Contributions to Management Science

Chen Zhang
Yu Gong
Steve Brown

Blockchain Applications in Food Supply Chain Management

Case Studies and Implications

Springer

Contributions to Management Science

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Case Studies and Implications

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Chapter 1
Introduction

In this chapter, the project background is introduced. This includes the motivation for this research and how the paper can contribute to the broader field of study. The current food system is complex, and food hazards are happening more frequently than ever. Therefore, the first section introduces food quality and safety issues in the current food industry. This section presents the food industry reality with real-world examples. The second section describes the food supply chain and its importance to the food industry. The third part discusses the issue of traceability and its contribution to food quality and safety. The following section presents some current traceability innovations. Blockchain is introduced in the fifth section with lists of real-world application examples. The last section proposes the research questions and sets out the structure of the research.

1.1 Food System

Food systems are complex and keep changing over time (Yakovleva, 2007; Wognum et al., 2011). There are many issues in the current food system, including climate change, foodborne diseases, food shortage, malnutrition, resources insufficiency, and food wastage, among others. Among all the issues, food quality and safety issues are gaining more attention due to an increasing trend of food hazards in recent years. Food safety is a major concern when customers are making purchasing decisions (Sims, 2018). Before the 1980s, food quantity was the major issue (Kaferstein, 2003). The food safety issue was first properly addressed in 1983 by the first Expert Committee that was held by World Trade Organization (WTO) and the Food and Agriculture Organization (FAO). Accessing nutritionally adequate and safe food is a basic human right, according to the joint FAO/WHO on International Conference of Nutrition in 1992. However, to satisfy the individual's right of food safety is more of a promising idea than a reality (Kaferstein, 2003).

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In terms of food hazards, unsafe foods can cause more than 200 diseases, with almost 1 in 10 people becoming sick each year (WHO, 2020). More specifically, as one of the counties with the safest food supply, the US still has 48 million cases of foodborne illness every year, which can result in about 3000 deaths and 128,000 hospitalisations, according to the FDA (2019a). In 2008 and 2009, nine people died and at least 714 people were infected from eating products containing salmonella-contaminated peanuts. It was one of the largest food disease issues in the USA's history (Steenhuysen, 2009). The inadequate level of cleanliness in the producing factory included mouldy ceilings and cockroaches, and the lack of a handwashing sink was reported (Steenhuysen, 2009) as a cause. In other developed areas, the horse meat scandal was revealed in the UK in 2013. The investigation found undeclared horse meat in beef burgers (Telegraph, 2013). Most recently, E. coli-contaminated lettuce has caused at least five deaths in the USA and spread across 35 states in the USA (Wheaton, 2018).

Compared to developed countries, the number of deaths and illnesses caused by food hazards in developing regions can only be higher due to multiple factors such as: population growth, lack of health-related infrastructures, lack of policies, poverty, and lack of hygiene education (Kaferstein, 2003; Aruoma, 2006). One of the most shocking food incidents in Chinese food history happened in 2008. One of the biggest national diary companies—Sanlu—was accused of using the toxic chemical melamine in milk powder to increase the protein content, this caused at least six babies' deaths and harmed the health of thousands of children (BBC, 2010). To increase the protein content, milk powder producers used melamine, which is a toxic ingredient normally found in plastic, fertilisers and cleaning products, to replace protein. After the incident was revealed, 19 people who were working in the factories were jailed for using toxic ingredients. The executives of Sanlu companies were also arrested because of selling toxic products (BBC, 2010; Business & Human rights resource centre, 2010). According to a survey in 2011, food safety was the top issue that concerned Chinese people (Lam et al., 2013). There were 6685 food incidents reported officially in China in 2012 (Lam et al., 2013).

The food trade is now one of the largest global businesses, and the food system is becoming even more complex with more stakeholders involved (Roth et al., 2008; Christopher et al., 2011; Storoy et al., 2013; Ringsberg, 2014; Mattevi & Jones, 2016). It is very common to have one food product with a combination of multiple ingredients sourced from various countries, as Roth et al. (2008) proposed that global sourcing of food and ingredients is extensive. According to the FDA report in January 2019, the volume of imported seafood, fresh fruit and vegetables are reaching 94%, 55% and 32%, respectively, in the USA (FDA, 2019b). The importing figure is showing a gradually increasing trend. There are a few reasons for such growth including decreased purchasing costs, limited local resources, and increased market demand (Ringsberg, 2014). However, global trade also increases the chances of food risks due to factors including geographical distance, cultural differences, the economy, and policies (Ghemawat, 2001). According to the sensitivity levels summarised by Ghemawat (2001), food products like meat and cereals, drinks and sugar, live animals and meat products are more sensitive to *cultural*

distance, *administrative* distance, *geographic* distance, and *economic* distance, respectively.

Food quality and safety is a worldwide phenomenon and very much associated with the globalisation and outsourcing phenomenon (Yakovleva, 2007). More than just ingredients and raw materials, processes such as food processing and transportation are also involved (Mai et al., 2010). Safety issues not only contribute to the growing problem of public health issues but also have a significant impact on national economies. A few researchers have mentioned the potential negative impacts of the globalised food trade, such as the disparities that cause vulnerability in the food supply chain, inefficiency in communication, low transparency, low accountability, and lack of proper monitoring (Ghemawat, 2001; Roth et al., 2008; Yakovleva, 2007; Ringsberg, 2014; Mattevi & Jones, 2016). In 2018, 28 out of 382 food recalls in the USA were due to foreign material contamination (Maberry, 2019). The case example mentioned above, Sanlu milk scandal not only caused the death of babies in China but also contaminated pet food in the USA (Waldmeir, 2008). After the issue was exposed, many countries such as Japan and Singapore had to ban the import of any Chinese dairy products and recalled products which may contain suspicious ingredients (BBC, 2010; Huang, 2014).

Given the complexity of the food supply chain system, how to solve the related issues and be more sustainable is meaningful and timely. The following sections introduce the background information of the food supply chain, food traceability, and blockchain application. The food supply chain can provide a "holistic perspective", which allows us to identify the problem and propose possible solutions to food system issues by "understanding the interrelatedness of processes" (Yakovleva, 2007, p. 78; Kouhizadeh & Sarkis, 2018). Food traceability is a strategic approach for both preventing potential food hazards and helping with food recalls. By operating technological innovations, food traceability systems are becoming more efficient. Among all the technologies, blockchain is emerging and gaining more attention due to its uniqueness and huge potential. It is believed to bring a significant change to the food traceability systems.

1.2 Food Supply Chains

The food supply chain is considered

> a network of organizations, which through economic relations with each other enable the functioning of the supply chain for the production and distribution of food (Yakovleva, 2007, p. 76).

From this definition, the food supply chain is about physical products flow, information flow, and financial flows from "farm to fork" (Stevens, 1989; Dani & Deep, 2010). Folkerts and Koehorst (1997, p. 11) provided another definition:

> a food supply chain is defined as a set of interdependent companies that work closely together to manage the flow of goods and services along the value-added chain of

agricultural and food products, in order to realize superior customer value at the lowest possible costs.

In this case, the importance of collaboration and information flow, which refers to the transparency of the supply chain and the openness of discussions between stakeholders, are emphasised to achieve the supply chain objective, which is to satisfy customer demand at minimum costs (Stevens, 1989; Boehlje, 1999; Lindgreen & Hingley, 2003; Trienekens & Zuurbier, 2008; Dani & Deep, 2010; Feenstra et al., 2011). On average, from retailer to consumer, there are 27 intermediaries across three to five countries that process 240 copies of documents to each batch of the product, and 95% of the information from the documents has no value. Food tracking to the origin takes about seven to 14 days and requires several organisations to cooperate (Cointelegraph and VeChain, 2020). According to Folkerts and Koehorst (1997), the supply chain becomes more market-driven, which emphasises customer demand more. Consumers need food products to be healthy, safe, of good quality, and with various choices. Particularly after the COVID-19 pandemic, there is a rising awareness of food safety among consumers (Trienekens et al., 2012; Cointelegraph and VeChain, 2020; McKinnon, 2020).

1.2.1 Prevent Potential Food Hazards

There are two defences of food safety in the food system before and after food hazards. The first one includes policies and inspections to prevent potential contaminated food products flow in the supply chain, while the second defence is the food recall system when food hazards are identified (Karthikeyan & Garber, 2019). Food security is considered as a shared responsibility for the whole supply chain and all stakeholders, including producers, governments, and customers (Kaferstein, 2003; Trienekens et al., 2012; Storoy et al., 2013; Aung & Chang, 2014; Karthikeyan & Garber, 2019).

To maintain food quality and safety, governments and non-government organisations have contributed to propose certification schemes, such as legalise food laws, give indicators for food quality, and make regular checks, in order to "reach a defined performance and to make this known to stakeholders…" (Ringsberg, 2014, p. 567). The increasing global food business also means the increasing importance of global certification standards (Ringsberg, 2014). For example, the International Organization for Standardization (ISO) 22,005 Food Safety Standard required companies to launch the one-up (suppliers) and one-down (customers) principle to know their immediate suppliers and customers (ISO, 2007). The Sanitary and Phytosanitary Measures (SPS Agreement) was proposed in 1995 to ensure that exporters should always meet the quality and safety requirements in the import market (WTO, 1998). In the food law area, EC General Food law regulation 178/2002 requires a traceability system for food products in Europe (European Commission, 2002). For developed countries, for instance, American food and

feed companies were required to register with the FDA to maintain records for traceability purposes (FDA, 2019c). Developing country governments also show a growing awareness of food quality and safety control due to globalisation (Trienekens & Zuurbier, 2008). For example, Chinese governments published more than 52 laws to address food hazards and increased the frequency of inspections (Tang et al., 2015).

For food companies, it is important to be proactive to identify potential supply chain risks and minimise the impacts (Dani & Deep, 2010). The food supply chain is considered as vast with multiple stakeholders and processes involved vertically and horizontally. However, it can be fragile in that one single unit failure can cause the collapse of the whole supply chain. For food products, extra attention is needed in the supply chain processes; factors such as temperature, humidity, and storage conditions can largely affect food quality and may cause safety issues (Aung & Chang, 2014). Hazard analysis at critical control points (HAPPC), therefore, has been developed to ensure the needed transparency and to prevent possible hazards (Aruoma, 2006; Trienekens & Zuurbier, 2008; Aung & Chang, 2014). This pre-check auditing method was recommended to many governments and policymakers to avoid excessive food testing (Lam et al., 2013). HAPPC principles include analysing hazards, identifying critical control points, building procedures to manage the control points, designing actions, verifying the whole system and record-keeping, and are used in many systems and regulations to ensure food quality and safety (Trienekens & Zuurbier, 2008). Besides running the risk analysing system, there are more things companies can do to prevent risks, such as giving hygiene education to employees (Kaferstein, 2003), building close and long-term relationship with suppliers (Lindgreen & Hingley, 2003), and complying with food safety policies (Kaferstein, 2003), among others.

Consumers also have responsibilities to ensure food safety (Kaferstein, 2003; Aruoma, 2006). A considerable number of illnesses and deaths are caused by unhygienic food preparation due to unhygienic cooking facilities, lack of personal hygiene, or cooking improperly, among other factors (Kaferstein, 2003). This situation is particularly serious in poverty areas, where the people have less awareness of cleanness, and insufficient infrastructures (Kaferstein, 2003). According to the WHO (2019), 35% of people from low- to middle-income countries lack water and soap for handwashing, while 19% of people have no improved sanitation. Although the number of diarrhoeal-related deaths has decreased in the past 25 years after improving water and sanitation, there were still about 1.3 million children killed by poor sanitation and unsafe food and water in 2015 (GBD Diarrhoeal Diseases Collaborators, 2015). Apart from development on consumer awareness and local infrastructures, Kaferstein (2003) also mentioned the lack of direct communication between consumers and other parties (governments and food companies) and suggested that close collaboration between partners is vital.

1.2.2 Food Recall

The second fence is food recall. Efficient food recall along supply chain is the last protection for customers (Karthikeyan & Garber, 2019). Food recall is a formal request made by companies to their customers based on the suspensions of dangers on food quality and safety (European Commission, 2002). In other words, food recall is the consequence of product failure. The food hazards mentioned above are only the tip of the iceberg. In 2018, there were 382 food products recalls in the USA, and the total food recalls are showing an increasing trend (Karthikeyan & Garber, 2019; Maberry, 2019). The issues can be caused by food contamination, excessive use of chemicals, inappropriate handling and storage, mislabelling, and undeclared allergens (Ringsberg, 2014; Maberry, 2019). For example, 160 out of 382 US food recalls in 2018 were caused by undeclared ingredients, such as milk or nuts, and 40% of the total recalls were due to microbiological contamination (Maberry, 2019).

During the products recall, it is not only the customers that face health threats; food companies also suffer economic loss from product recalls (Ringsberg, 2014). The average costs for one recall were $10 M for an American food company (Tyco Integrated Security, 2012). In 2011, 31 people were killed and thousands of people were infected by having German-produced bean sprouts (Sample, 2011). The outbreak brought huge compensation (210 m euros) to farmers and Germany suffered economic loss from restrictions on its exports of fresh food (BBC, 2011). In 2007, the American food brand ConAgra recalled 326 million pounds of Peter Pan and Walmart's peanut butter plus 99,953 cases of topping due to a salmonella outbreak (Nash,2007). The recall cost ConAgra company more than $78 m, plus 63% drop in sales in the year (Nash, 2007; Danovich, 2016).

Many researchers have mentioned that consumer confidence can drop significantly after recalls (Opara & Mazaud, 2001; Grunert, 2005; Kumar & Budin, 2006; Ringsberg, 2014; Tang et al., 2015). The large number of food hazards leads to increasing concerns over food quality and safety, which is also called "food scares" (Grunert, 2005). From the food safety survey in China in 2018, more than two-thirds (68.3%) of participants were concerned about food fraud problems (Fortune, 2018). For example, apart from Sanlu company, another 22 companies also involved in the milk scandal including other well-known national brands such as the Beijing Olympic dairy supplier, Yili company and one of the major national dairy brands of Mengniu (Huang, 2018). Moreover, other low-quality foods such as plastic seaweed and recycled food oil were also exposed and caused more panic on national food brands. Local authorities were also under investigation due to the suspension of bribery and covering up for criminals. All those scandals revealed the weakness of food law in China and destroyed the public trust in national food brands and government authorities (Huang, 2014). Grunert (2005) proposed that public perceptions of food risks do not apply in normal conditions, but can have a huge impact on customer confidence and buying choices during food hazards. Even 10 years after the Sanlu milk scandal, Chinese parents still tend to trust foreign brands more, and the fear of national food safety remains (Huang, 2018). Food recall-related indirect

losses and further damages on brand reputation and sales are countless. Other examples of customer confidence loss caused sales drop include: the horse meat scandal mentioned above, caused the major retailer brand TESCO lost an estimate $408 m due to the international sales drop by 4.6% (Ringsberg, 2014); the whole egg industry lost about $100 m in revenue in 2010 due to the salmonella outbreak (Danovich, 2016).

1.3 Traceability

Once food recall happens, it is important to identify problems and take the appropriate actions during the "golden hours" (Dani & Deep, 2010). Slow reaction and delays can only cause more damage and costs (Roth et al., 2008). In other words, speed of response to the problem is crucial. In many cases, the recall tends to be very complicated and slow (Lindgreen & Hingley, 2003). For example, to issue a recall in the USA, a few steps are needed beforehand, such as conducting inspections, collecting samples, and clarifying risks (Chamlee, 2016). It is possible to take more than 100 days to complete all the steps. After the FDA was informed of the potential risk, the average recall for companies can take another 57 days (Mccallister, 2017). Moreover, even when the recall decision is finally issued, it is still hard for the FDA to know how completely the recall has been carried out (Danovich, 2016). That is, dangerous food can remain due to food recall failure (Mccallister, 2017; Karthikeyan & Garber, 2019). For example, I.M. Healthy soy nut butter spreads and granolas were recalled due to an E. Coli outbreak, which caused 32 illnesses in 2017 (Karthikeyan & Garber, 2019). However, the contaminated products were still sold in some places 6 months after recall was issued. This example shows an extreme example of inefficiency of food recall in the food industry, which can lead to deeper food safety concerns.

In this case, an efficient traceability system is considered as an important mechanism, "core enabler" or "effective corrective actions" to reduce the negative consequences (recall costs, products wastes, social impact, reputation damage) during recalls (Garcia-Torres et al., 2018; Mai et al., 2010; Mattevi & Jones, 2016; Moe, 1998; Opara, 2003, p. 103). Traceability was introduced in the 1990s in the fields of health, space, and military activities, and has attracted more attention in the food industry in recent decades due to the increasing number of food hazards (Ene, 2013). There are many definitions of traceability by different organisations which depend on the food industries. Traceability is formed by three main components: record-keeping, tracing, and tracking. Record-keeping is the essence of traceability; it collects information and allows the information to be retrieved when necessary (Manos & Manikas, 2010; Opara & Mazaud, 2001). Efficient recording is useful to isolate certain products or suppliers particularly when the food supply chain is vast. The more information, the quicker the recall can be (Moe, 1998). Tracing backward and tracking forward allow products information to be checked in any step within a

supply chain, from the origins to customers—that is, "from farm to fork" (Aung & Chang, 2014; Pizzuti et al., 2014).

Moreover, it has the ability to provide a history and to localise selected products, by giving answers to these questions about food quality and safety, such as who (stakeholders), when(time), where (location), and why (causes) (Aung & Chang, 2014; Garcia-Torres et al., 2018). Therefore, traceability is not only a passive way to make food recalls but can also be used "in an active sense" to improve supply chain management and to gain consumer confidence (Jansen-Vullers et al., 2003; Moe, 1998, p. 403). Many researchers have discussed its ability to act as a proactive strategy/defence to monitor and prevent potential food quality and safety risks (Opara, 2003; Opara & Mazaud, 2001). It is worth noting that traceability itself cannot guarantee food safety and quality; rather, it can be used as tool that integrates with other quality assurance systems such as Hazard Analysis and Critical Control Point (HACCP), to assist in decreasing the number of potential incidents (Opara, 2003; Opara & Mazaud, 2001). In other words, traceability can give evidence of food products' quality meeting certain standards, by providing useful product information.

It is necessary to mention transparency when discussing traceability. Transparency is found to be closely related to consumer trust and confidence. Producers tend to provide information that benefits themselves to gain more profits, which can indirectly mislead customers and cause food crisis (Mao et al., 2018). Central authorities can also be tempted by bribes and cover up the truth. Many food incidents, such as the Sanlu milk scandal, were caused by lack of transparency in its supply chain at the first place and followed by the misuse of power by central authorities. Thus, customers are demanding to know more information before making their purchases, so more transparency of food supply chain is needed to keep customer confidence (Food Insights, 2019; Trienekens et al., 2012). One of the achievements in safeguarding food quality and safety is the compulsory labelling system introduced in the EU by the food law (European Commission, 2019; Wognum et al., 2011). The labelling rules provide a certain quality of products information such as ingredients and expiration dates and can help customers to make better choices before purchasing. By providing more transparency within the supply chain, parties will be able to have more knowledge of the current situations and make better decisions. The benefits include better inventory management, efficient transportation planning, and more accurate future demand forecasts among others.

1.4 Traceability Innovation

With the rapid advances in technology development, the wide use of computers, the internet and a variety of technological media has significantly changed the ways information is exchanged. Transactions and communication can be made via technological innovations to improve efficiency (Handfield & Bechtel, 2002).

Meanwhile, the costs of paperwork and labour can also be eliminated by digitising information.

Information systems are also more popular recently as information flow is crucial in food supply chains (Christopher, 2016; McMeekin et al., 2006). Companies tend to employ supply chain innovations to improve supply chain performance including improving customer services, reducing costs, or increasing efficiency (Franks, 2000; Hazen et al., 2012). Innovation is considered as something "new" which includes ideas, methods, or devices (Kahn, 2018). Supply chain innovation was defined by Arlbjorn et al. (2011, p. 8) as

> a change (incremental or radical) within the supply chain network, supply chain technology, or supply chain processes (or combinations of these) that can take place in a company function, within a company, in an industry or in a supply chain in order to enhance new value creation for the stakeholder.

Later, Storer et al. (2014, p. 490) defined it as follows:

> Supply chain innovation often involves collaborative and partnering relationships, particularly in terms of utilizing industry-led and industry-wide innovation, considered mutually beneficial, such as new technologies and information system

Canavari et al. (2010) proposed that technological limits can be one of the constraints that impact on the information flow in the supply chain. Christopher (2016) also pointed out that successful companies all have efficient information system to improve customer responsiveness. Many emerging technological innovations are employed in food supply chains to improve traceability. The innovations include Radio Frequency Identification (RFID), Wireless Sensor network (WSN), and Blockchain. The technologies are introduced fully in the next section, with an emphasis on blockchain applications.

1.5 Blockchain

Blockchain is a new concept that has attracted increasing attention in recent years. The global blockchain market in 2018 reached $583.5 million, and it is expected to reach $28 billion by 2025 (Meticulous Research, 2018). The key growth drivers are the increasing attention on blockchain, increasing adoption, and the growing trend of accepting cryptocurrency (Meticulous Research, 2018). The concept of blockchain was first announced by Satoshi Nakamoto in 2008. Nakamoto introduced a decentralised distributed database where everyone can access data and make transactions without central authorities. In this case, no single party in the blockchain can control or make changes to the whole database without total agreement from other users. Third parties such as governments and bank systems are not necessarily needed in transactions. The most successful practical example based on this concept is Bitcoin—a decentralised peer-to-peer electronic cash system. Financial use which includes transaction payments, cryptocurrency, and others accounts for the largest share of the global blockchain market according to Meticulous Research (2018). A

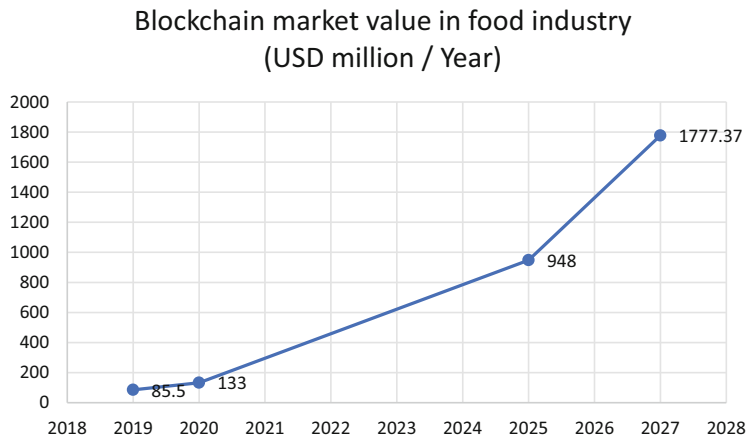

Fig. 1.1 Blockchain market value in the food industry (Source: Research and Markets, 2020; Verified Market Research, 2020)

significant body of research is also focused on its financial uses. Chen et al. (2017a, b) proposed a blockchain-based digital wallet to make transactions. Folkinshteyn and Lennon (2016) used the technology acceptance model (TAM) to examine the adoption intentions of the blockchain-based financial platform. Apart from its financial use, the blockchain concept has now been widely discussed and investigated by many fields where trust and value are important, such as banking systems, property management, retailing, diamonds supply chain, pharmaceutical industry, sustainability (Kouhizadeh & Sarkis, 2018) as well as food supply chains (Chen et al. 2017a, b; Lin et al., 2017; Sylim et al., 2018; Zhao et al., 2016).

For food supply chains, blockchain is adopted to adjust the information inequality between supply chain stakeholders. Blockchain is going to improve information transparency and improve traceability system (Petersen et al., 2018). According to a joint report by Cointelegraph and VeChain (2020), the combination of blockchain and IOT solution can save $70 billion in costs and create $47 billion income in the global food industry. The market value of blockchain in the food industry reached $85.5 million in 2019, $133 million in 2020, and is predicted to reach about $948 million in 2025 (Research and Markets, 2020) and $1777.37 million by 2027 (Verified Market Research, 2020). By 2023, 10% of the food products will be tracked by blockchain, and $300 billion worth food products will be blockchain-traceable by 2027 (Cointelegraph and VeChain, 2020). It is a promising solver for the current trust issues and will bring back public confidence in the food industry. It is one of the promising technologies that is expected to make revolutionary changes to supply chain management (Kouhizadeh & Sarkis, 2018). There is an increasing trend of research papers of blockchain applications in food supply chain management. All the previous papers are analysed by the content-based analysing method in the following chapter (Fig. 1.1).

1.5.1 Blockchain Applications

As blockchain is expected to improve traceability in food supply chains by providing transparency of information flow, trust between stakeholders, efficiency, and speed of tracing certain products it is gaining more attention for its promising potential to address supply chain issues. Many companies and organisations are engaged to apply blockchain to improve supply chain efficiency and products' quality such as IBM, Walmart, Moyee Coffee, and WWF (as summarised in Table 1.1).

IBM, after 18 months of testing, launched its blockchain-based food traceability platform—IBM food Trust platform, which allows the engagement of various stakeholders in the ecosystem including retailers, wholesalers, and suppliers (Stanley, 2018). The first adopters of the IBM Food Trust platform are French retailer *Carrefour*, a well-known food producer; *Nestle,* a supplier, and *BeefChain*. As a food traceability platform, it has three modules: tracing module, certification module, and data entry and access module. The *tracing* module can track products within

Table 1.1 The application of blockchain in food supply chain

Industry	Companies	Achievements
Food industry	IBM—IBM Food Trust Platform	1. Products' tracking 2. Certifying products
Food retailing industry	Walmart & IBM & Tstinghua university—Walmart food safety collaboration centre	1. Improving traceability system 2. Improving transparency 3. Assuring products authenticity and safety
Coffee industry	Moyee Coffee & Bext360 & KripC—KripC platform	1. Improving transparency 2. Eliminating middlemen 3. Cost reduction
Seafood industry	WWF & ConsenSys & Traseable	1. Eliminating illegal-caught products and unethical labour 2. Improve transparency
Seafood industry	Hyperledger—Sawtooth	1. Combining sensors and blockchain to track products. 2. Improving supply chain transparency and accountability
Agriculture products	AgriDigital commodity management platform—AgriDigital & CBH	1. Matching title transfer of the grain asset to payment 2. Supply chain provenance and traceability
Agri-Food &seafood	OwlChain & AMIS blockchain structure	1. Creating an open and tamper-resistant food provenance system which provide customer with more buying confidence, and help farmers to earn more 2. Helping on the products label authenticity and reduce unsustainable fishing behaviours.
Farming	ripe.io	1. Creating transparency, trust, and honesty in food supply chain

the supply chain, even across borders. The *certification* module is about nongovernment organisations certifying the products, such as fair trade or organic. *The data entry and access* module allows stakeholders such as growers to upload and manage the products' data. The latter is free to all stakeholders, while the first two modules cost a little every month. The data entry and access module is also simple to use and does not require users to be experts.

The world's largest retailer Walmart has also been working with IBM and Tsinghua University to create a blockchain-based food security system that targets traceability and food fraud (SupplyChain247, 2016). According to Yiannas (2018), in a pilot study, the time of tracing mangoes reduced from nearly 7 days to 2.2 s by using a blockchain system. By building a Walmart food safety collaboration centre in China and tracking pork, customers can now obtain maximum information such as farm details, factories, processing data, storage data, expiration dates, and shipping details on the products they purchase. The in-depth information potentially proves products' authenticity and addresses food safety issues. Due to the great success of the pilot studies, in September 2019, Walmart announced that it is compulsory for their leafy green vegetable suppliers to use blockchain to trace products (Kharif, 2018). After launching the plan, over 100 of its suppliers will have to use blockchain technology in 2019. Walmart also hoped to implement a blockchain-based traceability system to other fresh products within 2019. Walmart's vice president of food safety Frank Yiannas asserted: "This is a smart, technology-supported move that will greatly benefit our customers and transform the food system, benefitting all stakeholders". Blockchain engagement can also benefit other stakeholders, for example, retailers can manage products' shelf-life according to records (Yiannas, 2018).

Moyee Coffee is working with Bext360 and KripC on the world's first coffee blockchain project to improve coffee transparency and improve fairer trade (Moyee Coffee Ireland, 2017). Similar to IBM Food Trust platform, KripC platform also allows all stakeholders including farmers, roasters, retailers, and consumers to access data. As a complex industry, coffee producers used to only receive 2% added value as there were too many middlemen in the supply chain. The platform makes the whole coffee supply chain more transparent and reduces unnecessary costs, such as omitting the middlemen. Therefore, the platform not only provides customers with data and sources of the coffee they drink but also benefits the lower tier of the supply chain with more value added. The paperwork and physical inspectors can also be reduced by the blockchain platform and save up to 0.80 euros per pound of coffee (Moyee Coffee Ireland, 2017). The entire blockchain coffee supply chain was launched in 2017 and proved the traceability of 60,000 kg of coffee by June 2018 (Best360, 2018).

In terms of the seafood supply chain, the world-known environmental organisation, the World Wildlife Fund (WWF), is working with some partners such as technology companies ConsenSys and Traseable to develop a blockchain-based system in order to improve the traceability in the seafood supply chain (WWF, 2018). This innovative project can improve the transparency in the seafood supply chain, this means that customers are allowed to know the stories by scan packing behind the seafood they bought such as origins, vessels, and fisherman. Due to the

accessible information, therefore, unsustainable seafood such as illegal-caught products or unethical labour in the seafood industry can be avoided. Taiwan-based OwlChain platform does a similar job, which protects seafood label authenticity and improves fishing sustainability (OwlTing, 2017). Another blockchain application, Hyperledger Sawtooth, is being used in the seafood supply chain industry to improve its traceability and accountability (Sawtooth, 2018). It is a combination of sensors and blockchain to trace sea food products. From the sea to the table, products are recorded for their whole journey, which includes the location, temperature, humidity, motion, shock, tilt, and ownership transfers (Sawtooth, 2018). The recorded information allows customers to access before making their purchases. Customers, therefore, are guaranteed the products' quality and authenticity by blockchain and the application also benefits the local fishing industry.

For the agri-food industry, several start-ups have created blockchain structures to ensure food safety and quality, such as AgriDigital and CBH, OwlChain and AMIS, and ripe.io. In 2017, Australia-based AgriDigital and CBH launched a pilot study to test blockchain in the grain industry and achieved satisfactory results (AgriDigital and CBH Group, 2017; Antonovici, 2017). It is not only the growers and retailers who benefit from the instant payments, customers can also have buying confidence due to the efficient products' traceability. Based on Ethereum (Smart contract blockchain platform) platform, OwlChain and its partner AMIS created a Taiwan-based Agri-Food trade platform (OwlTing, 2017). By using blockchain, consumers gain more visibility on and trust in food quality and safety and are willing to pay higher prices. In this case, by earning more and paying low commission fees to the platform, farmers can have a higher income. Ripe.io is a platform that combines blockchain and IoTs and is aiming to provide transparency and trust between stakeholders including farmers, distributors, and consumers.

Table 1.2 provides more applications of blockchain in various industries. WaBi and VeChain are developed to prove products' authenticities including food, wine, cosmetics, and agricultural goods, among others. To eliminate fraud products, blockchain is popular in the pharmaceutical and luxury goods industries. BlockRx and Modumf are used on drugs delivery, to control temperatures and monitor processes. Everledger developed the Time-Lapse Protocol to prevent "blood diamonds" by tracing diamonds origins. There are also various blockchain applications in global shipping.

1.6 Research Objectives

The following sections present the research questions that this research aims to answer, and the research structure.

Table 1.2 Other examples of blockchain applications

Blockchain ledger	Area	Achievement	Details
WaBi (WABI)	Food industry (liquor, baby food), cosmetic industry.	Products authenticity	Inspired by Sanlu milk scandal, WaBi is a combination of RFID chips, QR codes, and blockchain, which allows customer to scan label before making purchase (Quittem, 2018).
VeChain platform	Agricultural, wine, luxury goods	Cost efficiency, and security, products authenticity and information transparency	It is a decentralised platform for business solutions without any intermediary. Stakeholders can share and manage products' information by using blockchain. For example, manufacturing can provide products' data to ensure products' authenticity and quality (Benson, 2018; Zwanenburg, 2018).
BlockRx (iSolve & Swiss pharmaceutic company)	Pharmaceutical industry	1. Reducing counterfeit drugs 2. temperature control on certain drugs	1. As blockchain can improve the transparency of the supply chain, stakeholders of the supply chain can make sure of the authenticity of the source of drugs. 2. Decentralised characteristic of blockchain technology can also reduce the risk of technology hackers and irresponsible authority. 3. Blockchain benefits the pharmaceutical cold chain. Blockchain can keep the temperature information transparent along the supply route and remind the manager or driver to monitor it on time.
Modum Blockchain (Swiss post & Modrum)	pharmaceutical	Temperature monitoring on delivery products	It is using smart contracts combined with IoT technologies to delivery temperature-sensitive products. The temperature data will be continuously recorded and automatically send notifications to senders and receivers if the temperature is out of limits. This technology can provide

(continued)

Table 1.2 (continued)

Blockchain ledger	Area	Achievement	Details
			customers with quality products and provide transparency during delivery (Das, 2018).
Ambrosus (AMB)	Food & Pharma industry	Supply chain optimisation, logistic tracking, quality assurance, anti-counterfeiting	Combination of blockchain and IoT (RFID chips, sensors, and QR codes) to track movement and temperature to achieve smarter, healthier and transparent food and pharma ecosystem connections with their stakeholders (Gutteridge, 2018; Quittem, 2018).
Time-lapse protocol (Everledger)	Diamonds	1. Eliminating counterfeit products 2. Eliminating "Blood diamonds"	For high-value luxury goods such as diamonds, blockchain is also helpful to reduce risks of counterfeit products and unethical products. 1. Blockchain-based Diamond Time-lapse Protocol is able to protect the transparency of the diamond trade, to assure the authenticity of diamonds and to provide the provenance of diamonds (Diamond Time-Lapse, 2018). 2. The technology can trace diamonds from the origin and eliminate the "blood diamonds"—diamonds that are produced to support unethical activities such as wars (Sunny, 2018). From mining to retailing, every process of the diamond supply chain is verified and can be checked by the public.
Blockfreight	Global cargo shipping industry	Improving market access Building financial strength in global trade	1. Smart contracts to securely, permanently define the bill of lading, terms of payment, and other key elements to a completed cargo shipment, built on the Ethereum blockchain. 2. A tradeable token built as a Counterparty asset, which

(continued)

Table 1.2 (continued)

Blockchain ledger	Area	Achievement	Details
			is secured by the bitcoin blockchain. This token pays for the transaction fees and effectively eliminates spam on the decentralised system. 3. Storage of the bill of lading and other documents too large to fit into a bitcoin block using the IPFS (Inter Planetary File System) protocol (Coleman, 2016).
ShipChain platform (ShipChain)	Shipping	Creating transparency and efficiency when within supply chain and during tracing and tracking items	It is a fully integrated system across the whole supply chain to provide transparency and efficiency. From leaving the factories to the harbours, from retailers to customers, all products can be traced and tracked. By using smart contract, shippers and carriers will have more visibility in the supply chain (ShipChain, 2018).
TradeLens (Maersk and IBM)	Global supply chain	Providing a shipping information pipeline paperless trade (Maxie, 2018).	It is an end-to-end blockchain-based platform to improve efficiency, provide transparency and trust, and reduce the risks in global supply chains (Biazetti, 2018; Maxie, 2018). At least 90 companies have joined and share data on the platform (Tradelens, 2018).
Waltonchain	Supply chain	Complete data sharing to reach information transparency, eliminating counterfeited products	It combines both RFID chips and blockchain to achieve Value internet of Things, which is a decentralised ecosystem of interconnectivity (Brauer, 2017). It aims to create a genuine, believable, traceable business model with total shared data and transparent information, and to address trust issues within the supply chain, and provides customers with authentic and good quality of products (Waltonchain, 2018).

(continued)