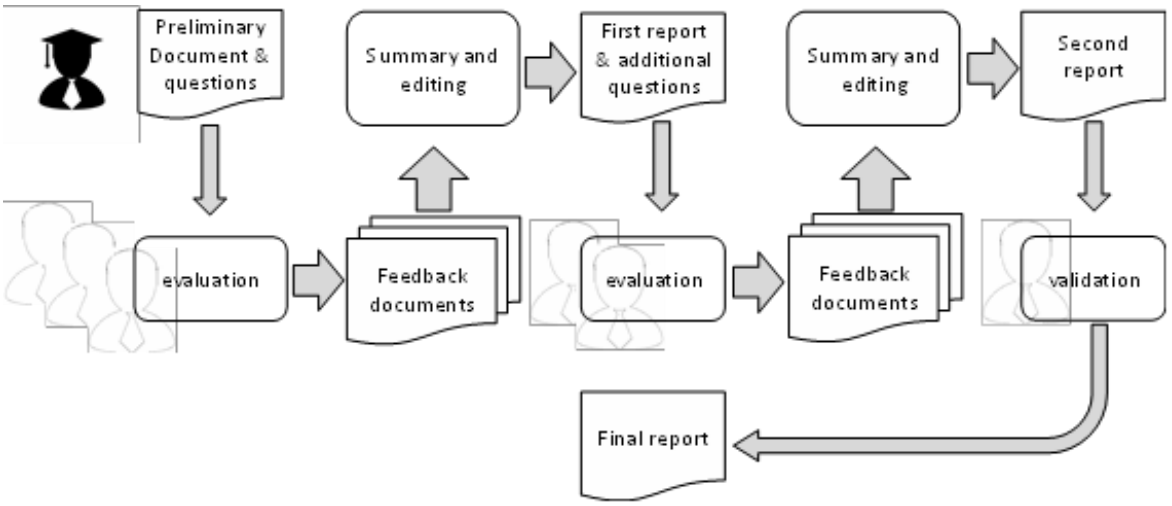

Figure 1. Research procedure

In line with the Delphi literature (Adler & Ziglio, 1996; Gordon, 1994), the first questionnaire was designed to outline a general and broad overview of the issue. Experts were required to reflect on the topic in a broad manner, by outlining future opportunities, threats, impacts, and consequences of Blockchain in the agri-food sector. Prior to that specific questions, as Dalkey & Helmer (1963) suggested, two other questions related to the career experience and the self-rating expertise in Blockchain were also included (Linstone et al., 1975).

2.3 First round

The first round was held by telephone on appointment. For 5 experts, it was also possible to conduct face to face interviews. On average, the interview lasted 20-30 minutes. During the interview, the first questionnaire was mainly presented. However, in some cases, to deeply understand the topic, more specific questions were asked, concerning, for instance, personal experiences or opinions not properly expressed. Altogether, 22 experts took part in the first round.

2.4 Second round and first feedback

Before the second round, participants were provided with a short report containing anonymised feedback from the other experts involved in the first round. The feedback was previously provided in order to allow experts to reflect on it. As reported in the literature (Gupta & Clarke, 1996), to convince experts to be an active participant, the approach endeavoured to provide at least one opinion from each expert.

During the second interview, held with the same methodology as the previous one, panellists were asked to agree or disagree with some reported judgements considered relevant for the analysis, such as the role of information in the supply chain, corporate reputation, Blockchain and its Social Value.

In the second round, as also expected according to literature (Skulmoski et al., 2007), seven experts dropped out, and as such 15 experts agreed to take part in a second interview.

When questionnaires were completed, data analysis according to the research paradigm (e.g. qualitative, quantitative and statistical summarising) was required for the production of feedback. In this case, a qualitative summary was considered the most appropriate approach. Experts' opinions were confronted, and analysis was compiled according to the answers. However, in panellists' answers, some common information was commonly reported and, therefore, grouped together.

2.5 Validation of the final Feedback

Going beyond the classical method, at the end of the research, it was decided to consult with four further experts to validate not only the most relevant consensus statements but also to underline relevant topics not properly considered during interviews. In our case, interviews were conducted individually and telephonically without using a specific questionnaire.

Results of the first and second round were commented upon according to experts' discretion. Their opinions were considered as a support for the outcomes proposed.

Experts were recruited according to their experiences and knowledge about the outcomes' content (Table 2).

Table 2.
Experts taking part in the final discussion

Experts (N=4)
1 Blockchain Consultant 1 Retailer Seller 1 Agricultural Policies Consultant 1 Agricultural Developer

3 Results

The majority of panellists had already heard about Blockchain, mainly in an international market context. Most of the respondents were able to define Blockchain features and applications, reporting also some examples. However, according to some of them, "*it would be interesting to determine state of the art, to really understand what experts such as supply chain managers, retailers and suppliers in the food sector are able to describe*." Indeed, some experts recognised that information is various and very confusing, and the association of Blockchain with cryptocurrencies certainly is not well understood and, therefore, an issue to consider. At first glance, talking about this technology, it may be a sponateous view to connect it with cryptocurrencies; nevertheless, Blockchain exists independently.

Regarding Blockchain for business, it was recognised by experts as an innovative system with great potential for both internal and external traceability management. During the interviews, a lack of statutory regulatory rigour was strongly recognised, which makes it difficult to manage long and spread-out supply chains efficiently and transparently. In the last decades, centralised systems displaying trust problems pushed companies towards the establishment of voluntary safety and quality standards, leading to a lack of common guidelines and data objectivity.

For this reason, as a decentralised system, Blockchain is recognised potentially to be able, not only to harmonise standards but also to streamline digital documentation; by reducing paper bureaucracy. As a consequence, having actors accountable for efficient control and communication of their processes and a greater efficiency and reliability of the system, would lead to the establishment and coordination of new supply chain relationships (Figure 2).

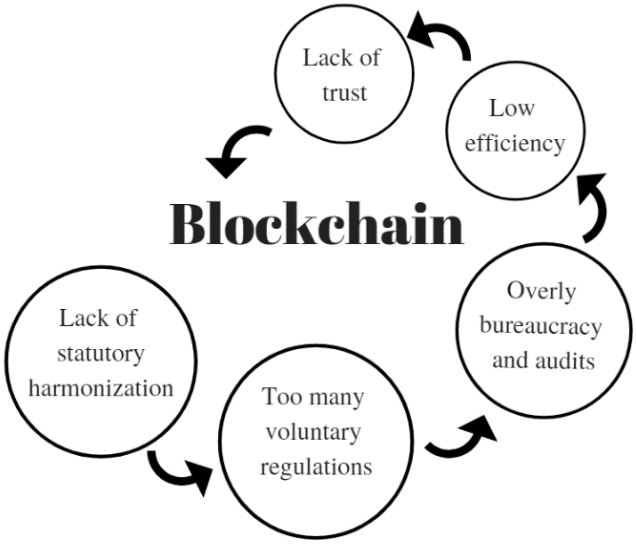

Figure 2. Reasons for Blockchain adoption according to panellists

3.1 Information: a priceless value

It was commonly pointed out, by unanimity, the likelihood that Blockchain being adopted in the B2B model would increase trust and efficiency in supply chain management. Further in time, this innovation would also be adopted in the B2C model.

For some experts, consumers will take part only in a passive way, maybe just looking at the linked webpage of the product, whereas according to other panellists, consumers will participate actively in a Blockchain platform if they are given a chance to do so. Particularly, panellists considered it interesting to include consumers in Blockchain also for further managerial and statistical control..

Despite this fact, even if consumers require transparency, it is unlikely that they will be able to correctly understand the amount of shared information in terms of traceability, labelling, certification, and guarantee of origin.

Indeed, according to experts, Blockchain will include every kind of information for managerial benefits, but what will be transmitted to consumers will be very limited. *"We will just emphasise culture, history and quality through a catchy story-telling and user-experience"*.

Nevertheless, this claim was considered inappropriate by the majority of panellists in the following round. For many, Blockchain is not just a communication technology, but it is a system able to increase security, efficiency, and trust within the B2B space. For this reason, in the future, mainly big players with a high marketshare and long branched supply chains will adopt Blockchain technology.

3.2 Products more prone to be Blockchain certified and key subjects for introduction

Experts forecasted Blockchain application on specific products' supply chains. By unanimity, Blockchain adoption is expected on: premium, long supply chain, exported, multi-ingredients and certified products. Opinions were mixed for fresh and unprocessed products. For some experts, Blockchain would be worthless on short life cycle products withinshort supply chains. For others though, it would be an added value proposition, especially for fresh-cut vegetables.

However, a scarce level of consensus was observed among key players.

The majority of experts recognised retailers as the key players in the supply chain: "*If retailers imposed Blockchain on their supply chain, suppliers must only accept it, and producers not involved in retailers' brand will be excluded from the market*". Whereas, other experts forecasted other main figures such as supply chain managers, certifiers, logistics companies, Blockchain start-ups and open-source players. For the majority, governments' role was considered as possible support but not fundamental. Just three experts, considered institutions as an essential entity in charge to subsidise Blockchain introduction and technical training.

Alternately, six experts considered consumers' as figures of major influence for Blockchain introduction. "*Are they interested in Blockchain certification? Do they want to pay more?*" Many experts are convinced about a higher willingness to pay for premium products using the system.

3.3 Obstacles hindering Blockchain adoption and Risks after its introduction

Obstacles were gathered into five main groups:

- Lack of resources such as financial, knowledge, expertise, technical (e.g., internet in remote areas) requirements.
- Low digital skills and great technical complexity, for both business and consumers' user-interface, which was considered highly time-consuming.
- Lack of regulation.
- Unsustainable energy expenses needed in computing power.
- Social resistance due to: (i) unethical behaviours, (ii) fear of decentralisation.

Experts agreed with the fact that resources will be the most limiting factor for Blockchain introduction. Some of them pointed out the interesting role that unethical behaviour in business and lack of regulation could play for its adoption: "*If your production is transparent you join Blockchain. Otherwise you prefer to stay out of it. That's why Blockchain is not spreading as expected,*" said an expert.

Concerning risks after Blockchain adoption, very few experts were able to recognise some possible threats:

- Any failure in data privacy and integrity will decrease Blockchain reliability and spread.
- As already mentioned, deception risks in information sharing.
  The gap between advanced companies and small companies would further increase.

During the second round, particularly the last point was further reiterated. Marginal consensus existed regarding the opportunity of Blockchain to consider the plurality of most marginalised stakeholders involved in the supply chain. Indeed, for some experts, Blockchain will allow small and anonymous stakeholders to actively take part in the supply chain, enhance their visibility, foster inclusivity, reduce barriers and increase business. On the contrary, for other experts, Blockchain will not be useful for the most vulnerable stakeholders of the supply chain. Instead, they will be excluded from the market, due to a lack of support, resources, training and expertise, as reported in the first round.

3.4 Blockchain and Social Value

Participants tended to agree that using Blockchain technology to monitor origin, production and transformation processes, opens up new fields for Corporate Social Responsibility. Companies should be driven by an "innovative mindset" to address social problems and needs in ways that are also beneficial both for the company and society.

"*Blockchain will help consumers to fully understand what values and commitments there are behind an apple. The problem is to recognise the additional information that could make the difference and justify certain actions or practices: it is difficult to understand what social value is meaningful for each stakeholder*".

By delivering a highly reliable service, it will encourage companies to invest in their processes more sustainably, allowing consumers to trust higher prices for guaranteed social and environmental certifications. Thus, Blockchain will aim at creating the conditions for the growth of both society and business itself, stimulating companies to exploit the market but also addressing social concerns. Authenticity and sustainability will allow both consumers and suppliers to rediscover their relationship with food. As a result, a common interest will encourage more collaboration in the long-term, bringing social and economic growth.

4 Discussion

The Delphi analysis performed in this study revealed interesting findings useful for further considerations.

4.1 Why will Blockchain develop in food traceability systems?

During interviews, it was strongly identified that there is a lack of statutory regulations, and these being unable to manage long and spread supply chains efficiently and transparently, as confirmed in the literature (Bosona and Gebresenbet, 2013; Kher et al. 2010).

In addition, experts recognised overwhelming bureaucracy and audits along the supply chain as an important burden to overcome. As already described in the literature, it is often difficult in a food traceability system to capture and share data, due to their variation, inconsistency and lack of common definition (McEntire et al., 2010; Canavari, Centonze, et al., 2010), leading to a range of controls and greater bureaucracy.

For this reason, in line with the literature (Trienekens & Zuurbier, 2008), experts opinion reported a lack of standards harmonisation and common guidelines that are completely different from country to country, and from company to company. Nevertheless, concerning the Blockchain system, an outcome of this study defined retailers as the most important determining actors for its introduction in the food supply chain, because of the awareness that retailers have significantly stronger attitudes toward adopting new food traceability systems than food manufacturers (Cho and Choi, 2019).

4.2 Blockchain and consumers

In line with other studies in this field (Kher et al., 2010; Verbeke, 2009), it was by unanimity pointed out that consumers' recognise only the basic concepts of food traceability, and they do not understand the main principles of the system, how it works and what traceability information means. Hence, this low familiarity with the system could frustrate the common goal of Blockchain. For this reason, Blockchain information will be strictly limited to a very short story-telling on a company's webpage, and perhaps thwarting the real Blockchain meaning. However, from this study, it emerged that consumers will trust Blockchain certification, without necessarily checking directly.

Indeed, according to experts, only a few consumers will actually interface a Blockchain portal, tracking back the supply chain and, in doing, spend more time during shopping. This claim was in line with the literature (Pozin, 2012) that reports a lack of consumers' interest in scanning QR codes. Nevertheless, a Blockchain Technical Consultant who took part in the final result validation said:

"*at the moment Blockchain user interface is very poor, and there is still much work to be done. In my opinion, in 10 years it will totally change. QR code will be replaced by much more innovative and practical tools interacting with products. High-tech is evolving at exponential levels, and also Blockchain complexity will be drastically reduced*".

Starting from these assumptions, pushing consumers to participate in Blockchain actively could be considered a great opportunity to involve the entire supply chain completely, from farm to table.

4.3 Blockchain in business

From this study, it can be assessed that even if the introduction of this technology for consumers will be strongly limited in the short term, Blockchain is considered by experts to be a significant development in business management. Similar findings were also reported by several studies analysing how Blockchain technology can be adopted for documentation management, control of products distribution (Loklindt, Moeller, & Kinra, 2018) and better services in work-flow management (Panetto et al., 2020; Viryasitavat, Da Xu, Bi, & Sapsomboon, 2018).

Starting from these assumptions, also during the validation of the final results, Blockchain was highlighted by the interviewed Retailer Manager, as "*a new way of working and thinking*". "*Blockchain is a technology able to reinvent the way we collaborate and build food supply chain networks*". It should not be considered by business as a mere marketing tool, but as a new system of management, guarantee, and supply chain education; from the farm to the plate.

This innovation intervenes at the beginning of the chain, creating shared competences, enhancing collaboration and trust in B2B (Kumar et al., 2019, Longo et al., 2019) that if missing, as reported in the literature (Fritz and Schiefer, 2010, Athaide, Meyers, & Wilemon, 2003) could be a strong limiting factor; leading to missing important profitable opportunities (Canavari, Fritz, Hofstede, Matopoulos, & Vlachopoulou, 2010) (Figure 3).

4.4 Blockchain creating Shared Value

Shared Value is defined by (Porter & Kramer, 2019) as a business strategy that recognises and addresses social problems, focusing on measurable business value. Unfortunately, the correlation of Blockchain and Shared Value is not under active research investigation yet, and very few published articles can be considered, the exception being that of Proisy (2017) and Pazaitis, De Filippi, & Kostakis (2017), in analysis of Blockchain in sharing economies.

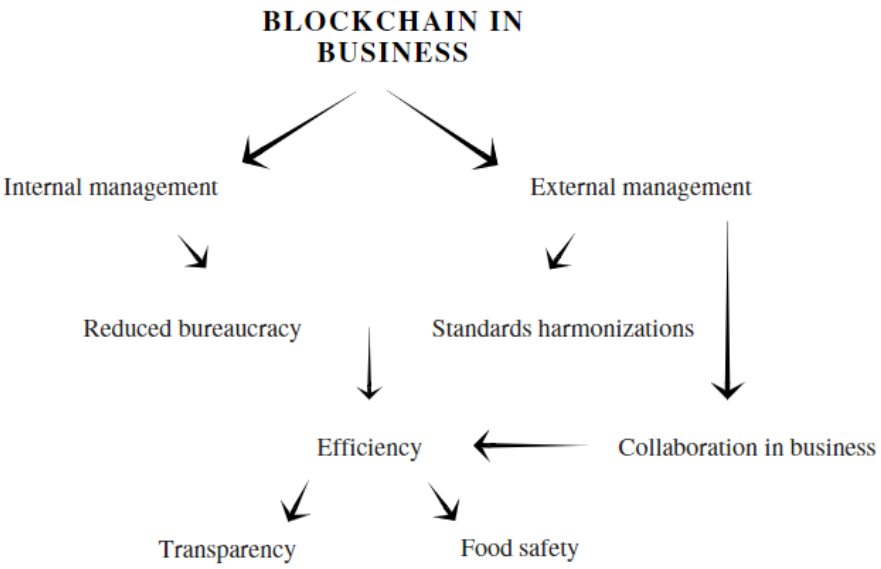

Figure 3. Conceptual map of Blockchain in business

However, during interviews, Blockchain was considered not only as a possible medium but also as an interesting trigger of Shared Value. Blockchain, delivering a highly trusted service, will encourage companies to invest in value sharing, ensuring consumer their reliability and transparency. Companies, having a trusted medium of information sharing, are more prompted to ameliorate their processes and products and make them more sustainable. Indeed, it was assessed that thanks to Blockchain, consumers will be more likely to pay higher prices for guaranteed social and environmental certifications, thus leading to higher profits (Figure 4).

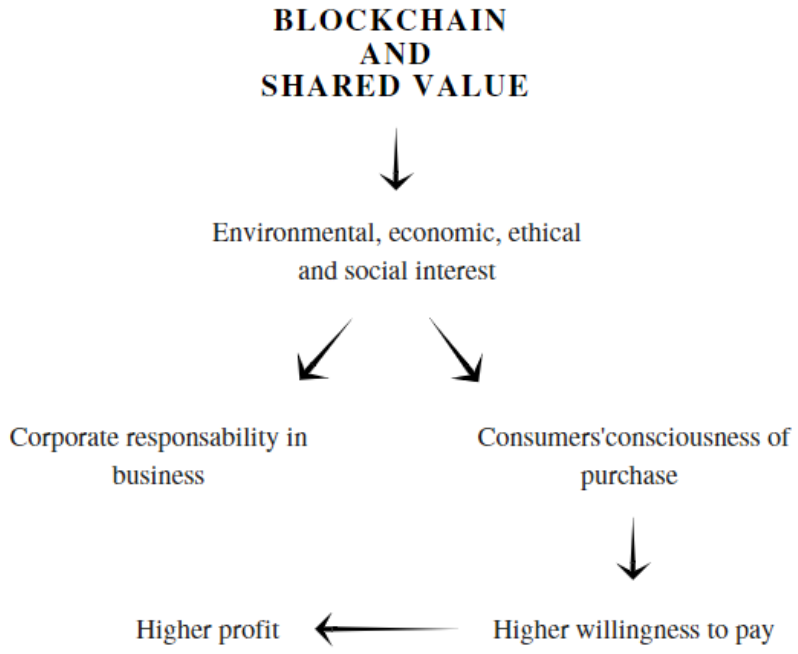

Figure 4. Conceptual map of Blockchain and shared value

5 Outlook for Blockchain studies: a research agenda

In order to successfully implement this technology, it is necessary to consider also technical and social challenges that may be associated with future obstacles and negative impacts. This Delphi study can be considered a useful starting point for further investigations.

5.1 Research in B2B

In this research, Blockchain was considered a system not useful to replace human control, but able to enforce it by chronologically and immutably recording users' consensus on real products. Therefore, understanding how human control and Blockchain are going to cooperate harmoniously will be a great future challenge.

Businesses will need to adapt to new conditions, for example, implementation of new organisational and strategic structures in internal and external management, such as new inventory methods, innovative logistic systems and communication approaches. For these reasons, the ability to change according to innovative stimuli in an uncertain environment should be further explored.

In this research, Blockchain was identified as a technology able to give small and medium enterprises the power to flourish. However, despite its great potential, internal weaknesses should be accurately examined. Only after that, may Blockchain's success be further investigated in relation to companies' visibility, effective consumers' awareness and profit.

In addition to internal evaluation, it would be interesting to investigate how this technology would affect supply chain management in relation to external actors. Indeed, one of the main business challenges will be to choose the best agreement to foster the most profitable and trusted relationships. In this research, it was not specifically defined which Blockchain structure (either permissioned or permission-less) should be suggested in food supply chain management.

5.2 Research in B2C

Future research should consider the ncorporation of Blockchain into products identity and to analyse the most suitable manner to allow consumers to access shared information easily. Indeed, according to experts, the current user-interface, is considered to be highly time-consuming and user-unfriendly, and should be completely revised.

In addition to the improvement of technology acceptance, information quality and accuracy are important topics that need to be considered. Specifically, it is necessary to verify whether the capability to share knowledge would enhance consumers' trust and perceived value. To this end, purchasing intention and willingness to pay for certain information could be interesting starting points for the operationalisation of Blockchain success. Moreover, sellers should define whether transparency and information sharing of such innovation would attract in the long-term differentiated markets, such as those of high-value products, or mainstream categories, for example, food commodities.

Furthermore, it would be interesting to explore in the longer-term how consumers will actively interact with this innovation. Particularly, in helping them to rationalise all the possible benefits coming from the spread of meaningful knowledge, unexpected opportunities such as Agri-Tourism promotion and Agri-Education development.

5.3 Governance research

Considering the fundamental role of institutions, it would be important to investigate how these would affect economic and social performances, understanding which pressures (e.g. a forced adoption) would have the greatest influence on Blockchain establishment.

Nevertheless, in order for them to be effective, these measures should be formulated after a strict analysis of the private sector, which has been considered the most important playmaker so far. Indeed, the promotion of inclusive economic growth, mainly of small- and medium-sized agri-food supply chain actors should be one of the fundamental priorities for rural development in policy agendas.

6 Conclusions

Recently, Blockchain has been suggested as a possible information and communication system potentially able to solve the issues mentioned above by guaranteeing a safe and transparent information exchange (Zhao, Fan, & Yan, 2016; Nakamoto, 2008). For this reason, this study aimed at defining how this innovation may impact the future of the agri-food sector, thus fostering the formulation of a research agenda.

Although forecasting Blockchain success in a long-term was not a simple task, it was possible to identify key positive characteristics that may influence the long-term adoption of this technology.

Regarding the B2B model, Blockchain was recognised by experts as an innovative system with great potential for both internal and external traceability management, by harmonising safety and quality standards, but also to reduce overly bureaucracy. As a result, greater efficiency and reliability of the system would lead to the establishment and coordination of new supply chain relationships.

Therefore, in a well-coordinated network, greater food transparency was acknowledged as an important consequence, with obvious implications also for business-consumers' communication. Nevertheless, in this Delphi study, although consumers were defined as fundamental actors for Blockchain introduction, they would be unlikely to comprehend and take advantage of Blockchain potential fully.

For this reason, Blockchain application will benefit primarily business performances, leading to costs reduction, profit increase, advantageous collaborations and greater visibility.

In addition, in this study Blockchain was described as a technology able to add value also for the society in the long term. Authenticity and sustainability will allow both consumers and suppliers to rediscover their relationship with food. As a result, a common interest will drive tighter collaborations directed at social and economic growth.

Retailers were considered the key subjects for Blockchain introduction, not only dictating the pace of its development but also granting companies their permanence on the market. Nevertheless, institutions were acknowledged as the most formidable player for Blockchain establishment and governance.

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