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Blockchain implementation in the food supply chain: A systematic literature review

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Abstract

This study explores the literature on the implementation of Blockchain in Food Supply Chain Management (FSCM) and attempts to disseminate key insights along with potential directions for future research. A systematic and rigorous process of searching and scanning resulted in 53 peer-reviewed papers for the review. Findings from the selected papers include drivers and barriers to the adoption of the technology, current applications of Blockchain, and typical structure of the system in FSCM. Suggestions for future researches include empirical works to examine Blockchain implementation at supply chain level and influential factors to the implementation process.

Keywords: Blockchain, Food Supply Chain, Implementation

Introduction

Popularized via decentralized transaction networks such as Bitcoin, Blockchain has emerged as a transformative technology for Supply Chain Management (SCM). Blockchain fundamentally can be defined as a digitalized, decentralized, and distributed ledger system for storing and sharing data (Iansiti and Lakhani, 2017, Saberi et al., 2018). SCM is a highly promising field for Blockchain implementation due to existence of several pinch points (Iansiti and Lakhani, 2017; Casino *et al.*, 2018). In particular, Blockchain applications can bring significant improvement in terms of transparency, efficiency, and sustainability (Benton *et al.*, 2016; Francisco and Swanson, 2017; Cole *et al.*, 2019; Saberi *et al.*, 2019).

Among all supply chains, Food Supply Chain (FSC) has received the most attention and has been at the forefront in exploring Blockchain for improved performance. The food industry has witnessed some of the earliest as well as some of the most developed 'Blockchain-for-SCs' initiatives (Galvez *et al*., 2018; Kshetri, 2018, Wang Y *et al*., 2019a). The momentum for adopting Blockchain in SCM in general and FSC in particular

continues to grow strongly. Recently, Albertsons joined more than 50 other organizations as member of IBM's Blockchain based Food Trust network, alongside with many other giants such as Walmart and Carrefour (Wolfson, 2019). According to Gartner, a leading research and advisory company, Blockchain would be incorporated into as much as one fifth of the world's top grocers for food safety and traceability by 2025 (Omale, 2019); while analyst from Bitcoin Magazine of Nasdaq optimistically labeled 2019 as the year of Blockchain-based Food Supply Management (Manning, 2019).

The number of publications on Blockchain applications for food are rapidly increasing (Kamilaris *et al*., 2019; Zhao *et al*., 2019). Various dimensions of Blockchain implementations have been studied, ranging from designing end-to-end traceability solution based on Blockchain (Tian, 2016; Cairo *et al.*, 2018; Tsang *et al.*, 2019); to analyzing factors influencing Blockchain adoption (Queiroz and Wamba, 2018; van Hoek, 2019; Behnke and Janssen, 2020). As this stream of research is growing at an exponential speed, scholars inherently attempt to capture the overall state of Blockchain implementation in FSC via literature review studies. In an effort to contribute to the Blockchain implementation in FSC body of literature, this study presents a Systematic Literature Review (SLR) of relevant studies to recommend evidence-based research avenues.

Methodology

SLR is recognized as a robust methodology for critical review of literature in the field of management research (Tranfield *et al.*, 2003). Compared with the traditional narrative-led approach to literature review, SLR provides a scientific, replicable, and transparent approach to accumulate studies, summarize existing information, and minimize bias (Tranfield *et al.,* 2003; Rousseau *et al.*, 2008). Drawing from Tranfield *et al.* (2003)'s suggestions and other examples of SLR works in the field of operation management (e.g. Seuring and Muller, 2008; Colicchia and Strozzi, 2012; Ghagde *et al.,* 2012), this study used a review protocol with three main stages: selecting relevant studies, reviewing selected studies, and disseminating the state-of-art of the body of literature and future research direction.

Therefore, this study identified "Blockchain", "Food supply chain", "implementation", and "benefits" as key fields and based search strings accordingly. The following search strings were developed:

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(blockchain OR "smart contract" OR "distributed ledger") AND ((food
OR agriculture OR perishable OR fresh) AND ("supply chain" OR "value
chain" OR "demand chain" OR logistics OR "cold chain")) AND
(implementation OR traceability OR transparency OR visibility OR
tamper* OR security OR safety OR integrity)
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A search for relevant papers was conducted on Scopus, EBSCo, and Web of science (WoS). The time horizon of the search was set from year 2009 to 2019. From the initial findings of 2215 studies, at the final stage 47 papers were selected for data analysis. Six papers published after initial screening, December 2019, were found suitable and thus included to the final selection of 53 papers.

Descriptive analysis

The study first looked at the year of publications. Figure 1 showcases the distribution of 51 papers by year. It can be observed that peer-reviewed academic papers started to emerge from 2018, and the number quickly rose in 2019 (from 9 as of 2018 to 35 as of 2019). The number of studies published in 2020 is counted for the first three months, hence many more can be expected in the rest of the year. There are studies regarding

Blockchain and FSC prior to 2018 such as Tian (2016) and Hackius and Peterson (2017); however they are conference papers. Since the final selection consisted of exclusively peer-reviewed papers, those papers were excluded. Overall, it can be concluded that the research stream about Blockchain implementation in FSC is in early stage of development and has started to gain strong momentum.

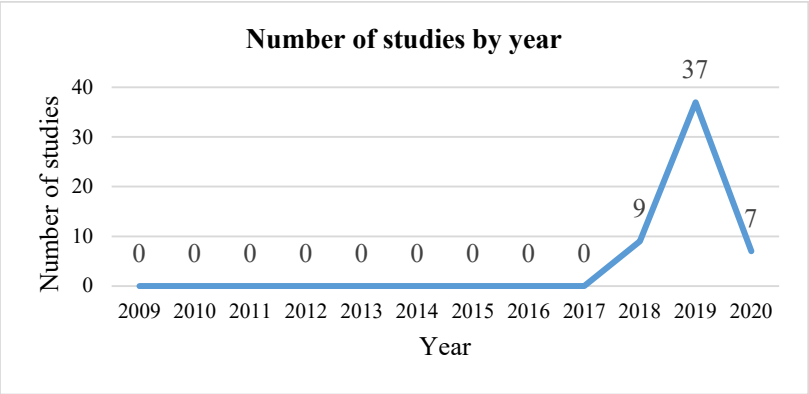

Figure 1. Publication by year

Two most common research approaches found are conceptual (27.5%) and proof of concept (27.5%). Conceptual papers analyze the phenomenon of Blockchain using existing knowledge in SCM, while proof of concept papers are more pilot stage studies, proposing a Blockchain-based solution for FSC problems. Review papers are the next large group of researches (17%), followed by case studies (14%). Quantitative method (8%), using surveys, and qualitative method (2%), using interviews, were also found, though at this stage empirical researches are noticeably harder to conduct. One study, by van Hoek (2019), used a mix method of survey and case study to collect data for their analysis. Overall, the research approaches reflect the infancy stage of Blockchain development in FSC, as academics focus more on making sense of the technology and how to employ it.

Thematic analysis

Thematic analysis can provide a comprehensive and interpretative examination of literature (Ghadge *et al*., 2012). There are two approaches to thematic analysis in social studies (Terry *et al.*, 2017). One is deductive approach, which builds predetermined themes based on existing theories, then uses them as guidelines in the coding process. This approach echoes the standard scientific method, moving from theory to hypothesis (identifying themes) then testing hypothesis (coding). The other is an inductive approach, which aims to build themes throughout the examination of the available information. Braun and Clarke (2012) suggest to start with coding the contents and then develop and finalize themes during and after the coding process. This study employed a mix approach to examine the literature. Initial themes were derived based on the researchers' familiarity with the review subject and other works on technology implementation in SCM such as Reyes et al., (2016). Initial themes were used as guidelines for the coding process. Afterwards, the the themes were under constant revision and adjustment to best represent the insights from 53 selected papers. Figure 2 presents the finalized themes.

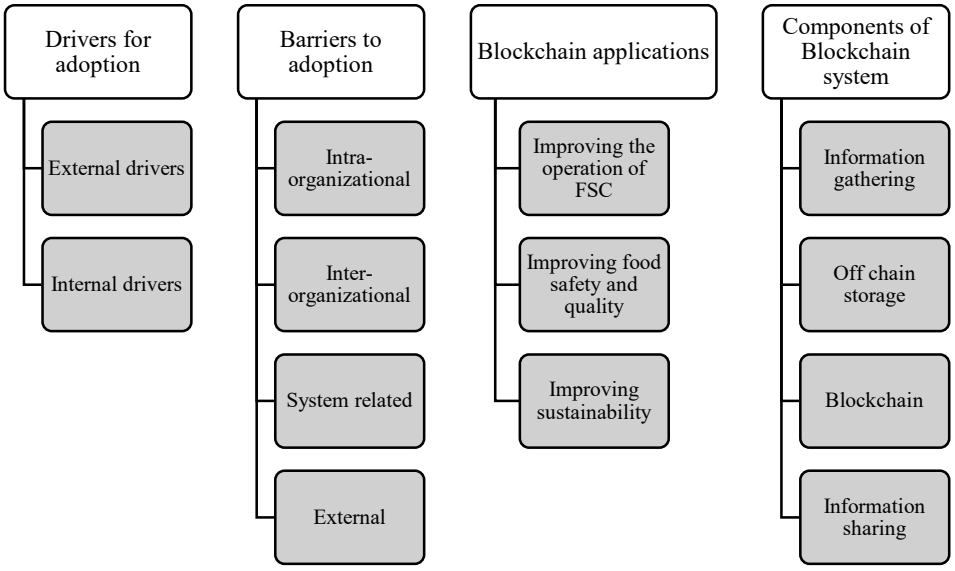

Figure 2. Themes emerged from selected papers.

Drivers for adoptions

1- Internal drivers

Blockchain is expected to bring great improvements to various areas of business, hence the enthusiasm toward the technology. Reviewed papers reveal that businesses are mostly interested in Blockchain ability to enhance food traceability, transparency, and efficiency. Other motivations found include combating food fraud and saving cost.

Food traceability is the ability of tracking food products throughout multiple processes and entities in the FSC. Food traceability in current agriculture-food chain is difficult since the food supply line is complex and globalized, with multiple tiers of supplier and buyers (Ksheri, 2018; Mao et al., 2018b; Cole et al., 2019). With its distributed and tampered-proof ledger design, Blockchain can guarantee every party in the FSC to have access to authentic information at any given time. Therefore, businesses expect to be able to track food in real time (Kos and Kloppenburg, 2019) with more accuracy and effectiveness than conventional centralized system (Galvez et al., 2018, Al-Jaroodi and Mohamed, 2019, Pearson et al., 2019, Morkunas et al., 2019).

Transparency can be defined as the ability to see from one end of the supply chain to another (Zelbst et al., 2019). Transparency is important in FSCM because of its influence on the management of key areas such as food safety, quality, and sustainability (Ksheri, 2018; Bumblauskas *et al.*, 2019, George *et al.*, 2019). Blockchain has the ability to bring every nodes in a Food chain to a common information sharing system/platform (Bumblauskas *et al.*, 2019; Kumar *et al.*, 2019; Mondal *et al.*, 2019), and creates digital twin of processes and products movement along the chain (Galvez *et al.*, 2018; Hang *et al.*, 2020). Businesses can rely on Blockchain to obtain vision of other areas in FSC, thus gain more control over their own products and present such information to consumers to gain an competitive edge if necessary (Kumar *et al.*, 2019; Montecchi et al., 2019; Helo and Hao, 2020).

Organizations expect Blockchain to increase the efficiency of critical activities in FSCM. Blockchain could improve the process of responding to food safety and quality outbreaks, which is frequently mentioned in literature as one of the biggest challenges (Astill et al., 2019; Kumar et al., 2019; van Hoek, 2019). Transparent and immutable records of transactions and activity stored on Blockchain can help firms to quickly locate and separate the areas of contamination (Chang et al., 2019; Creydt and Fischer, 2019; George et al., 2019), thus the entire supply line does not have to shut down completely.

Furthermore, as Blockchain is popularized by its use in finance, the technology is predicted to streamline and speed up the payment process between entities of FSC (Galvez et al., 2018; Astill et al., 2019; Chen et al., 2020). Other logistical processes can also be optimized with the help of Blockchain such as inventory management and transportation planning (Astill et al., 2019; Cole et al., 2019).

2- External drivers

External drivers arise from outside of a company's environment and motivates firms to adopt Blockchain as potential solution. The examined literature specifies pressure from consumers, competitors and regulatory bodies within FSC as external drivers.

Consumers are increasingly concerned about the quality and safety of food products due to a series of violations in the recent years (e.g. horse meat scandal in EU, infant milk incident in China, salmonella and E. coli outbreak in the US) (Mao *et al.,* 2018; Astill *et al.,* 2019; Tsang *et al.,* 2019; Chen *et al.,* 2020). Furthermore, consumers are becoming highly aware of the environmental and social impacts associated with FSC by-products (Wang *et al.*, 2019). Thus, organizations view Blockchain as a tool to cope with recent changes in consumers' preferences. Honest firms in FSC, via using Blockchain, can provide reliable information about product provenance and assure consumers about their sustainable practices.

With growing focus on use of modern technology in digital era, several times competitors indirectly drives need for adopting Blockchain. An example is Carrefour, as the organization launched a Blockchain project to monitor various product lines such as poultry, tomato, honey etc to tackle competition from other enterprises such as Amazon (Chang *et al*., 2019). Since consumers are more conscious about where their food is coming from, Blockchain can enable an organization communicate comprehensive and reliable information on product provenance to consumers, distinguishing their products from competitors (Galvez *et al.*, 2018; van Hoek, 2019). Moreover, the leading company in adopting Blockchain can in turns pressure other entities in the FSC to adopt the technology. For instance, following successful pilots, Walmart planned to expand their Blockchain and started to request farmers and suppliers to join their system (Ksheri, 2018; Chang et al., 2019).

Transparency in food chain has always been under strict scrutiny from the regulatory bodies. For instance, Canada enforces the use of barcode and tags to identify the initial herd of animals, and Australia uses a national scale system to track animals from birth to slaughter (Wang *et al.*, 2019). Introduction of the new act in USA (2011), regulators can demand firms to present full traceability of high-risk product (Bumblauskas *et al.,* 2019). Policies are also moving toward mandating sustainability development, for instance fishing companies are now required to report annually about slavery and human trafficking in the US and UK (Howson, 2020). Under the pressure of regulations getting stricter on multiple fronts, firms in food industry are pressured to explore Blockchain, in order to adhere to requirements more effectively.

Barriers to adoptions

1- Intra-organizational barriers

Intra-organizational barriers are inhibitors to Blockchain which derived from within an organization. Four intra-organizational barriers are identified as high implementation cost, lack of knowledge and expertise, and privacy versus transparency dilemma.

Investing in Blockchain can be expensive, and firms are concerned that the benefits of the technology might not trump high cost (Wang Y. *et al*., 2019b; Wong *et al.*, 2019; Zhao *et al.*, 2019). The complexity of Blockchain could require considerable time and resource from firms to master (Wong *et al*., 2019); while the cost of hiring Blockchain specialist can be exceptionally high due to large demand (Kshetri, 2019); and moreover firms often must invest in additional devices such as RFID or sensor for a comprehensive Blockchain solution (Chen *et al*., 2020). In the cases of less financially resourceful entities, it might be difficult to justify such investment.

Lack of knowledge and expertise about Blockchain technology is one of the blockages to Blockchain. Implementing Blockchain is a complex and lengthy process, requiring firms to have certain level of knowledge, infrastructures, and technological capability (Chang *et al,*. 2019; Wong *et al.*, 2019; Helo and Hao, 2020). Hence it could be difficult for small to medium farmers and companies in FSC (Ksheri, 2019; Zhao *et al*., 2019), as they may not have sufficient resources and expertise to engage in Blockchain implementation.

Blockchain provides transparency by allowing each participant to track, trace, and view all transactions stored on the chain. In the context of supply chain, this enables companies to see activities and products movements further upstream or downstream. However companies also face the risk of leaking private information (Kamilaris *et al.*, 2019; Zhao *et al.*, 2019; Chen *et al.*, 2020). Despite technical solutions such as encryption or masking identity; basic information e.g. product type, price, time, location are still revealed (Zhao *et al*., 2019). Therefore, critical insights of organization's operation can still be uncovered from such information.

2- Inter-organizational barriers

There are barriers at the inter-organizational level which obstruct the implementation of Blockchain. Literature emphasizes supply chain readiness, inaccurate inputs, and variations of companies' standards as inter-organizational barriers.

Blockchain's ability to facilitate end-to-end traceability and to increase transparency would be greatly undermined if only a small number of nodes in the FSC can join the network (Galvez *et al.*, 2018; Tsang *et al.*, 2019). Therefore even though large enterprises are able to initiate Blockchain projects, smaller firms need to participate for the projects to be fruitful (Cole *et al*., 2019; Wang *et al*., 2019; Chen *et al*., 2020). However, not every node in a Food chain has the sufficient technological expertise and financial resources (Ksheri, 2019; Zhao *et al*., 2019; Hang *et al*., 2020). As a result, firms could hesitate to invest in Blockchain if the majority of other organizations in FSC are not yet capable to adopt the technology.

Blockchain assures that no changes can be made once the information is stored on chain. However, manipulations or mistakes can still fetch incorrect data into the system, reducing the overall reliability of the system and making it difficult to fix (Galvez *et al.* 2018, Kamilaris *et al.*, 2019; Tsang *et al.*, 2019; Howson, 2020). IT experts in organizations stressed that even with measures such as automatic data capture using sensors, the integrity of input information cannot be fully guaranteed (Wang Y. *et al.*, 2019b). This possibility subsequently hinders the adoption of Blockchain.

3- System-related barriers

This section addresses the limits of the Blockchain technology itself when being used for FSCM. Reviewed literature identifies scalability of Blockchain as the most serious obstacle in this regard. By design, Blockchain constantly has to updates the ledger at every node to ensure that there is only one single version of information in the system.

While this feature enables information on Blockchain to be transparent and trustworthy, it also creates a problem for system scalability. FSC has large number of actors involved from the point of production to the point of consumption (Person *et al.*, 2019, Zhang et al., 2020), and the amount of information generated is extremely large (Kumar *et al.*, 2019; Tsang *et al.*, 2019). The more entities are added to the network, the latency problem is further multiplied. Consequently, organizations find that scaling Blockchain implementation beyond the pilot stage is very difficult (van Hoek, 2019; Wang Y *et al.*, 2019).

4- External barriers

External barriers refers to challenges coming external stakeholders such as institutions or government who are not directly benefited from FSC activities (Saberi et al., 2019). In a complex supply chain such as food, participants may locate in different parts of the world, thus are placed under different restrictions and regulations (Galvez et al., 2018; Zhao et al., 2019; Howson, 2020). This could potentially be a problem in the case of dispute. Overall, the lack of unified regulation frame for Blockchain can make implementation less plausible under the view of firms.

Blockchain applications in Food chain

This theme presents how organizations in FSC can utilize Blockchain. Drawing from actual use cases of Blockchain in food industry and solutions proposed by researchers, it is determined that the use of Blockchain includes products traceability, enhancing food safety and quality, process optimization, and sustainability improvement.

From a conceptual perspective, Blockchain technology which provides real-time information about operations matches the pre-requisite of asynchronous supply chain. Therefore Blockchain & FSC initiatives prioritize heavily on end-to-end product traceability. Some prominent examples are Walmart pilot projects, IBM food trust group, Carrefour's project, Provenance's solution (Ksheri, 2018; Cole *et al.*, 2019; Chang *et al,.* 2019; Zhao *et al,.* 2019).

Numerous Blockchain projects set out to specifically target the current quality and safety issues in FSC. For example, Alibaba's initiative , Food Trust Group by IBM and Walmart Chinese retailer JD collaboration with Walmart, IBM, and Tsinghua(Ksheri, 2018; Mao *et al.*, 2018; Chang *et al.*, 2019),.

Blockchain can be used to tackle various sustainability issues in FSCM. Through Blockchain pilots, Walmart was able to gain more comprehensive data of products' shelf-life and use such data to target food waste issue via optimizing operations (Helo and Hao, 2019). Plastic Bank introduced a platform built on Blockchain for plastic waste recovery, which also involves firms such as Henkel and Eat Natural, to incentivize waste collection and minimize oceanic pollution (Howson, 2020). Blockchain furthermore can be used to address social concerns. Coca-Cola has experimented with Blockchain to address forced labour in the sugarcane sector (Kamilaris *et al.*, 2019). Many Blockchain initiatives include monitoring of animal welfare, such as Hendrix Genetics (Kamilaris *et al.*, 2019) and Carrefour (Chang *et al,.* 2019).

Typical components of a Blockchain system

The typical architecture of a Blockchain based system in FSC is presented in this section. This is drawn primarily from the proof of concept studies (*cf* Tsang et al., 2019; Hang et al., 2020) together with the discussions from conceptual paper such as Galvez *et al.*, (2018) and review such as Zhao *et al*., 2019.

- Information acquisition: collects necessary information generated through various activities within the FSC. Since Blockchain is fundamentally a solution for data storage, supplementary technologies such as RFID and sensors must be used for this module.
- Data storage: is the main location for storing all data gathered from the previous module. This design is a mean to counter the scalability and latency issue of Blockchain. Selective information will proceed to Blockchain network for validation or for smart contract, the rest is stored in this module.
- Blockchain network: is often permissioned in the case of business use, since the network has more control over privacy and performance of the system.
- Application layer: includes all the necessary interface or service for stakeholders to interact with the Blockchain system. Examples are website for businesses to view tracking data or mobile phone apps for customer to scan QR code for information.

Conclusion and future research agenda

Food is an important aspects in today's society and economy. Businesses in food industry have been active in exploring Blockchain as a prominent solution to existing issues in managing food such as safety, quality, and sustainability. Realizing this trend in the industry, researchers have also been more interested in the topic of Blockchain and FSC, indicating by the significant increase of papers in the recent years. 53 relevant and quality papers were identified mainly from the period of 2018 to mid 2020.

Descriptive analysis of selected papers shows that this research stream is still at its infancy, nonetheless the growth has been impressive and is expected to advance faster in the future. Thematic analysis synthesized four major themes from the data set: the drivers and barriers to the adoption of Blockchain, current uses of Blockchain, and the typical components of a Blockchain system in FSC. Based on the synthesis of the study, three recommendations on future research directions of Blockchain implementation in FSC are identified:

1- Various drivers and barriers were identified in the current body of literature about Blockchain and Food chain. However, there are more possible factors limiting or enabling the implementation of Blockchain as the technology continues to develop (Bumbalaukas et al., 2019; Kamilaris et al., 2019). Thus, future research can explore the drivers and barriers of Blockchain further through case study and empirical works.

2- Until now, successful Blockchain initiatives for Food chain are pilots and small scale projects (Cole *et al*., 2019, Hughes *et al*., 2019; Karmilaris et al., 2019; Pearson *et al*., 2019). Implementing Blockchain at Supply Chain level remains a difficult task, however it is also an opportunity for research. Empirical studies on implementing Blockchain at SC level would provide valuable contribution to this aspect.

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