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Research article

Exploring opportunities and challenges to the adoption of blockchain technology in the fresh produce value chain

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Abstract: This study investigates the attitudes and perceptions of businesses and consumers towards the application of Blockchain technology (BCT) to fresh produce supply chains. Semi-structured interviews and focus groups (FG) were performed with fresh produce company managers and consumers, respectively. The fresh produce sector, in this context, concerns the fresh and chill chain, value-added vegetables, fruits and salads and the ingredients of these used in further food value-added processes and products. A total of five themes were identified as factors influencing BCT adoption: the novelty of the technology, supply chain characteristics, open data issues, cost-benefit analysis, and role of public stakeholders. From these, twelve sub-themes were developed and discussed. Findings provide a framework with opportunities and challenges that the fresh produce system must face in adopting decentralised systems for managing supply chain data like BCT.

Keywords: distributed ledger technology; blockchain; value chain analysis; food supply chain; food safety; traceability

1. Introduction

Distributed Ledger Technologies (DLT) are technological infrastructures combining peer-to-peer networking and cryptography to store and manage data. Blockchain technology (BCT) can be defined as shared DLT, facilitating transactions recording and assets tracking in a business

network [1]. Further, BCT allows linking together successive records regarding business transactions and storing them into a shared, decentralised, distributed and retroactively unchangeable data structure [2]. In BCT, information records are formed by chains of hashes, identifying where and by whom the transaction was generated and its current destination [3]. Thus, BCT provides a means to ensure the permanency of records and the potential to facilitate the sharing of data between disparate actors without business intermediaries. This kind of innovation has opened new doors to businesses that require improvement in real-time information sharing among partners, without depending on third parties that may slow down communications; and without being subjected to manipulation. Besides the several merits, BCT also has omissions and shortcomings that, to date, mainly occurred in cryptocurrencies markets. For instance, the pseudonymity model characterising cryptocurrencies lacks retroactive operational security, which means that users can be identified by historical pieces of information, via social networks [4] or with third-party web trackers [5]. Another issue is related to the technology footprint, as solving BCT algorithms requires a huge amount of energy compared to traditional transactions [6].

Notwithstanding these limitations, BCT (and, more generally, DLT) is considered a highly promising technology. As such, it is an important and interdisciplinary topic since it is expected to transform current economic organisation and governance in the years to come in several sectors [7,8]. To date, BCT applications have been introduced in finance [3,9], in the real estate and healthcare industry [10] and in the agri-food sector [11], for which BCT was even considered one of the evolutionary next steps [12]. In the agri-food, the implementation of BCT among supply chain actors can open relevant opportunities for a paradigm shift based on transparency and trust, ultimately ensuring food integrity [13–16]. Food safety issues have become major problems for the food supply chain. Fraudulent activities, including tampering with products, mislabelling and misrepresentation, product substitution, dilution, fake/synthetic food, and food adulteration, are all forms of food fraud issues facing the current fresh produce supply chain. In the UK, food fraud is estimated to cost the food and drinks industry up to £11 billion per year [17].

A modern technological infrastructure enabling effective communication between food chain stakeholders can guarantee higher food safety and products' traceability along the food supply chains. In fact, in the current food system, food chain actors track and record data on paper and/or on their own centralised digital system, thereby hindering the emerge of common languages and restricting communication among supply chain parties. Issues concerning the poor traceability capabilities arise in foodborne diseases outbreaks, with hundreds of documents that will have to be pieced together [18]. For example, it took the United States Food and Drug Administration (FDA) two weeks to trace the source of the E-Coli 0157:H7 outbreak of contaminated spinach in 2016. Another outbreak concerning contaminated Romaine lettuce in 2018 took the FDA close to three months to bring the situation under control after the source of contamination was identified [19]. Furthermore, consumers may raise doubts about traceability information's truthfulness since they control food production and distribution companies [20].

Current food system inefficiencies tragically reveal themselves in foodborne disease outbreaks and place a huge cost on society. A 2014 estimate from the U.S. Department of Agriculture placed the direct and indirect costs associated with illnesses caused by major foodborne pathogens at $15.6 billion per year. The Grocery Manufacturers Association and the Food Marketing Institute estimated that the average cost for a food recall in the United States was $10 million of direct costs to companies, including retrieval and disposal of the recalled product; and a higher indirect cost, such

as lawsuits, damage to a company's or product's reputation, and sales losses [21].

Despite growing attention from the agri-food sector in seeking solutions to these problems, the application of BCT is still not experiencing the increase one could have expected. Many barriers existing among supply chain actors have hindered its widespread adoption, like the lack of technical expertise, technology costs, and privacy issues [11]. Also, the rapid but unpredictable direction of such innovation makes the technology particularly hard for commercial organisations and government agencies to make a strategic decision on how to respond to BCT [22]. Nevertheless, given the rapidly increasing level of digitisation, demand for data, and product integrity, the agri-food sector is in a unique position to explore opportunities for innovations such as those offered by BCT.

This study aims to understand why the adoption of BCT is not growing in the fresh produce supply chain, identifying the major opportunities and challenges surrounding its adoption. The context chosen is the UK fresh produce supply chain (fresh and chill chain, value-added vegetables, fruits and salads and the ingredients of these used in further food value-added processes and products), which in many ways is considered at the forefront of production, value-adding and trade in fast-moving food markets. Interestingly, despite the UK having sophisticated stakeholders along the supply chain [21,22] and the largest e-commerce market in Europe [23], BCT in the fresh produce supply chain is not growing, remains untested and is limited to theoretical context.

With these aim and context set out, this study's primary goal was to investigate the readiness of fresh produce supply chain actors concerning the adoption of DLT, particularly BCT.

1.1. Background and motivation

DLT applications can improve the information flow along the fresh produce value chain, which is among such sectors that seek to improve their current operations' efficiency. The complexity of the fresh produce supply chains can drive stakeholders to search for efficient technologies that will increase visibility across the value chain [24].

Overall, the UK is a net importer of fresh fruits, vegetables, and salad products, from the EU and other countries [25]. Food products travel across international borders with thousands of documents that provide information on products' origin, description, regulatory certificates, intended use, destination and other data required to transfer goods and services between nations. Long supply chains operate in the UK, including, among other actors, those food processors and packhouses sourcing certain products and ingredients that are not in production domestically, and retailers that need to stock fruit and vegetable products that are out of season or cannot be produced in the country.

Due to the complexity of these various supply chain scenarios, actors are faced with challenges of high operating costs and issues of data management, like product traceability and transparency. In trying to address these issues, DLT applications can provide a full accounting of food movements along the supply chain. Permanent digital records can be produced for every food product travelling along the supply chain from farm to fork transparently so that processors, wholesalers, distributors, delivery carriers, and consumers can be informed in a timely fashion about where the food comes from and how it was produced [26]. Transparency may be further improved due to an acting party's responsibilities (liability) when trading with another party, which is determined by this kind of technology [27].

Examples of BCT application providers and startups in the food and agriculture sector are IBM, Chainvine, Ripe, Provenance, Ambrosus, Agriledger, TraceRegister, io:Ripe, OriginTrail, TE-FOOD, Blockgrain, FoodCoin, EzLab, and Alibaba, the Chinese e-commerce business trialling a BCT platform to prevent food fraud in China [28,29]. For instance, IBM recently partnered with Maersk, a logistic company, and Walmart, a retailer, with a BCT platform called Hyperledger Fabric, with the operating objectives of integrating the existing electronic data interchange (EDI) information and the enterprise resource planning (ERP) systems [30]. This solution aimed to facilitate the integration of retailers, wholesalers and food manufacturers in fresh produce supply [31]. Another BCT application partnered between IBM and Walmart demonstrated to increase the traceability speed of a global mango supply chain from days to seconds [18]. This feature could be used for strategic product recall in case issues of food safety occur.

The context described above emphasises the motivation of this study concerning understanding why the adoption of DLT is not growing in the fresh produce supply chain, being limited only to the literature, models, and specific pilot projects.

2. Materials and methods

2.1. Research design

In this study, an exploratory research design was adopted to enable participants to express their views freely on the topic [32]. In this way, the set objective has been to seek to extend current theory and generate new insights concerning the DLT-BCT phenomenon. Research exploration was conducted in semi-structured interviews with fresh produce supply chain experts, i.e., managers, and in focus groups performed with fresh produce consumers. A Focus group (FG) is based on a qualitative research technique and relies on the interaction between individuals to obtain personal and emotional responses about a particular area of interest. FGs have previously been used to investigate possible implications deriving from the adoption of novel technologies in the agri-food sector with broad implications on society [33].

The sample consisted of six business managers for the interviews and four consumer focus groups, composed of 20 members, altogether. The companies were selected on the basis that they were operating in the UK, handling fresh produce at a point in their operations and sharing information across their current supply chain. The six managers' choice coincides with scholars [33] that usually at least four cases are sufficient to amplify external validity and establish generalisable theories. The requirements to join the FG were that participants eat fresh produce and are resident in the UK. Also, to bring out diversity in consumer focus groups response, it drew upon various profiles, such as parents, students, and professionals from different backgrounds.

The semi-structured interviews contained questions that concerned the knowledge of BCT, the perceived opportunities and challenges deriving from its potential adoption, and the way information is currently shared along the supply chain, resulting in a total of 7 open-ended questions. FG discussions were conducted by means of support questions that stimulated participants' curiosity towards the following topics: concerns about the fresh produce and the supply chain, type of information expected from food supply chain actors, and expectations toward BCT, resulting in a total of 7 questions. All the questions used in the study are reported in Appendix I.

The data collection sessions were performed during September 2018-July 2019. The interviews

lasted between 30 minutes and 1 hour and 45 minutes and were conducted at company headquarters, except the one with Company C's manager, with whom the interview was conducted over the phone. FGs lasted around 1 hour and 30 minutes, except for the smaller group (FG C) that lasted 45 minutes. The FG took place in reserved public places or caf é, as following detailed.

Transcriptions from both interviewees' answers and FG discussions were compared and used to develop research discussions themes. The analysis of the interview answers and the FG discussions was performed by means of thematic analysis [34], in which themes deemed to represent recurring patterns of meaning within sample data were identified.

2.2. Materials

Before starting interviews and FGs, both text and non-text–material was provided to participants to introduce the topic and stimulate the discussion. In particular, a textual overview of study aims was shared with participants who could access it through a tablet provided or their smartphone. Thus, an article from IBM newsroom describing a BCT application in the food industry was presented. After this, a YouTube video on BCT and food safety was presented; the video included an 18-minute long conference held in 2017 by Frank Yiannas, vice president for Food Safety at Walmart, who introduced BCT features and IBM-Walmart joint pilot projects (see Appendix II to access the textual overview, the IBM press article and the YouTube video). The additional non-text material was considered to be a richer and more accessible way of introducing novel technology.

Interviews and FG discussions were recorded with a digital audio device while taking notes of key quotations. The recorded interviews were transcribed verbatim.

2.3. Sample description

In this section, an overview of food processing companies and the participants interviewed is provided. All participants had not prior BCT knowledge, with the only exception of Company A's manager.

Company A. It is one of the leading potato packing and fresh potato value-adding companies in the UK, supplying major retail chains. The company has sites across the UK, with growers supplying potatoes nationwide. The company's main activity includes procurement, washing, grading, and potatoes' packing for their customers. Their concern is on yields (quantity) and quality of potatoes coming to their factory. One manager was interviewed, the Director for Innovation (ID-A).

Company B. Based in the UK, it imports fresh produce not produced in the UK from countries outside the EU, specifically from Asia, the US and Europe. The company's core business is transforming selected fruits and vegetables into finished and semi-finished products to supply small independent retailers, national and multinational supermarket chains, food manufacturers and foodservice companies. They supply a wide range of cooked ingredients, sauces, dips, dressings, drizzles to customers throughout Europe and non-EU countries. Four managers were interviewed: the Commercial Director (CD-B), the Technical Director (TD-B), the Supply Chain Director (SD-B), and the Production Director (PD-B).

Company C. Leading freshly prepared food provider is present in five countries, including the UK, the US and China, with 48 different sites supplying 5500 different products. Their major

customers include large retail and foodservice chains. The company's primary purpose is to develop and produce innovative, commercially successful food that offers choice, quality, convenience, and freshness. Their products include ready meals, salads, desserts, fresh pizza, and bread. The company sources over 5000 different ingredients around the world from selected growers and suppliers they know and trust. The interview was performed with the Process development manager (PDM-C).

FG A (n = 5, 45–70 years). It was conducted in the suburbs of the Greater London area and was composed of a retired high school teacher, a retired nurse, a housewife, a husband and her wife (with children), respectively, working in a factory and as a public tax officer.

FG B (n = 7, 18–25 years). It was composed of students from various universities and colleges in the southwestern part of the UK. The group consisted of a master's student, a Bachelor student, a first–Degree graduate, and four college students. The interview was conducted at the community centre for youth.

FG C (n = 3, 25–45 years). Participants were working professionals, including an accountant, a religious minister (Church pastor) and a nurse. The interview was conducted at the city library as participants regularly come here for their research.

FG D (n = 5, 25–45 years). Participants were from the South East London district and included a medical doctor, a distiller, a science teacher, a human resource officer, and a project administrator officer. The meeting took place in a Café.

3. Results

Results allowed identification of five major themes: the novelty of BCT, supply chain characteristics, open data, cost-benefit analysis, the role of public stakeholders, each of them characterised by a number of sub-themes that may constitute challenges or opportunities concerning the adoption of BCT (Table 1).

3.1. Novelty of BCT

This theme was further divided into BCT knowledge and issues concerning the BCT compatibility/integration with the existing ITC systems.

3.1.1. Knowledge of technology

Most of the managers interviewed had no previous knowledge about the application of BCT in the fresh produce supply chain, pointing out they were unfamiliar with it:

"We have come across a number of platforms to allow us to identify our information points for reporting globally, […] but not specifically BCT; and we are not aware of it" (TD-B).

"Blockchain technology is not something I am particularly familiarised with. No one has ever approached me about the technology, and I have never discussed it before" (PDM-C).

Although one manager had prior knowledge about the BCT through articles from literature as his job includes researching into new opportunities to improve production efficiency, he confirmed that his company has no plans of running projects on the topic:

"The technology will connect points of data collection and therefore improve traceability and transparency within the supply chain. Blockchain is on our radar, but currently, we are not running

any project on the application of the technology to our supply chain" (ID-A).

The lack of awareness of the opportunities of BCT in the food sector has also been acknowledged from the consumer side and appeared to be the major reason why consumers are not pushing for the adoption of the technology:

"The only issue is lack of education. The publicity is not there; I never knew such technology existed" (C-2).

"We need to be educated. I will need to be educated on the agri-food supply chain system as I do not sometimes understand the terms they use" (C-1).

3.1.2. System integration

UK operators fear BCT will disrupt current processes, as it has not been proven. Although BCT has been tested and implemented by Walmart and Carrefour outside of the UK as described earlier, it has not yet been tried and proven in the UK.

"The challenges will be the management of the project in terms of software/hardware integration into our current system, and clear benefit identification for our business" (PDM-C).

"It is difficult to say whether or not we will be able to implement the technology at this stage unless the technical and economic aspects of the technology are fully understood" (CD-B).

3.2. Supply chain characteristics

Interviewees deeply debated this theme, and it is associated with the pros and cons of the current UK food system that emerged from discussions. Three main interrelated points emerged from the discussion: the information flows along the supply chain, the nature of the products, and the supply chain dimensions, in terms of the number of both products used and actors involved.

3.2.1. Information flow

The product flows along with the UK food system, mostly based on a centralised food system with large-scale supermarkets and regional distribution centres [35], were recognised as efficient. Fresh produce goes through a speedy supply chain network, and food waste is reduced through timely delivery of products to retail stores from production sites. Despite the material flow of products was not questioned, the speed of information flow across international supply chains is challenging to the current food systems. As observed, the whole data management, including data collection, distribution, and storage on a centralised system, delays the information flow across the network, as members do not share data in real-time:

"We are currently operating on a system that [only] allows our suppliers and national authorities to supply us documents ten days after the products has been shipped from the port to us here in the United Kingdom" (TD-B).

3.2.2. Type of product

It was noticed that for companies handling single natural integral products like vegetables, the need for BCT as a mean to guarantee food safety is minimal as produce undergoes further processing

like cooking to reduce and or eliminate certain food safety risks such as pathogens. For instance, a single fresh produce category like potatoes is not seen as high-risk in the way that meat is and, therefore, does not require much visibility from their customers and consumers at large:

"There isn't a compelling and commercially valuable need of the technology now, as the fresh produce sector is not a high-risk area compared with the meat industry that needs to redeem its image after the horsemeat scandal[1]" (ID-A).

Table 1. Themes, opportunities, and challenges contributing to BCT adoption.

THEMES	SUB-THEMES	Opportunity/ Challenge	Contribution
3.1. Novelty of BCT	3.1.1. Knowledge of technology	C	• Scarce awareness of BCT by firms and lack of education on the technology for the public
	3.1.2. System integration	C	• Fear of the disruption of current processes
3.2. Supply chain characteristics	3.2.1. Information flow	O	• Interest to increase the speed of information flow
	3.2.2. Type of product	C	• Vegetables are associated with fewer safety concerns
	3.2.3. SC size	O/C	• The more products are treated and the longer the SC is, the higher is the need for BCT (and vice-versa)
	3.2.4. Role of retailer(s)	O/C	• Retailing is in a higher bargaining position concerning technology adoption
3.3. Open data	3.3.1. Data democratisation	O	• Consumers want to know more about food
	3.3.2. Strategic information disclosure	C	• Companies are reluctant in sharing confidential information
3.4. Cost-benefit analysis	3.4.1. Undefined costs	C	• Uncleared cost items surround BCT
	3.4.2. Additional value perception	O	• Consumers can value BCT adoption, increasing the safety of food
3.5. Role of public stakeholders	3.5.1. Citizen pressure	O	• Consumers' request for food safety protection mechanisms
	3.5.2. Brexit	C	• Uncertainty concerning the BCT impact on UK/EU trade

Source: Authors' elaboration.

3.2.3. SC size

The need for a change towards BCT adoption was highlighted by a manager whose company handles hundreds of ingredients imported from other countries. He justified the assertion by

[1] The reference is to the horsemeat scandal in the UK in 2013, where horse meat ingredient was passed off as beef [46].

admitting objective difficulties in handling information coming from upstream actors supplying, even with some time delay, numerous raw materials:

"Produce does not grow in the UK all year round, so we source for our raw materials around the world" (PDM-C).

The supply chain's size also depends on the number of actors involved. In the UK, supermarkets are dealing directly with producers and setting up facilitates at farms in the UK and abroad, so that packed products can be delivered directly to distribution centres [36,37]. This mode of supply chain operation shortens the journey of products, and its accompanying information, as they go through fewer steps before reaching the final consumer. As such, the view from one of the managers is that BCT may not be necessary for such a food system where operators are easily identified in such a short chain, whereby:

"Traceability from the perspective of consumers and customers (retailers) are fully met with our current system" (ID-A).

3.2.4. Role of retailer(s)

Although some of the interviewees did not see a specific need for the technology in their operations, it was acknowledged the influence of customers, mostly retailers, on their decision to adopt new technologies like BCT for visibility purposes. In this regard, all managers companies expected retail companies to lead the campaign for the implementation of BCT in the current food system, sometimes regardless of the supplier view:

"We are led by what the retailers tell us because they hold the guns and are the dominant players. Without them, our products do not get to the consumer" (PD-B).

"Should there be a need from the consumer or [retailer] customer for the application of Blockchain technology, there will be adoption should the [retailer] company see a need for the application of Blockchain" (ID-A).

3.3. Open data

From discussions, it clearly emerged the potential of BCT in bridging food information gaps. This issue affected consumers concerned by the lack of information surrounding food production and supply chain actors, some of whom interpreted totally open data as potentially a competitive threat.

3.3.1. Data democratisation

With the notion of being left out on decision making, most of the participants highlighted the need for alternative ways to be included in the food supply chain network as stakeholders:

"I would like to see a system where I can scan products bar code with my phone and get all the information, I need to make a decision […] the technology will give us options through information provided and help us to decide for ourselves" (D-3).

"The supply chain as it is now should be updated in line with the current technologies we have. They should work together so that the system can be improved for the consumer as things are changing" (C-1).

"People want to know the content of their food; people are becoming aware of what they eat

and want more information. I think for justice to be done; the scope of activities carried out within the food industry must be given but broken down into sections so that we can see everything clearly" (A-1).

"We are diverse people, and each individual may be interested in different information like place of origin, how it is grown, process, and stored. I think individuality in information request should be considered in the design of this system" (A-4).

"I want to know the country of origin of my fresh produce, when it was harvested and how long it has been in the supply chain. This information will inform my decision and also protect me as a consumer" (D-4).

3.3.2. Strategic information disclosure

The public's request for knowledge is set against the competitive atmosphere surrounding the supply chain systems. With the fear of antagonising competition through wrongful data sharing among competitors, companies are not ready to operate a single platform to manage information for rival customers. A view may be that opening up to the public with sensitive information, such as identification of the origin of certain ingredients that make a company identifiable in the market, may hold back the adoption of BCT:

"From a competitive perspective, can a consumer know everything about us that we don't want our competitors to know?" (CD-B).

3.4. Cost-benefit analysis

Economic assessment is the basis of every technology adoption. The participants made sense of BCT by engaging in a cost-benefit analysis whereby they weighed up the potential advantages and disadvantages of the technology. Opinions seemed to carry uncertain risks and benefits.

3.4.1. Undefined costs

Managers typically wanted BCT providers to come up with costs surrounding the technology's adoption. However, costs in terms of software; (these usually being license costs), hardware; (referring to purchasing and maintaining equipment), training, and operational cost, are unknown. Until the fog is cleared, the adoption of the technology will continue to face challenges due to the un-cleared cost element surrounding the technology:

"It will come down to cost and payback. We will need a capital expenditure proposal to demonstrate that the money we are spending will be paid back over a certain period; that is, the scale of the project and the payback time should be acceptable. It will come down to what will benefit us as a company and where that cost will be demonstrated, for example, will the cost be passed down to the consumer?" (PDM-C).

3.4.2. Additional value perception

In general, consumers foresee a competitive advantage for supply chains that will implement the technology. Further, they may be willing to pay a bit extra for products that can be traced on BCT

platforms, as this will give them confidence when buying fresh produce:

"I am willing to pay a little bit more for fruits and vegetable that are on Blockchain technology, as that will guarantee my health and safety should there be any food scare" (C-2).

"I will pay for this technology, knowing that when there is a foodborne disease outbreak from a particular country, I will know and stay away from it" (B-1).

However, a sizeable share of consumers believes that technology should not be costing the final consumer extra money in terms of price increment. In their argument, the technology is not going to add extra satisfaction to what they are already enjoying but rather increase the efficiency of the supply chain:

"I am not willing to pay something extra for products on Blockchain. I believe Blockchain is not adding anything new. Product value, quality and quantity will remain as it is why to charge me more?" (D-5).

"For me, no, looking at the current economic situation, I will not like to see any changes in prices at the shops. The technology should be a replacement for the existing systems, and therefore it should be free to the consumer" (D-3).

3.5. Role of public stakeholders

During FG discussions, the feeling was that consumers heavily rely on public bodies in order to guarantee food safety standards. At the same time, they would like to see food system organisations work together in consumers' best interests. Last, in the participants' view, Brexit (the United Kingdom leaving the European Union) might have posed further challenges as this was not yet signed at that time.

3.5.1. Citizen pressure

The view that emerged was that public stakeholders should encourage the adoption of BCT in the food system, as they completely depend on these to protect their best interest through their assurances:

"The government, the consumer organisations, food regulators and other authorities should enforce the adoption of such technologies because we believe in them in making sure we consume safe food" (C-1).

3.5.2. Exit of the UK from the EU

For some managers, the uncertainty of the outcome of the UK leaving the European Union might have had a great effect on their decision to adopt new technologies such as BCT, as they currently rely on the EU free entry policy to import produce from other EU states. Although Brexit was later signed, the speculations about this issue were a sign of the potential role of BCT to ease the disruption deriving from an unusual, dramatically impacting event.

4. Discussion

The novelty of BCT, coupled with low publicity about its application in the fresh produce

supply chain, has contributed to the slow adoption of the technology and will likely challenge it for the years to come. BCT is a new topic and is still unknown to most industries [38]. At the same time, the development of the technology may become a pull for industry operators if they foresee a competitive advantage in adopting the technology earlier than their competitors. On the other hand, BCT's novelty might also become a barrier if there is an anticipated fear of disruption to current processes. Companies have been using their current digitalised central systems over the years and have become accustomed to them. As such, they may not be ready to change for a newer technology that has not been tested in their sector continuously. One of the main constraints for most technology solutions is the unsolved issues of standardisation of communication technologies and protocols. Before an industry adopts solutions on a large scale, technology incompatibility issues and lack of standardisation must be resolved [39]. Questions surrounding BCT compatibility with complex supply systems have not been answered with its application in the UK setting. Due to the technology's novelty, operators continue to worry about how applicable BCT is with their current supply chain systems and why they should adopt the technology if the current system is serving its purpose [31].

Intrinsic characteristics of the fresh produce supply chain pose several opportunities and constraints concerning the adoption of BCT. With the opportunities offered by BCT in increasing transparency and information flow in supply chain systems, companies who are challenged with the speed of information delivery along the supply chain would be interested in the adoption of similar solutions for their operations.

The decision to adopt BCT also depends on the nature of the food product and the sector. Risks associated with certain food groups may drive stakeholders and government agencies to seek new technologies, such as BCT, to improve visibility in their operations. For example, after the horsemeat scandal in the UK in 2013, the meat industry was identified as a high-risk sector, forcing operators of the supply chain and the food standards agencies to look for innovative ways to reclaim their lost dignity. However, the fresh produce sector is not a high-risk area compared to other food sectors; thereby, under this point of view, a compelling need for DLT is not evident.

However, most long supply chain systems of fresh produce may have processing steps along the chain due to fresh produce's perishable nature. Food processing companies transform raw materials and ingredients from different countries into finished products combined with other source ingredients. It is difficult for companies to trace each step in the journey of a specific product back to its origin of production due to a lack of records and data reliability [39]. This fact raises issues concerning the rapid traceability that BCT can allow to timely overcome possible food-related disease outbreaks.

From the interviews, it emerged that retailers often play a pivotal role even in technological upgrading. Retailers, described as "channel captains" due to the large amount of produce purchased and their influence over other actors within the food system [35,40], in fact, have the power to initiate a program for their suppliers and the conditions/technologies controlling product supply. Thus, they influence which technological systems to adopt and discourage the adoption of any technology that does not suit them. Retailers have the power to push for consideration of BCT. The influential UK retail chains are currently considered gatekeepers [39,50] and can influence other supply chain members to accept technologies such as BCT.

Another theme that emerged from the debates concerned open data, to which BCT is also strictly related since DLT is suitable for disclosing and sharing information [41]. Open Data is the

idea that all data, excluding the data having clear reasons for non-disclosure, should be freely available to everyone with no intellectual property control restrictions [42]. Today consumers are more concerned about their health and the quality of food they are purchasing; therefore, they are more exigent when it comes to the origin of the product [43]. The study confirmed this attitude: consumers would like to know what constitutes their food and the journey it went through before arriving at their table. The possibility of disclosing information about the food supply chain was opposed by companies that spotted market threats in disclosing high importance business information since this disclosure can advantage competitors. On the other hand, competition in the market is a major barrier to adopting any innovation [39].

Cost is one of the principal factors that influence innovation adoption. It is understood that a large majority of fresh produce stakeholders (including farmers) will not implement new practices until reliability and cost benefits are assessed. With scarce knowledge of BCT from supply chain stakeholders, it is not surprising that even cost items surrounding BCT are uncleared. Actually, uploading and retrieving data attached to a BCT can be very costly [44]. Thus, this will be a barrier to the widespread adoption of BCT in the food sector. Nevertheless, interviewed consumers hinted they would appreciate any DLT adoption provided that food safety features are enhanced.

Moreover, consumers see regulating bodies as enforcers of good practices, as they (consumers) acknowledge regulators of having some level of influence over the UK's food supply chain system. Public opinion in the form of collective behaviour plays an important role in decision making and can act as a paradigm shift for the acceptance and decline of projects [39].

5. Conclusions

In this study based on interviews with food processing companies and consumer FGs, five main themes and twelve sub-themes were identified as factors influencing the adoption of BCT in the fresh produce supply chain.

The study identified several opportunities from supply chain characteristics and consumer behaviour as major factors that can drive BCT adoption. Regarding the supply chain, opportunities include increasing information flow speed, especially when the supply chain is long with multiple nodes. The traceability process becomes difficult to manage when the supply chain members operate different systems to record and share data across the network. Food processing companies sourcing hundreds of ingredients worldwide face this problem since they are expected to account for each ingredient in their product when food safety issues arise. A system that will enable food processing companies to trace ingredients to their source in a reasonable time requires a high level of coordination and would benefit from BCT-based solutions [45].

Consumers want to know more about food and are most concerned about their health. They are open to new technologies that will give them insight into the supply chain actors' operations. Also, fraudulent activities like the horsemeat scandal of 2013 and the cumin seeds substitute case of 2015 have reduced consumers' confidence in operators to provide them with credible information on product packages. To win back consumer trust, industry players, including government agencies and regulators, are concerned with putting measures in place to increase visibility in the current food systems. The consumers involved in this study welcome the idea if the piloted project can be extended to other food categories, including fresh produce. In this context, supply chain actors should investigate a common approach to applying BCT in existing food safety protocols in whole

chain sourcing and supply.

Other factors hamper the adoption of BCT in the food supply chain. First, there is still scarce awareness of BCT (and of DLT in general) by supply chain actors that determines on the one hand fear of the disruption of current data management processes and the disclosure of confidential information while hiding at the same time cost elements surrounding the technology. In this regard, education, trials and stakeholder consultations can pave the ground for a better understanding of BCT by supply chain actors. Unless BCT is fully demonstrated and recognised to solve the problems of its intended purpose at a reasonable price, its adoption will not be taken up easily by its users.

Suspended between opportunity and barrier, retailers tip the balance in decision-making and supply channel governance. Their importance positions them also in a potential mediating role concerning BCT adoption. For this reason, their significance in this context deserves further research. Much effort should be placed in studying BCT solutions in the food value chain to understand whether the technology will contribute to commercial gains and add trust in supply chain operations.

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Conflict of interest

The authors declare no conflict of interest.

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Supplementary

Appendix I

Interview guided questions for fresh produce supply chain managers:
a) How much do you know about Blockchain Technology?
b) Can you briefly describe your current system of information sharing between you and your suppliers?
c) How flexible is your company in the adoption of new technologies?
d) Can you identify any opportunities you might derive in using Blockchain technology?
e) What will be some of the challenges in the adoption of Blockchain Technology to your operations?
f) If Blockchain technology is offered to you, will your company be readily adopting it and why?
g) Who do you think should drive the implementation of Blockchain technology in the fresh produce supply chain?

Interview guided questions for consumer focus groups:
a) What are your concerns on the current supply chain of fresh farm produce, specifically fruits and vegetables?
b) As a consumer, what information do you want food processing and packaging companies to provide you and why?
c) How will Blockchain improve the current fresh produce supply chain?
d) Will you be willing to pay a little more for products on Blockchain?
e) In your opinion, what will be some of the challenges in the implementation of Blockchain?
f) Who do you think should drive the implementation of Blockchain technology in the fresh produce supply chain?
g) Do you see the implementation of Blockchain in the fresh produce supply chain soon?

Appendix II

Overview of Research Aim and introduction to Blockchain technology:

Blockchain has been reported to offer a solution to food safety issues facing the food industry, specifically issues relating to food safety, traceability, transparency and trust.

The aim of this research is to understand why the adoption of Blockchain technology is not growing in the fresh produce supply chain in the United Kingdom but remains untested and limited to the literature, models and pilot projects studies in the United States of America and France.

The study is designed to help us understand how stakeholders of the fresh produce (fruits, vegetables and salads) supply chain are informed about Blockchain technology and its application in their operations and/or activities. The study will help identify approaches in tackling issues surrounding the adoption of the technology and identify effective methods in creating technological awareness, Knowledge, and implementation.

Link 1—Article from IBM news room:
https://newsroom.ibm.com/2018-10-08-IBM-Food-Trust-Expands–Blockchain-Network-to-Foster–A

-Safer-More-Transparent–And-Efficient-Global-Food-System-1 (last access on March 27, 2021).

Link 2—YouTube video Genius of Things: Blockchain and Food Safety with IBM and Walmart, including a presentation from Frank Yiannas, vice president for Food Safety at Walmart: https://www.youtube.com/watch?v=MMOF0G_2H0A (last access on March 27, 2021).

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