

# Blockchain adoption in food supply chains: a review and implementation framework

Nam Vu , Abhijeet Ghadge  and Michael Bourlakis 

Centre for Logistics and Supply Chain Management, Cranfield School of Management, Cranfield University, Cranfield, UK

## ABSTRACT

Blockchain technology has received significant attention from the food industry; however, due to the scarcity of successful Blockchain projects and sector-specific studies, a step-by-step approach for implementing Blockchain in food supply chains (FSCs) is still missing. A systematic literature review of 69 high-quality, peer-reviewed articles is utilized to capture Blockchain adoption drivers and barriers, applications, and implementation stages within FSCs. Current Blockchain issues such as scalability, regulations, privacy, and incentivization are identified as future research opportunities. Following innovation adoption theory, a three-stage conceptual framework for Blockchain implementation in FSCs is developed. The proposed framework is novel and is expected to benefit food chain managers in establishing the suitability of Blockchain for their organization and/or wider supply network. Identified influential factors, case examples, and implementation stages are expected to guide practitioners in developing a roadmap for adopting Blockchain in the food industry.

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## 1. Introduction

Popularized via decentralized transaction networks, Blockchain is emerging as a transformative technology for Supply Chain Management (SCM). Blockchain can be defined as a digitalized, decentralized, and distributed ledger system for storing and sharing information (Iansiti and Lakhani 2017; Nofer et al. 2017; Saberi et al. 2019). Stored data/information on a 'chain of blocks' is immutable, transparent, traceable, and tamper-proof (Nofer et al. 2017; Kumar, Liu, and Shan 2020). SCM is a highly promising field for Blockchain implementation due to several pinch points (Iansiti and Lakhani 2017; Martinez et al. 2019). In particular, Blockchain applications can bring significant improvements in terms of transparency, efficiency, and sustainability (Cole, Stevenson, and Aitken 2019; Saberi et al. 2019). The technology has been experimented for better managing supply chains in several industries, namely food (Kamilaris, Fonts, and Prenafeta-Boldú 2019), construction (Wang, Chen, and Zghari-Sales 2021), apparel (Fu, Shu, and Liu 2018), pharmaceuticals (Hackius and Petersen 2017), and is highly regarded as the next significant innovation for SCM by industry practitioners (Capgemini 2018).

Research developments linking Blockchain with SCM are growing at an exponential speed. To date, various dimensions of using Blockchain for SCM have been investigated, ranging from conceptualizing the benefits of the technology (Cole, Stevenson, and Aitken 2019; Saberi et al. 2019); examining successful cases of Blockchain application for SCM

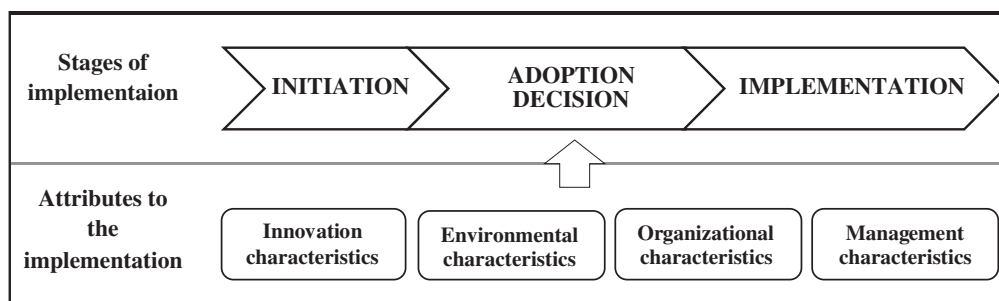
(Kshetri 2018; Wang, Chen, and Zghari-Sales 2021), to exploring influential factors concerning the decision of adopting Blockchain (Wong et al. 2019; Wamba, Queiroz, and Trinchera 2020). Due to massive growth in research interests in this field, scholars are attempting to capture the development of Blockchain, following literature review studies. Table 1 presents nine literature reviews found in Operation and SCM literature, exploring the potential of Blockchain in SCM.

Except for Cole, Stevenson, and Aitken (2019), all studies chose a systematic literature review (SLR) to synthesize insights from the literature. Further, most studies provide an overview of Blockchain, such as its potential, challenges, usage, etc., within SCM in general (e.g. Cole, Stevenson, and Aitken 2019; Gurtu and Johny 2019; Pournader et al. 2020; Wang, Han, and Beynon-Davies 2019). Several review studies, shown in Figure 1, have a narrower scope. For example, Queiroz, Telles, and Bonilla (2019) focus on Blockchain integrated supply chain management, while the use of Blockchain in the food industry has drawn considerable attention from academia (e.g. Kamilaris, Fonts, and Prenafeta-Boldú 2019; Zhao et al. 2019; Duan et al. 2020; Feng, Wang, Duan, et al. 2020).

FSCs have been at the forefront of exploring Blockchain since it first emerged as a promising technology for SCM. The food industry has witnessed some of the earliest and most developed 'Blockchain-for-Supply Chains' initiatives (Galvez, Mejuto, and Simal-Gandara 2018; Kshetri 2019; Wang, Han, and Beynon-Davies 2019). According to a report

**Table 1.** Summary of recent reviews on Blockchain for SCM.

| Reference                                    | Aim of the study                                                                                                                                                                                          |
|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cole, Stevenson, and Aitken (2019)           | To examine Blockchain technology and its potential in Operation and Supply Chain Management (OSCM) and to address whether common theories in OSCM can be useful in studying the phenomenon of Blockchain. |
| Gurtu and Johny (2019)                       | To review the current literature on Blockchain technology to determine the overall potential of Blockchain for SCM.                                                                                       |
| Pournader et al. (2020)                      | To review literature about the implementation of Blockchain in the supply chain, logistics, and transport for future applications and research directions.                                                |
| Queiroz, Telles, and Bonilla (2019)          | To determine current applications, the main challenges, and future research directions of the research stream about Blockchain supply chain integration.                                                  |
| Wang, Han, and Beynon-Davies (2019)          | To examine future influences of Blockchain to supply chain practices and policies.                                                                                                                        |
| Kamilaris, Fonts, and Prenafeta-Boldú (2019) | To identify the goals, designs, enablers, and barriers of Blockchain initiatives in the food and agriculture industry.                                                                                    |
| Zhao et al. (2019)                           | To determine applications, main challenges, and future directions of Blockchain implementations in food supply chains (FSC).                                                                              |
| Duan et al. (2020)                           | To investigate how Blockchain has been used to manage food products, benefits and challenges of the technology, and how it can help address food security.                                                |
| Feng, Wang, Duan, et al. (2020)              | To understand how Blockchain can facilitate a food traceability system for FSC.                                                                                                                           |

**Figure 1.** Hypothesized stages and determinants of Blockchain implementation.

by McKinsey in 2017, many among the very first Blockchain initiatives focus on food products (Alicke et al. 2017). Some notable examples include a Blockchain-based food tracking platform created by IBM and a successful Blockchain pilot by Walmart for tracking its pork supply in China. The momentum for adopting Blockchain in the FSC continues to grow strongly. In 2019, Albertsons joined more than 50 other organizations as a member of IBM's Blockchain-based Food Trust network, alongside many other retail giants such as Walmart and Carrefour (Wolfson 2019).

Blockchain adoption in the food industry is growing and, thus, providing an excellent opportunity for theoretical and practical contributions to Blockchain-enabled food supply chains. While existing review studies on Blockchain for FSCs (Table 1) provides an ideal starting point for researchers, certain aspects have not been fully realized. Specifically, there is a need for exploring the process of implementing Blockchain in the specific FSC setting. Blockchain is a novel technology; nevertheless, the subject of implementing new technological innovation in SCM has been long studied under the perspective of Innovation Adoption (IA) theory (Zhu, Kraemer, and Xu 2006; Martins, Oliveira, and Thomas 2016; Hossain, Quaddus, and Islam 2016). The implementation process is considered an essential facet in studying innovations since such a process is seldom straight-forward and a thorough understanding regarding the integration of new technology/ideas is key to realizing the wider benefits for businesses (Zhu, Kraemer, and Xu 2006; Damanpour and Schneider

2006; Hossain, Quaddus, and Islam 2016). The importance of this topic, together with the scarcity of successful Blockchain initiatives within the food industry (Kamilaris, Fonts, and Prenafeta-Boldú 2019), led us to explore the following research question: *What is the process for implementing Blockchain in FSCs?* To address the defined research question, this study presents a review of relevant studies to recommend evidence-based research avenues and provide a conceptual framework for implementing Blockchain in FSCs. This work contributes by strengthening the body of literature interfacing Blockchain and FSCs.

The rest of the paper is structured as follows: Section 2 provides the background to the research, Section 3 presents the methodology of this paper, Section 4 and Section 5 provide the descriptive and thematic analysis, respectively. Section 6 develops a conceptual framework of Blockchain implementation in the FSC based on findings from the data set and established theories. Section 7 concludes this study with future research avenues, discussion and concluding remarks.

## 2. Research background

### 2.1. FSC challenges

FSC-oriented research is compelling since food products possess distinctive characteristics (Ghadge, Er Kara, et al. 2020). A large number of food products are perishable, temperature-sensitive, seasonal, and dependent on nature for

production (Akkerman, Farahani, and Grunow 2010; Shukla and Jharkharia 2013; Fredriksson and Liljestrand 2015). Food is an integral aspect of today's societies and economies. On average, a household in the UK allocates 10% of its total spending on home meals and another 7% for catering services, according to the 2018–2019 report from the UK government (Office for National Statistics 2020). The EU acknowledges the food and drink industry as the largest manufacturing sector in this region, with a turnover of 1.2 trillion Euros in 2019 (Food Drink Europe, 2019). For the US, agriculture and its related industries account for 11 percent of total employment and 5.2% of GDP (United States Department of Agriculture 2020). Similar figures are observed in developing countries, and this portrays the criticality of FSC. Therefore, researchers need to 'adapt and develop solutions that fit the specific demand for food products' (Fredriksson and Liljestrand 2015, 16). This study echoes the view and further argues that a dedicated review for implementing Blockchain in FSCs is necessary. Moreover, such a focussed study can provide a meaningful contribution to the research on food supply chain management.

## 2.2. Defining stages and determinants of Blockchain implementation

It is crucial to study the phenomenon of Blockchain under appropriate theoretical lenses (Cole, Stevenson, and Aitken 2019; van Hoek 2019; Saberi et al. 2019), as theories can help to understand different aspects of the phenomenon better. Since this study looks at implementing new technology (i.e. Blockchain) for managing FSCs, use of IA theories is a suitable approach. Blockchain can be categorized as an innovation, as the technology is new to the adopting units and benefits are anticipated from the changes brought by the latest technology (Damanpour and Schneider 2006). Moreover, theoretical lenses were successfully used in studying the implementation of preceding technological innovations such as RFID (Hossain, Quaddus, and Islam 2016). IA theories and models have also been used to explore various facets of Blockchain adoption recently, such as individual user acceptance (Queiroz and Wamba 2019), defining adoption processes (Hughes et al. 2019) and identifying determinants of Blockchain adoption (Wong et al. 2019; Wamba and Queiroz 2020).

A structured model is often used to capture the implementation process, as the adoption of new technology happens over sequential phases (Hameed, Counsell, and Swift 2012; Pichlak 2016). The dichotomy of stages is found to vary between models. According to Rogers Everett (1995), the adoption of innovation unfolds in five stages: knowledge, persuasion, decision, implementation, and confirmation. Drawing on the technological diffusion perspective, Kwon and Zmud (1987) and Cooper and Zmud (1990) constructed a model for IT implementation comprising six steps: initiation, adoption, adaptation, acceptance, routinization, and infusion. More recent studies tend to suggest a model with a lower number of stages but providing extensive meaning. Hameed, Counsell, and Swift (2012) considered a three-stage model for innovation implementation, including pre-

adoption, adoption-decision and post-adoption; and Pichlak (2016) suggested a process of adoption with initiation, adoption decision, and implementation phases. Though the generalization of concepts and categorization of terms differ in the literature, the essential activities are consistent throughout existing models: (1) Initiation – the organization rationalizes the decision of adopting the innovation, (2) Adoption decision – the organization decides whether and how to implement the innovation, and (3) Implementation – the organization deploys/applies the innovation.

Four main categories of influential attributes towards the implementation process are further determined as: innovation characteristics, organizational characteristics, environmental characteristics, and management characteristics. To outline these attributes, several vital studies were reviewed. Damanpour and Schneider (2006) examined multi-dimensional factors influencing innovation adoption phases focusing on public organization. Zhu, Kraemer, and Xu (2006) assessed the assimilation of e-business for organization and determinants for such processes. Hameed, Counsell, and Swift (2012) developed a conceptual model for adopting IT innovation based on the integration of Diffusion of Innovation and Technology Organization Environment frameworks. Pichlak (2016) combined RBV and various innovation adoption models to develop a conceptual framework for determinants of the innovation adoption process. A more in-depth discussion about the four clusters of influential factors is provided in Section 6, where the construction of a final conceptual framework is presented.

In defining the innovation adoption process, and combining them with identified influential attributes, a preliminary conceptual model was proposed as shown in Figure 1. With insights generated from a thematic analysis of Blockchain interfacing FSCs studies, this model will be further refined to represent the implementation of Blockchain specifically for FSCs.

## 3. Methodology

This study examines the existing literature using the Systematic Literature Review (SLR) approach to answer the research question. The SLR is recognized as a robust methodology for a critical review of literature in management research (Tranfield, Denyer, and Smart 2003). Compared with the traditional narrative-led approach to the literature review, SLR provides a scientific, replicable, and transparent approach to accumulate studies, summarize existing information and minimize bias (Tranfield, Denyer, and Smart 2003; Denyer and Tranfield 2009). In Operations and SCM, SLR has become an essential review tool for researchers (Durach, Kembro, and Wieland 2017).

Drawing from SLR examples in medical research, Tranfield, Denyer, and Smart (2003) suggested a review protocol with three main stages (planning – conducting – reporting). While some studies followed this structure precisely (e.g. Queiroz, Telles, and Bonilla 2019), other researchers have adapted this to develop improved step-by-step approaches for conducting the SLR (e.g. Seuring and Müller 2008; Ghadge, Dani, and Kalawsky 2012). Nevertheless, the essence of the process

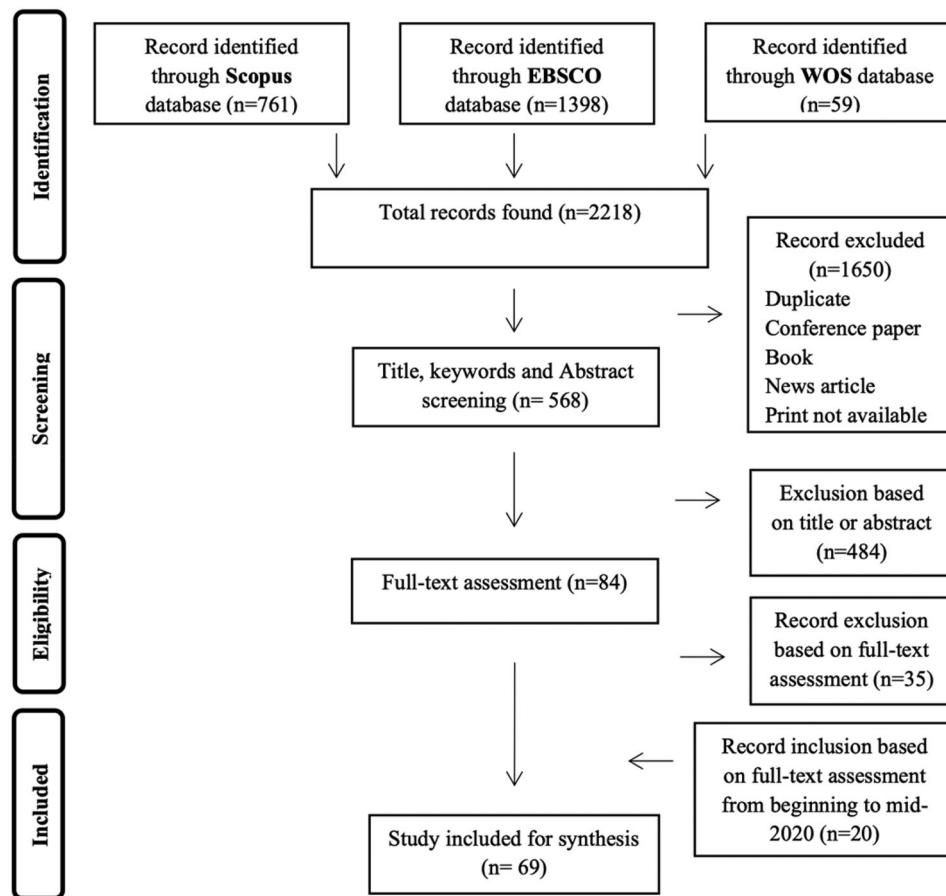


Figure 2. PRISMA flow diagram.

remains as selecting relevant studies, synthesizing insights from the dataset, and disseminating the state-of-the-art and future research directions. These fundamental stages are adopted in this study for the literature review on Blockchain implementation in FSCs.

The time horizon of the search was set from the year 2009 to June 2020. Many SLR studies on Blockchain understandably selected 2009 as the starting point for their data search (e.g. Queiroz, Telles, and Bonilla 2019; Wang, Han, and Beynon-Davies 2019) as it marks the launch of Bitcoin, the first proof of Blockchain's practicality (Iansiti and Lakhani 2017; Helo and Hao 2019). The authors, after careful consideration, came up with the following search strings to select relevant sources:

```
(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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Tachizawa and Yew Wong (2014) suggested that a search string should identify all papers suitable for answering the research questions, while also being narrow enough to ensure the relevance of those results. Therefore, this study identified 'Blockchain', 'food supply chain', 'implementation' and 'benefits' as keywords and the search strings were defined accordingly. Three reputable databases for academic publications, namely Scopus, EBSCO, and Web of Science

(WoS), were selected for the search. Using the search strings, 2218 studies between 2009 and 2020 were identified, as shown in Figure 2. WoS returned a noticeably lower number of results as this search engine employs different criteria for full text searching in contrast with Scopus and EBSCO. Given the nascent stage of Blockchain technology and its application in FSCs, full-text searching helped to determine relevant papers to the topic comprehensively.

Selecting studies with high quality and relevance is essential for accurate and meaningful synthesis (Ghadge, Dani, and Kalawsky 2012). Inclusion and exclusion criteria were introduced to screen the initial search results for filtering out the most relevant studies for the data synthesis. Figure 2 presents the screening process in the PRISMA diagram. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach helps to visualize the selection process followed for SLR (Moher et al. 2009). Since this review's objective was to deliver academically strong findings, stringent inclusion and exclusion criteria were defined by the authors. Papers appearing only in peer-reviewed studies were included. Although conference papers, book chapters, and news articles provide useful insights, such grey sources were excluded. In total, 1650 papers were excluded from the initial result of 2218 papers. The first author scanned the title, abstract, and keywords of the remaining papers to determine their relevancy to this study's aim. Eighty-four studies were qualified, and these were followed

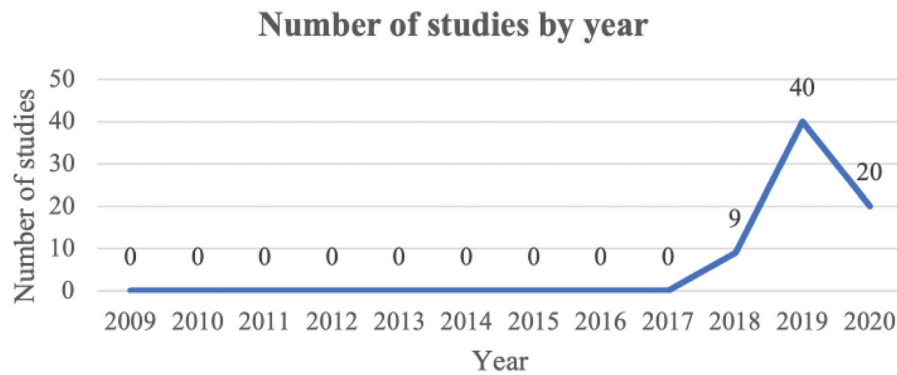


Figure 3. Publication by year.

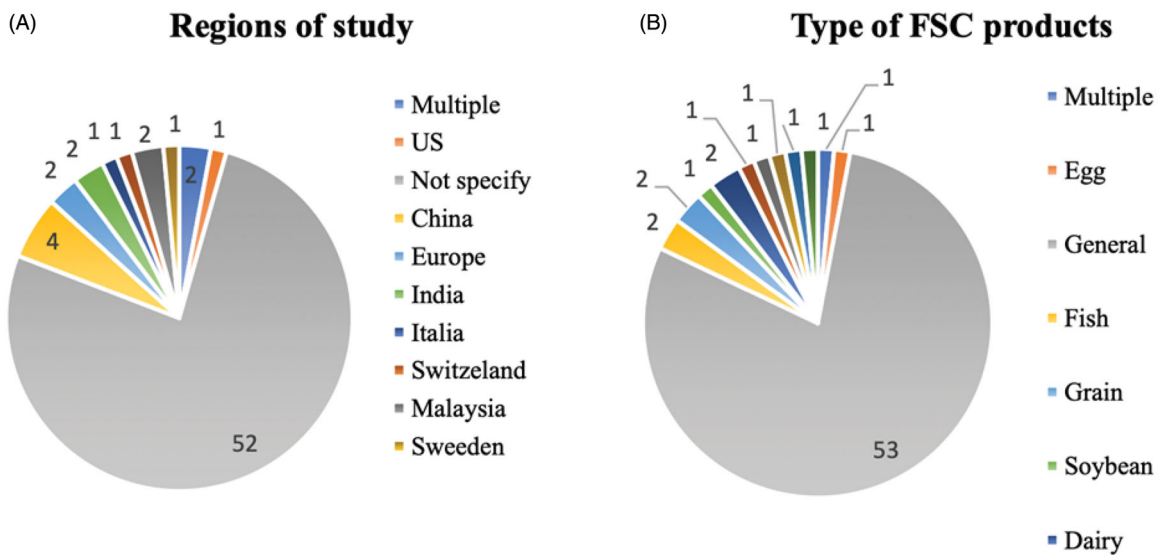


Figure 4. FSC regions of studies (A) and products type (B) covered in the data set.

up with full-text evaluation by a pair of authors. Papers were deemed eligible if they focus mainly on employing Blockchain for FSCM or address the FSC as one of the main fields for Blockchain applications. This search included academic journals from multi-disciplinary areas to obtain a holistic perspective of the field. The initial search was conducted at the end of 2019. However, to make the review most up to date, 20 papers published from January to June 2020 were included based on a full-text assessment. In the final stage, 69 papers were selected and approved by the authors for conducting data synthesis.

Data synthesis was conducted following a descriptive and thematic analysis approach proposed by Tranfield, Denyer, and Smart (2003). The descriptive analysis captures the overall state of the research stream, while thematic analysis examines, in-depth, the selected literature for specific themes emerging from the reviewed paper (Ghadge, Weiß, et al. 2020).

#### 4. Descriptive analysis

This section provides an overview of the research field under study – capturing publication trend, geographical and food product focus, and adopted theories and methods for

conducting research. The publication trend indicates a growing interest of researchers on Blockchain interfacing FSCs. Figure 3 showcases the distribution of 69 papers by year. It can be observed that peer-reviewed academic papers started to emerge mainly from the year 2018 and, since then, this number is continuously growing. The number of studies in 2020 captured only published work in the first half of the year. There are several exciting studies regarding Blockchain and FSC before 2018 – such as Tian (2016) and Caro et al. (2018), but they were excluded as they are conference papers. Overall, it can be concluded that the research stream about Blockchain implementation in FSCs is in an early stage of development and has started to gain strong momentum since 2018.

Next, the focus by geographic regions and by type of food products are captured in Figure 4. It can be observed that the majority of the selected papers investigated the use of Blockchain for the agri-food industry in general, rather than focussing on a specific type of food chain or region. Those papers, which focussed explicitly on a food chain, indicated that the interest in using Blockchain stems from numerous geographical regions and across varied food product types.

Concerning the use of theories, around one-fifth of the papers (22%) use established theories or existing conceptual

**Table 2.** Use of theories and conceptual framework.

| Use of theories/conceptual frameworks | References                               | Theories/conceptual frameworks                                                                                     |
|---------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| 15 papers (22%)                       | Queiroz and Wamba 2019                   | Combination of Network theory and Technology Acceptance Model (TAM).                                               |
|                                       | Hughes et al. 2019                       | Diffusion of innovation, specifically the model of innovation decisions process proposed by Rogers Everett (1995). |
|                                       | Kouhizadeh et al. 2020                   | ReSOLVE model for the circular economy.                                                                            |
|                                       | Roeck, Sternberg, and Hofmann 2020       | Transaction cost theory.                                                                                           |
|                                       | van Hoek 2019                            | Adaption from Reyes' 2016 model of RFID implementation.                                                            |
|                                       | Martinez et al. 2019                     | Combination of Resource-Based View and Information Processing theory.                                              |
|                                       | Morkunas, Paschen, and Boon 2019         | Utilization of the business model framework by Osterwalder and Pigneur.                                            |
|                                       | Wang, Singgih, et al. 2019               | Sensemaking theory.                                                                                                |
|                                       | Zelbst et al. 2019                       | General living systems theory.                                                                                     |
|                                       | Wong et al. 2019                         | Technology Organisation Environment framework.                                                                     |
|                                       | Behnke and Janssen 2020                  | Adaption from the conceptual framework developed by Aung and Chang in their 2014 research.                         |
|                                       | Caldarelli, Rossignoli, and Zardini 2020 | Combination of Knowledge-based view and Gold <i>et al.</i> 's 2015 model.                                          |
|                                       | Hew et al. 2020                          | Combination of Institutional theory and Innovation Diffusion theory.                                               |
|                                       | Sternberg et al. 2021                    | Interorganizational System (IOS) Model.                                                                            |
|                                       | Wamba, Queiroz, and Trinchera 2020       | Technology adoption models, mainly TAM and Unified Theory of Acceptance and use of technology.                     |

frameworks to study Blockchain for FSCs. This is an expected observation given the nascent state of research on Blockchain-interfacing supply chains. Table 2 presents 15 studies adopting established theories and/or conceptual models, whilst the remaining papers (78%) do not include any theoretical lenses/elements.

The research approaches/methods which were adopted in the selected papers are summarized in Table 3. The choice of research approach/methodology and the proportion of each type reflect the preliminary stage of Blockchain development in the FSC. Most of the effort from scholars has been directed to conceptualize various aspects of Blockchain implementation, experiment with the technology on a small scale, and synthesize up to date understanding about Blockchain. The two most common research approaches found comprise of conceptual (25%) and proof of concept (26%). Conceptual papers analyze the phenomenon of Blockchain using existing knowledge in SCM, while proof of concept papers are pilot stage studies, proposing a Blockchain-based solution for specific FSC problems. Review papers account for 19% of the total number of papers. Lack of large-scale projects and adopters is potentially attributed to lower numbers of empirical studies comparing other kinds of studies. There are 10 case study papers (17%), five papers using quantitative methods (10%), one using a qualitative method (1.5%), and one using mixed methods of survey and case study (1.5%).

## 5. Thematic analysis

Thematic analysis can provide a comprehensive and interpretative literature examination (Ghadge, Weiß et al. 2020). There are two approaches to thematic analysis in social studies (Terry et al. 2017). One is the 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 the hypothesis (coding). The other is an inductive approach, which aims to build themes throughout the examination of the available information. Braun and Clarke (2012) suggested starting with coding the contents and then developing and finalizing themes during and after the coding process.

This study employed a mixed approach to examine the literature. First, the researchers outlined potential themes based on concepts frequently found in the IA literature regarding the process of ingraining new technology (Hameed, Counsell, and Swift 2012). The initial themes then served as guidelines for the coding process. With support and guidance from the other two researchers, the first author thoroughly read each selected paper and recorded insights associated with Blockchain implementation (activities and influential factors). Subsequently, the key findings were gathered in a group with similar underpinning themes. Findings were circulated and agreed upon among all authors. An iterative process was followed to best represent the body of literature on Blockchain and the FSC. Figure 5 presents four broad themes utilized for conducting the thematic analysis.

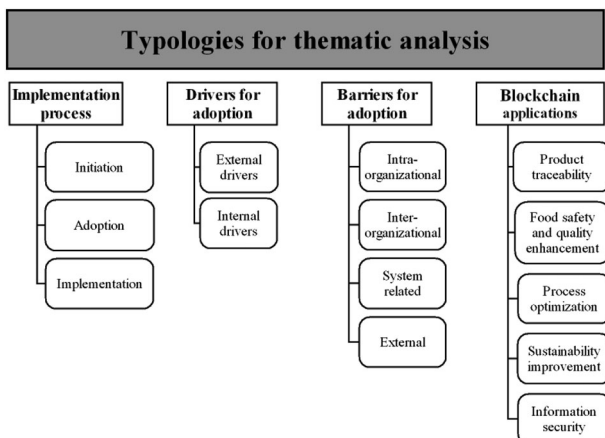
### 5.1. The implementation process

As indicated by the literature regarding the adoption of innovation (Zhu, Kraemer, and Xu 2006, Hameed, Counsell, and Swift 2012; Pichlak 2016; Sternberg, Hofmann, and Roeck 2021), a new technological innovation typically goes through the phases of imitation, adoption decision, and implementation to be ingrained fully into organizations. Literature about Blockchain for FSCM has reported similar activities suggested by IA literature; however, it is apparent that the emphasis is placed on only specific activities.

Among the selected studies, the topic of adopting Blockchain can be seen as either sole focus (e.g. Queiroz and Wamba 2019; van Hoek 2019; Wong et al. 2019) or part of the discussion (e.g. Bumblauskas et al. 2020; Caldarelli,

**Table 3.** Research approaches.

| Research approach | Number of studies (%) | References                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Conceptual        | 17 (25%)              | Ko, Lee, and Ryu (2018); Galvez, Mejuto, and Simal-Gandara (2018); Al-Jaroodi and Mohamed (2019); Astill et al. (2019); Chang, Iakovou, and Shi (2020); Cole, Stevenson, and Aitken (2019); Creydt and Fischer (2019); Heinrich et al. (2019); Kos and Kloppenburg (2019); Kumar, Liu, and Shan (2020); Kshetri (2019); Montecchi, Plangger, and Etter (2019); Morkunas, Paschen, and Boon (2019); Pearson et al. (2019); Saberi et al. (2019); Howson (2020); Zhang et al. (2020a) |
| Proof of concept  | 18 (26%)              | Leng et al. (2018); Mao, Wang, et al. (2018); Mao, Hao, et al. (2018); Perboli, Musso, and Rosano (2018); George et al. (2019); Helo and Hao (2019); Lin et al. (2019); Mondal et al. (2019); Salah et al. (2019); Tao et al. (2019); Tsang et al. (2019); Wang, Li, et al. (2019); Casino et al. (2020); Feng, Wang, Chen, et al. (2020); Hang, Ullah, and Kim (2020); Prashar et al. (2020); Shahid et al. (2020); Zhang et al. (2020b)                                           |
| Review            | 13 (19%)              | Antonucci et al. (2019); Hughes et al. (2019); Juma, Shaalan, and Kamel (2019); Kamilaris, Fonts, and Prenafeta-Boldú (2019); Pournader et al. (2020); Wamba et al. (2020); Wang, Han, and Beynon-Davies (2019); Zhao et al. (2019); Chen et al. (2020); Feng Wang, Duan, et al. (2020); Lin et al. (2020); Gonczol et al. (2020); Hastig and Sodhi (2020)                                                                                                                          |
| Case study        | 12 (17%)              | Kshetri (2018); Azzi, Chamoun, and Sokhn (2019); Bumblauskas et al. (2020); Chong et al. (2019); Kouhizadeh, Zhu, and Sarkis (2020); Martinez et al. (2019); Roeck, Sternberg, and Hofmann (2020); Behnke and Janssen (2020); Caldarelli, Rossignoli, and Zardini (2020); Shin, Kang, and Bae (2020); Sternberg, Hofmann, and Roeck (2021); Rogerson and Parry (2020)                                                                                                               |
| Quantitative      | 7 (10%)               | Queiroz and Wamba (2019); Kamble, Gunasekaran, and Sharma (2020); Sander, Semeijn, and Mahr (2018); Wong et al. (2019); Zelbst et al. (2019); Hew et al. (2020); Wamba, Queiroz, and Trinchera (2020)                                                                                                                                                                                                                                                                               |
| Mixed methods     | 1 (1.5%)              | van Hoek (2019)                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Qualitative       | 1 (1.5%)              | Wang, Singgih et al. (2019)                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

**Figure 5.** Themes emerging from selected papers.

Rossignoli, and Zardini 2020; Sternberg, Hofmann, and Roeck 2021). Drawing from IA literature, three broad phases, initiation – adoption – implementation, were suggested for the implementation of Blockchain (Cole, Stevenson, and Aitken 2019; van Hoek 2019; Sternberg, Hofmann, and Roeck 2021). In particular, during the initiation stage, a firm can realize a need, acquire knowledge about the technology, and propose a suitable solution fitting with the firm's current situation. An example is a case study conducted by Caldarelli, Rossignoli, and Zardini (2020), in which an Italian cheese producer opted for Blockchain due to the desire to reach final consumers and reduce the risk of counterfeit products. Subsequently, the company took the time to learn about the technology and analyzed their current situation to outline the most suitable Blockchain solution (being run by a consortium, using third-party software, etc.). For the adoption phase, extant literature mainly focussed on determining influential factors which constituted the

decision to adopt/use Blockchain, such as relative advantages of the technology, cost of adoption, pressure from competitors, etc. (Queiroz and Wamba 2019; Kamble, Gunasekaran, and Sharma 2020; Wong et al. 2019). A more detailed discussion about these factors can be found in the later sections. Lastly, piloting Blockchain is seen as the standard choice for organizations before rolling out on a mass scale (Cole, Stevenson, and Aitken 2019; van Hoek 2019; Bumblauskas et al. 2020). However, since most Blockchain for FSC projects are pending for large scale deployment or on hold after the pilot (Kamilaris, Fonts, and Prenafeta-Boldú 2019; Zhao et al. 2019), activities beyond this step have not been established.

While literature about Blockchain for FSCs has identified several activities during the implementation process, others might still be in the dark. For instance, during the adoption phase, IA researchers have determined that companies also take the step of allocating necessary resources for the implementation, in addition to the adoption decision (Hameed, Counsell, and Swift 2012; Pichlak 2016). Similarly, the implementation phase does not stop at large-scale deployment of the technology, but the organization needs to take further actions to integrate it into the existing infrastructure, such as training or routinizing (Martins, Oliveira, and Thomas 2016) and, perhaps, continuing to extend the scope of the project (Hossain, Quaddus, and Islam 2016). The lack of these recognised activities could be attributed to the novelty of both Blockchain use for FSCs and the infancy stage of the corresponding stream of research, further motivating researchers to explore this uncharted territory.

## 5.2. Drivers for adoption

This section presents the drivers for Blockchain implementation in the FSC. Drivers found in the selected literature can

be broadly grouped into internal and external drivers. The former are motivations emanating from within an organization, while the latter are factors coming from outside an organization. These motivational drivers originate primarily from the challenges faced by the FSC and explore whether Blockchain can provide potential solutions.

### 5.2.1. Internal drivers

Reviewed papers reveal that businesses are most interested in the Blockchain ability to enhance food traceability, transparency, and efficiency. Other motivations found include combating food fraud and cost-saving.

**5.2.1.1. Enhance food traceability.** Food traceability is the ability to track food products throughout multiple processes and entities in the FSC. Traceability in the current agricultural-food chain is difficult to execute since it is complex and globalized, with multiple tiers of suppliers and buyers (Mao, Hao, et al. 2018; Azzi, Chamoun, and Sokhn 2019). Moreover, current practices of centralizing tracking information cause severe data fragmentation and information asymmetry in the FSC (Salah et al. 2019; Tsang et al. 2019). With its distributed and tamper-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 systems (Al-Jaroodi and Mohamed 2019; Pearson et al. 2019). Businesses further anticipate Blockchain to accelerate the speed of the tracking process significantly, as Walmart's Blockchain pilot saw a significant amount of time reduced for tracing mangoes and pork (George et al. 2019; Kamilaris, Fonts, and Prenafeta-Boldú 2019; Wang, Singgih, et al. 2019).

**5.2.1.2. Enhance food chain transparency.** Transparency can be defined as the ability to see from one end of the supply chain to another (Zelbst et al. 2019). Lack of transparency can result in quality and safety issues in FSCM. For instance, an E. coli outbreak (2015) in the US caused not only tremendous damage to people and businesses but also took a substantial amount of time to resolve due to the lack of visibility in the supply chain (Kshetri 2019; George et al. 2019). Blockchain can broadcast information of products' movement and custody along the chain to every participant in real-time (Kumar, Liu, and Shan 2020; Mondal et al. 2019), enabling FSCs to be more transparent. This is a meaningful improvement in managing food quality and safety, especially for product lines in which different grades and types of food can be easily mixed, such as processed meat (Pearson et al. 2019) or soybean (Salah et al. 2019). Halal food is another example where increased transparency is hugely beneficial (Hew et al. 2020). Furthermore, businesses can rely on Blockchain to obtain reliable information about food provenance and communicate such information to consumers to gain a competitive edge over others in the market (Helo and

Hao 2019; Montecchi, Plangger, and Etter 2019; Caldarelli, Rossignoli, and Zardini 2020).

**5.2.1.3. Increase efficiency.** 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 the literature as one of the biggest challenges of FSCM (Astill et al. 2019; Kumar, Liu, and Shan 2020; van Hoek 2019). Transparent and immutable records of transactions and activity stored on Blockchain can help firms quickly locate and separate contamination areas (Creydt and Fischer 2019; Gonczol et al. 2020), thus avoiding the necessity to shut down the entire supply line. Other logistical processes can also be optimized with the help of Blockchain. For instance, businesses can obtain comprehensive information regarding food products' shelf life to manage inventory and plan transportation accordingly, increasing profit and reducing waste (Astill et al. 2019; Roeck, Sternberg, and Hofmann 2020). It is further suggested that trustworthy information provided by Blockchain can speed up the claims-processing system in agriculture and payment process between FSC entities (Kamilaris, Fonts, and Prenafeta-Boldú 2019; Kumar, Liu, and Shan 2020; Hang, Ullah, and Kim 2020).

**5.2.1.4. Combat food fraud.** Counterfeit food products are a serious problem in modern food chains. Malicious parties can take advantage of the complex and fragmented food supply line to substitute food and ingredients with those of lower quality (Creydt and Fischer 2019; Hang, Ullah, and Kim 2020). As product movements are documented, verified, and protected with Blockchain, firms can prevent false products from mixing in and reaching consumers (Galvez, Mejuto, and Simal-Gandara 2018; Caldarelli, Rossignoli, and Zardini 2020). Moreover, Blockchain can accelerate the process of auditing and settling disputes since audit trails of every activity are recorded and protected in the chain (Chang, Iakovou, and Shi 2020; Kamble, Gunasekaran, and Sharma 2020), thus discouraging the unethical practice of violating food integrity.

**5.2.1.5. Reduce cost.** Blockchain can help companies to reduce cost. The cost of implementing a Blockchain-based system for a group is possibly less than an individual organization investing in a separate solution (Roeck, Sternberg, and Hofmann 2020). Blockchain can potentially remove the middle entities in a certain part of FSCs, lowering the over-cost of goods sold (Wong et al. 2019; Chen et al. 2020). A smart contract, a computer program with the ability to self-execute based on predetermined conditions, can be run on Blockchain to reduce further expense (Creydt and Fischer 2019; Kumar, Liu, and Shan 2020). For example, the smart contract can authorize payment automatically to suppliers once buyers provide proof of delivery and confirmation of the condition of goods, minimising human involvement to save time and effort.

### 5.2.2. External drivers

External drivers arise outside the company's environment and motivate firms to adopt Blockchain for better

management of food. The examined literature specifies pressure from consumers, competitors, and regulatory bodies within the FSC as external drivers.

**5.2.2.1. Pressure from consumers.** Consumers are increasingly concerned about the quality and safety of food products due to a series of violations in recent years (e.g. the horsemeat scandal in the EU; infant milk incident in China; salmonella and E. coli outbreak in the US) (Sander, Semeijn, and Mahr 2018; Astill et al. 2019). Frequent problems of counterfeit food (Hang, Ullah, and Kim 2020) and mislabeling (Astill et al. 2019; Kamilaris, Fonts, and Prenafeta-Boldú 2019) also broaden this concern. Furthermore, consumers are becoming highly aware of the environmental and social impacts associated with FSC by-products (Heinrich et al. 2019; Kouhizadeh, Zhu, and Sarkis 2020; Wang, Han, and Beynon-Davies 2019). Thus, organizations view Blockchain as a tool to cope with recent changes in consumers' preferences. Using Blockchain, trustworthy firms in FSCs can provide reliable information about product provenance and assure consumers of their sustainable practices.

**5.2.2.2. Pressure from buyers/suppliers and competitors.** With a growing focus on the use of modern technology in the digital era, several competitors indirectly drive the need for adopting Blockchain. For example, Carrefour (a major French grocery retailer) launched a Blockchain project to monitor product lines such as poultry, tomato, honey, etc., anticipating that traceable food products would give them a competitive edge over other retailers (Chang, Iakovou, and Shi 2020). Moreover, the leading company in adopting Blockchain can, in turn, pressure other entities in the FSC to adopt the technology. For instance, following successful pilots, Walmart now mandates farmers and suppliers to join its growing Blockchain system (Kshetri 2018; Chang, Iakovou, and Shi 2020). Global suppliers can exert similar pressures to streamline industries for Blockchain use. Since the benefit of using Blockchain is multiplied with a larger number of users (Chen et al. 2020), pioneering firms cannot neglect the participation of smaller organizations, and often urge them to join the Blockchain network (Cole, Stevenson, and Aitken 2019; Wang, Han, and Beynon-Davies 2019).

**5.2.2.3. Pressure from regulations.** FSCs have always been under strict scrutiny from regulatory bodies on multiple aspects. For instance, Canada enforces the use of barcodes and tags to identify the initial herd of animals, and Australia uses a national scale system to track animals from birth to slaughter (Wang, Li, et al. 2019). Furthermore, 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 becoming stricter on multiple fronts, firms in the food industry are pressured to explore Blockchain for better compliance to the requirements (Casino et al. 2020), as the technology can help track a product through multiple stages and provide reliable records of sustainable practices.

### 5.3. Barriers to adoption

In this theme, barriers to adopting and/or implementing Blockchain in FSCs are discussed. Saberi et al. (2019) and Cole, Stevenson, and Aitken (2019) classify barriers to Blockchain adoption within SCM into four main categories: intra-organizational, inter-organizational, system-related, and external barriers. Adopting this classification, barriers for implementing Blockchain in FSC are assessed.

#### 5.3.1. Intra-organizational barriers

Intra-organizational barriers are reasons derived from within an organization, making managers reluctant to adopt Blockchain. Four intra-organizational barriers are identified namely, high implementation cost, lack of knowledge and expertise, transparency versus privacy dilemma and uncertainty about Blockchain suitability.

**5.3.1.1. High implementation cost.** Investing in Blockchain can be expensive, and firms are concerned that the benefits of technology might not outplay high cost (Wang, Singgih, et al. 2019; Zhao et al. 2019). The complexity of Blockchain could require a considerable amount of time and resource from firms to master (Wong et al. 2019); meanwhile, the cost of hiring Blockchain specialists can be exceptionally high due to large demand (Kshetri 2019). Moreover, firms must often invest in additional devices such as RFID or sensors for a comprehensive solution (Chen et al. 2020; Zhang et al. 2020a). Pioneers in exploring Blockchain include large enterprises such as Walmart or Carrefour since they are financially capable of investing in costly projects with an expectation of rewards in the long term (Cole, Stevenson, and Aitken 2019; Wang, Han, and Beynon-Davies 2019). For others, it might be difficult to justify such an investment. In the case of small and medium farmers or companies with low margins, a sudden spike in cost due to implementing Blockchain is a major concern and could hinder the chance of adoption (Kamilaris, Fonts, and Prenafeta-Boldú 2019; Zhao et al. 2019).

**5.3.1.2. Lack of knowledge and expertise.** Lack of knowledge and expertise about Blockchain technology is a concern for several organizations. Implementing Blockchain is a complex and lengthy process, requiring firms to have a certain level of knowledge, infrastructure, and technological capability (Chang, Iakovou, and Shi 2020; Helo and Hao 2019; Wong et al. 2019). For FSCs, small to medium farmers and companies make up a relatively large portion of the network (Leng et al. 2018; Kshetri 2019; Zhao et al. 2019), and they may not have sufficient technological understanding and expertise to engage in Blockchain implementation. Moreover, a lack of understanding about Blockchain from top managers can postpone implementation for the firm (Zhao et al. 2019; Chen et al. 2020). van Hoek (2019) further concludes from interviews with managers that the difficult part for many companies is not the technology but, rather, how to obtain the right experts to start the Blockchain project.

**5.3.1.3. Transparency versus privacy dilemma.** Blockchain provides transparency by allowing each participant to track, trace, and view all transactions stored in the chain. Companies can see activities and product movements further upstream or downstream in the context of the supply chain. Increased visibility brings inherent benefit such as end-to-end traceability; however, companies also face the risk of leaking private information (Lin et al. 2019; Chen et al. 2020). The trade-off between transparency and privacy could make organizations hesitate in investing in Blockchain. For instance, Sander, Semeijn, and Mahr (2018) found that large meat providers, who compete on a cost base, are reluctant to share their information about sources. Despite technical solutions such as encryption or masking identity, basic information, e.g. product type, price, time, location can still be revealed (Zhao et al. 2019). This is less of an issue for permissioned Blockchain networks since access to information can be controlled and authorized (Kumar, Liu, and Shan 2020; Wang, Han, and Beynon-Davies 2019); nonetheless doing so would compromise the visibility of the FSC.

**5.3.1.4. Blockchain suitability.** An inhibitor of Blockchain adoption is that technology might not be suitable for every organization or every kind of product. Companies may implement Blockchain due to the hype around it or the fear of competition (missing out) rather than the actual need (van Hoek 2019; Wang, Han, and Beynon-Davies 2019). Kumar, Liu, and Shan (2020) argue that if conventional solutions still prevail, investing in Blockchain will not be necessary. Kshetri (2019) further suggests that implementing Blockchain to manage high-value food products, for example high-end Australian beef is more realistic as it can potentially yield better returns. Return on investment is often critical to the decision of implementing technology such as Blockchain (Kouhizadeh, Zhu, and Sarkis 2020; Saberi et al. 2019); thus, the suitability of the technology can greatly dictate, and in some instances postpone, such decisions.

### 5.3.2. Inter-organizational barriers

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

**5.3.2.1. Supply chain readiness.** The Blockchain's ability to facilitate end-to-end traceability and increase transparency would be greatly undermined if only a small number of nodes in the FSC can join the network (Perboli, Musso, and Rosano 2018; Tsang et al. 2019). Although large enterprises can initiate Blockchain projects, smaller firms' participation is required for fruitful results (Wang, Han, and Beynon-Davies 2019; Chen et al. 2020). However, a large number of nodes in the food chain relate to farmers or small and medium-sized firms with limited technological expertise and financial resources (Leng et al. 2018; Kshetri 2019; Hang, Ullah, and Kim 2020). They are not likely to have the adequate

capability to adopt Blockchain. Practitioners, indeed, voice concern that while a single pilot might be plausible, implementing Blockchain on a supply chain scale is a great challenge (van Hoek 2019). As a result, firms could hesitate to invest in Blockchain if the majority within the FSC are not yet capable of adopting the technology.

**5.3.2.2. Inaccurate inputs.** Blockchain assures that no changes can be made once the information is verified and stored. However, manipulations or mistakes can still introduce incorrect data into the system, reducing the system's overall reliability and making it difficult to fix (Kamble, Gunasekaran, and Sharma 2020; Tsang et al. 2019). Sternberg, Hofmann, and Roeck (2021) found in a Blockchain pilot – ReLog – that fake red wine can still enter the system because Blockchain can only guarantee digital trust but not the physical monitoring of products. IT experts in organizations have stressed that even with automatic data capture using sensors, the integrity of input information cannot be fully guaranteed (Wang, Singgih et al. 2019; Creydt and Fischer 2019). Kumar, Liu, and Shan (2020) further pointed out that malicious entities can band together and falsely validate inputs into Blockchain in a permissioned network – the preferred choice for business. Subsequently, inaccurate inputs due to various reasons can compromise the ability of Blockchain to facilitate trust and transparency, hindering the motivation to adopt the technology from organizations.

**5.3.2.3. Variations in standards.** Since companies adhere to different policies and use different information systems, there is a lack of standards when it comes to the traceability of information and data format (Galvez, Mejuto, and Simal-Gandara 2018; Behnke and Janssen 2020). For example, food producers or processors from the US are required by law to always have information 'one step forward one step back' available (Bumblauskas et al. 2020); this might not be the case for firms in other regions of the world. Thus, it can be challenging to introduce standard Blockchain at the SCM/FSC level since there is no existing consensus on what information must be included. Moreover, early adopters tend to employ different Blockchain solutions; therefore, it is possible that one supplier/retailer might have to comply with many Blockchain systems at once (Pearson et al. 2019). This scenario can impose more cost and confusion to organizations, creating a non-welcoming attitude towards technology.

### 5.3.3. System-related barriers

This section addresses the Blockchain technology limits for FSCM and the challenges in designing an effective Blockchain system for the FSC.

**5.3.3.1. Scalability.** Scalability is a vital issue when using Blockchain for FSCM. To fully understand the nature of this problem, we need to review the core principle of technology. Blockchain is referred to as distributed ledger technology because each network participant has an identical version of the ledger (Kumar, Liu, and Shan 2020). When a change

happens, such as adding a new block, the system must update the ledger at every node to ensure a single version of truth among all entities. When the network scales up with more members and data, this update process is consequently slower, and latency becomes a more significant issue. The FSC has many actors involved from the point of production to the point of consumption (Pearson et al. 2019, Zhang et al. 2020b), and the amount of information generated is extremely large (Lin et al. 2019). Even though permissioned can process much more than public Blockchain – up to 3500 transactions per second for Hyperledger compared to 30 per second for Ethereum (Perboli, Musso, and Rosano 2018; Chang, Iakovou, and Shi 2020) – it is still not sufficient to handle the amount of data typically generated from FSC activities (Hang, Ullah, and Kim 2020). Consequently, organizations find that scaling Blockchain implementation beyond the pilot stage is very difficult (van Hoek 2019; Wang, Singgih et al. 2019).

**5.3.2.2. Smart contract designing.** An essential feature of the Blockchain system is the smart contract, which is fundamentally a computer program with the ability to self-execute based on predetermined conditions (Tao et al. 2019). A smart contract is stored in Blockchain and has access to data in the chain, increasing its validity and reliability. However, designing smart contracts for complex business logic remains a great challenge, and companies are somewhat hesitant to believe that all activities can be fully captured via smart contracts (Cole, Stevenson, and Aitken 2019; Kumar, Liu, and Shan 2020).

### 5.3.3. External barriers

External barriers refer to challenges originating from external stakeholders such as institutions, or the government, that are not directly benefitted from FSC activities (Saber et al. 2019). In a complex supply chain such as food, participants may be in different regions; thus, they are placed under different restrictions and regulations (Sander, Semeijn, and Mahr 2018; Howson 2020). The question then arises – What laws the Blockchain system must choose to build its policy? Furthermore, regulations from different countries may not align, e.g. a smart contract is recognized under US contract law, but it is not under other jurisdictions (Kumar, Liu, and Shan 2020; Chen et al. 2020). This could potentially be a problem in the case of a dispute. Overall, the lack of a unified regulation frame for Blockchain can make implementation less plausible.

## 5.4. Applications of Blockchain in FSCM

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

### 5.4.1. Product traceability

From a conceptual perspective, Blockchain technology, which provides comprehensive and real-time information about operations, matches the pre-requisite of a fragmented supply chain. Therefore, Blockchain in FSCs initiatives heavily prioritizes end-to-end product traceability. Walmart has cooperated with IBM since 2017 to pilot a Blockchain-based system to track mangoes and pork (Hughes et al. 2019; George et al. 2019), IBM introduced a Food Trust platform based on Blockchain (Chang, Iakovou, and Shi 2020; Pournader et al. 2020), and Carrefour launched the first Blockchain project in the EU for tracking its poultry products (Chang, Iakovou, and Shi 2020). Moreover, there are third-party Blockchain solutions that are tailored to food traceability. Notable examples include Provenance tracking fish in Indonesia (Kshetri 2018; Cole, Stevenson, and Aitken 2019), OpenSC tracking seafood from Australian waters (Howson 2020), and ChainNova tracking rice in China (Chong et al. 2019). Nevertheless, the majority of Blockchain projects for FSCM remain either pilots or small-scale implementation.

Additionally, a large amount of academic research also aims to facilitate end-to-end traceability for food products. Wang, Li, et al. (2019) and Salah et al. (2019) developed applications using Blockchain and smart contracts for food traceability; Lin et al. (2019) integrated Blockchain with an existing food traceability system (EPCIS) for an improved solution. Perboli, Musso, and Rosano (2018) applied a five-step model (GUEST) to design a Blockchain application for a European fresh food chain. Combining Blockchain with information-capturing technologies, e.g. RFID or sensors, Mondal et al. (2019) designed a generic solution for tracking food, and George et al. (2019) designed one specifically for food service businesses. The literature also frequently refers to BigchainDB proposed by researcher Tian, a real-time food tracking system based on Blockchain (Azzi, Chamoun, and Sokhn 2019; Juma, Shaalan, and Kamel 2019; Wang, Li, et al. 2019).

### 5.4.2. Food safety and quality enhancement

Food quality and safety are critical factors to a business's competitiveness (George et al., 2019; Heinrich et al. 2019; Tsang et al. 2019). Food recalls/incidents have placed tremendous pressure on the FSC to improve quality and safety monitoring (Zhao et al. 2019). Numerous Blockchain projects set out to specifically target the current quality and safety issues in the FSC. Notable examples are Alibaba's initiative (Kshetri 2018), the Food Trust Group by IBM and Walmart (Mao, Hao, et al. 2018), and collaboration between the Chinese retailer JD, Walmart, IBM, and Tsinghua University (Antonucci et al. 2019; Chen et al. 2020). Moreover, expensive food products are often the victim of food fraud, causing severe harm to legitimate businesses (Kshetri 2019). Thus, organizations can share traceability information on Blockchain with consumers to ensure they purchase authentic products. Examples of such initiatives include ChainNova for high-value rice from a specific region of China (Chong et al. 2019), San Rocco Dairy applying Blockchain for its Italian dairy products (Caldarelli, Rossignoli, and Zardini 2020), and

Ireland Craft Beers using Blockchain for the authenticity of artisan beer (Wamba et al. 2020).

#### 5.4.3. Process optimization

Blockchain could increase the efficiency of various activities in FSCM in terms of speed and accuracy. For instance, Blockchain helped Walmart reduce the tracking time from days to minutes in their most recent pilot (Astill et al. 2019; Wong et al. 2019). Mao, Wang, et al. (2018) and Tao et al. (2019) designed Blockchain-based systems to supervise FSC actors' credibility. Upon testing, Blockchain effectively accelerated the process of validating credibility while it also increased the trustworthiness of the results. Casino et al. (2020) used a pilot case of local private Blockchain for dairy products to demonstrate how the smart contract can lubricate the handling of traceability.

#### 5.4.4. Sustainability improvement

Blockchain can be used to tackle various sustainability issues in FSCM. Through Blockchain pilots, Walmart gained more comprehensive data of products' shelf-life and used such data to target the food waste issue via optimizing operations (Helo and Hao 2019). Organizations can also identify spoilage with increased precision, leading to less food going to landfill (Mao, Wang, et al. 2018, Wang, Han, and Beynon-Davies 2019). Resource usage in agriculture production can be made transparent using Blockchain, thus improving natural resources management (Kamilaris, Fonts, and Prenafeta-Boldú 2019; Zhao et al. 2019). Blockchain can be further used to address social concerns. Coca-Cola has experimented with Blockchain to address forced labour in the sugarcane sector (Kamilaris, Fonts, and Prenafeta-Boldú 2019). Many Blockchain initiatives also aim to monitor better animal welfare, such as Hendrix Genetics (Kamilaris, Fonts, and Prenafeta-Boldú 2019) and Carrefour (Chang, Iakovou, and Shi 2020; Feng, Wang, Duan, et al. 2020).

#### 5.4.5. Information security

Blockchain requires validation for each transaction and ensures no changes can be made after the information is stored, making falsification of data extremely difficult (Queiroz and Wamba 2019; Wang, Singgih, et al. 2019). Further, as a distributed ledger technology, Blockchain eliminates the single-point-of-failure existing in the conventional centralised system (Chang, Iakovou, and Shi 2020). Thus, the technology can be effectively used to ensure information security for FSCM (Salah et al. 2019; Zhao et al. 2019). A number of proposed proof-concepts also demonstrate this use of Blockchain; for instance, Zhang et al. (2020b) and Hang, Ullah, and Kim (2020) designed Blockchain applications to strengthen information security in the rice supply chain and fish farms respectively.

## 6. Towards a framework for Blockchain implementation

The above developments of Blockchain interfacing FSCs highlight a lack of empirical research and successful large-scale implementation examples in the food industry. Moreover, there are limited studies about executing Blockchain and the best practices for implementing it (van Hoek 2019; Saberi et al. 2019; Zhao et al. 2019). This aspect is crucial since understanding how innovation is ingrained into an organization is the key to materialising business benefits (Zhu, Kraemer, and Xu 2006). To address this established gap, insights synthesised on Blockchain-interfacing food chains literature (Section 5) are incorporated with the preliminary conceptual model (Figure 1) to develop a conceptual framework (capturing phases and influential factors) for implementing Blockchain in FSCs. The final integrated conceptual framework for Blockchain implementation in FSCs is presented in Figure 6.

As defined in the preliminary model construction (see Section 2.2), implementing Blockchain can happen through three main phases: initiation, adoption decision, and implementation. Eight activities were identified from the innovation adoption literature. First, an organization recognises a need for innovation, obtains knowledge of it, and proposes a plan of implementation (Hameed, Counsell, and Swift 2012; Pichlak 2016). Second, organizations must decide whether to adopt the innovation (Zhu, Kraemer, and Xu 2006; Martins, Oliveira, and Thomas 2016) and, if they choose to do so, they will allocate resources for adoption (Hameed, Counsell, and Swift 2012; Pichlak 2016). Third, the innovation is deployed, and the adopter must take the necessary steps to fully infuse it at an organizational and individual user level. Typical activities at this phase include developing the solution, implementing it at a large scale, training end-users, and routinizing the new technology (Cooper and Zmud 1990; Hameed, Counsell, and Swift 2012; Pichlak 2016). For adopting Blockchain in the food industry, five specific activities were echoed in the relevant literature. Companies first recognize a need for Blockchain to better track food products (Bumblauskas et al. 2020; Sternberg, Hofmann, and Roeck 2021) or ensure food authenticity (Kouhizadeh, Zhu, and Sarkis 2020), then engage in learning more about the technology (Caldarelli, Rossignoli, and Zardini 2020), and outline a pertinent solution (Chong et al. 2019; Caldarelli, Rossignoli, and Zardini 2020). Subsequently, the adoption decision is made after considering various factors (Kamble, Gunasekaran, and Sharma 2020; Wong et al. 2019). Further, a pilot is commonly carried out before full implementation (van Hoek 2019). The extant literature currently provides little insights about post-implementation activities, possibly due to the scarcity of successful large scale Blockchain projects for FSCM (Kamilaris, Fonts, and Prenafeta-Boldú 2019). This study predicts that further development of this stage will require major advancement of Blockchain in FSCs. Nonetheless, based on the IA literature, several activities can be hypothetically suggested, such as: training, routinizing, and extending the use of the technology (Cooper and Zmud 1990; Martins, Oliveira, and Thomas 2016; Hossain, Quaddus, and Islam

2016). Both actual activities recorded from literature and hypothetical were presented in Figure 6, with the latter in dotted boxes.

Furthermore, studies about Blockchain for FSCM unveiled interesting, influential factors to said process. Damanpour and Schneider (2006) argued that the process of incorporating innovation into an organization is not only multi-phased but also multi-dimensional, thus encouraging researchers to look at not only the stages of dissimilation but also influential factors and their effects. In this case, the determinants of the Blockchain implementation process can be drawn from insights synthesized from studies about Blockchain for FSCM, constituting the second important aspect of the conceptual framework.

As described in the preliminary model (Figure 1), four categories of determinants to the implementation process include innovation characteristics, organizational characteristics, environmental characteristics, and management characteristics. Insights drawn from the literature about Blockchain for FSCM were mapped and grouped under pertinent groups of attributes. For instance, innovation characteristics refer to the attributes of the innovation in consideration, which can affect the adoption decision and how the adoption process unfolds (Hameed, Counsell, and Swift 2012; Pichlak 2016). For this case, the cluster includes the *applications* of Blockchain, which outlines the use and potential of Blockchain, together with the *system-related barriers*, which identifies the constraints of the technology. For example, organizations need to determine the specific aim of the Blockchain project, e.g. for product traceability and understand the current technical limitations/challenges of Blockchain, before evaluating the feasibility of its implementation.

Subsequently, organizational characteristics are certain attributes of the adopter that can influence the adoption process (Damanpour and Schneider 2006; Hameed, Counsell, and Swift 2012). Intra-organization *drivers*, which are the improvements anticipated by organizations from using Blockchain, and several *intra-organizational barriers*, such as lack of capability or fear of losing privacy, can be considered as characteristics of an organization. Those factors can potentially impact different stages of implementation, as found in prior studies examining different technological innovation (Hossain, Quaddus, and Islam 2016; Martins, Oliveira, and Thomas 2016; Pichlak 2016). For instance, a barrier such as lack of IT capability is found to have an impact during the initiation and adoption phases (Martins, Oliveira, and Thomas 2016).

Further, the environment characteristics include factors originating from the surroundings of an organization, such as industry or market (Damanpour and Schneider 2006; Pichlak 2016). In the particular situation of using Blockchain for FSCM, it can be seen that inter-organization barriers, external barriers and external drivers belong to this category. Similar attribution can also be found in extant IA literature, in a conceptual model such as Hameed, Counsell, and Swift (2012) or empirical model such as Martins, Oliveira, and Thomas (2016) and Hossain, Quaddus, and Islam (2016).

Management characteristics are theorised to play an important role in the whole process of adopting innovation at an organizational level (Damanpour and Schneider 2006; Hameed, Counsell, and Swift 2012; Pichlak 2016). This attribute is highlighted in the literature on Blockchain for the FSCs. Saberi et al. (2019) considered the lack of top management support as a barrier to Blockchain. The involvement and commitment of managers can not only accelerate the project (van Hoek 2019) but also motivate other stakeholders to embrace this technology (Hastig and Sodhi 2020). Surprisingly, the discussion regarding the impact of top managers on adopting Blockchain for FSCM has not been articulated strongly among the selected papers in this SLR. Overall, these are important aspects providing the reason to keep them in the final conceptual framework. Future work can explore them further following an empirical study.

## 7. Conclusion and future research agenda

### 7.1. Future research avenues

Based on the synthesis of the study, six recommendations on future research directions of Blockchain implementation in FSCs are identified:

#### 7.1.1. Need for empirical work exploring the implementation process of Blockchain in FSCs

The extant literature has shed some light on the process of implementing Blockchain for organizations in FSCs, such as the constitution of adoption decisions (Wong et al. 2019) or how firms engage in Blockchain projects (Caldarelli, Rossignoli, and Zardini 2020). Nevertheless, further exploration is needed. As demonstrated in this study, IA literature can sufficiently outline the framework for implementing Blockchain in FSCs. However, in-depth insights from the agriculture and food industry are needed to develop robust and tailored frameworks for Blockchain-for-FSCs implementation to achieve desired results.

#### 7.1.2. Investigating scalability issues in the context of Blockchain implementation at the SC network level

Until now, successful Blockchain initiatives for food chains include pilots and small-scale projects (Cole, Stevenson, and Aitken 2019; Hughes et al. 2019; Kamilaris, Fonts, and Prenafeta-Boldú 2019). Thus, Blockchain implementation at the supply chain network level is a promising area for researchers. Scalability is a significant inhibitor of Blockchain implementation (Kumar, Liu, and Shan 2020). Therefore, examining the impact of this issue and how to effectively tackle it can establish grounds for adopting Blockchain at the inter-organizational level.

#### 7.1.3. Overcoming the fundamental challenges to Blockchain adoption

Particularly how to balance the trade-off between transparency and privacy, and how to overcome the problem of oracle – a gateway between Blockchain and the physical

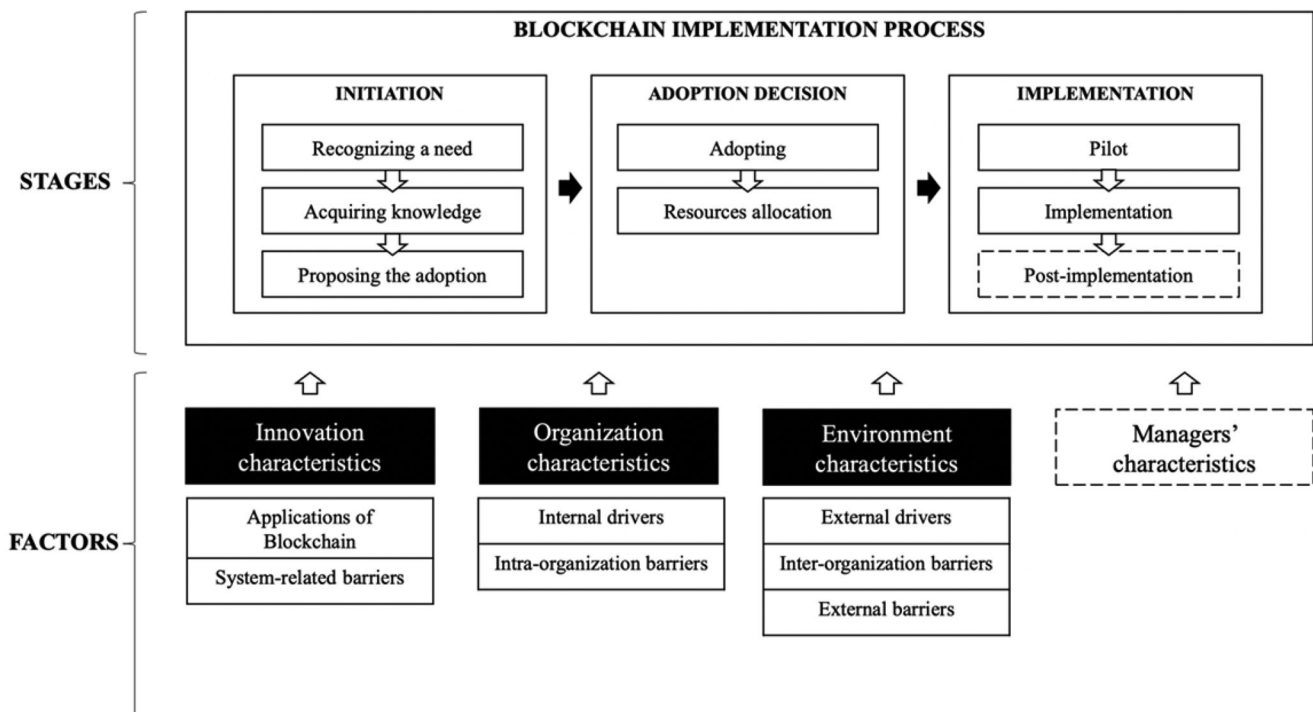


Figure 6. Conceptual stage model for Blockchain implementation in FSC.

world (Caldarelli, Rossignoli, and Zardini 2020). Both challenges were stressed as main concerns when adopting Blockchain for FSCM (Zhao et al. 2019; Caldarelli, Rossignoli, and Zardini 2020). For the former, a case study can observe how the transparency and privacy dilemma is addressed in an established Blockchain system. For the latter, even though inaccurate inputs are a major concern with Blockchain (Tsang et al. 2019; Sternberg, Hofmann, and Roeck 2021), modest effort has been put into exploring how to guarantee that an oracle can convey the correct information to Blockchain. Further work in this area can strengthen the validity of Blockchain use in FSCs.

#### 7.1.4. Capturing the aspects of incentivization

Incentivizing is an important mechanism for the permissioned Blockchain network as, when done correctly, it encourages willingness and responsibility in sharing data (Cole, Stevenson, and Aitken 2019; Pearson et al. 2019). Nevertheless, there has not been an ideal approach to incentivization. For public Blockchain, participants are encouraged by financial reward when validating the data (mining) (Nofer et al. 2017). For permissioned Blockchain, the incentive for providing information and endorsing transactions is not as clear. Hence, future research can investigate designing an effective method of incentivization.

#### 7.1.5. Using Blockchain to strengthen sustainability in the FSC

While several projects feature sustainability as a key objective, most Blockchain applications focus on bringing operational benefits to FSCM. Nonetheless, the technology can enhance sustainability in the food chain (Saber et al., 2019;

Kouhizadeh, Zhu, and Sarkis 2020); thus, future works can further explore how Blockchain can be used for sustainable development. For example, in-depth case studies can explore how Blockchain can be utilised to monitor waste or to ensure a fair share to the upstream farmers.

#### 7.1.6. Regulations for governing Blockchain networks:

The decentralization characteristic of Blockchain can bring certain advantages in terms of trustworthiness and transparency; however, it can be a limitation for the business use case, where overall control must be retained (Pearson et al. 2019; Hughes et al. 2019). The current body of literature about Blockchain and FSCM has offered a limited discussion on this subject. Several governance forms were mentioned, such as by participants of the network (Perboli, Musso, and Rosano 2018), by smart contracts (Chong et al. 2019; Salah et al. 2019), or the consortium that initiated the Blockchain project (Caldarelli, Rossignoli, and Zardini 2020). However, they are briefly examined, and in-depth analysis of each form is lacking. Further inquiries are needed to shed light on this important aspect.

#### 7.2. Discussion and concluding remarks

While attempting to address the defined research question – *What is the process for implementing Blockchain in FSCs?* The study synthesized four major themes: implementation process, drivers and barriers to adopting Blockchain, and current uses of Blockchain within the FSC context. It was found that organizations typically go through the process of initiation – adoption – implementation to assimilate the technology. Further, increasing transparency and efficiency were identified as two key internal drivers for Blockchain, whereas

pressure from consumers, competitors and regulatory bodies were critical external drivers. The main barriers to adoption included the privacy versus transparency dilemma, high implementation cost, the supply chain's readiness for Blockchain, and the scalability of Blockchain technology. Facilitating end-to-end traceability and strengthening food safety and quality were found as the most prominent use of Blockchain. The study makes a novel contribution to the field of supply chains in general and FSCs in particular. The study provides academically strong findings regarding the overall state of Blockchain implementation for the food supply chain and a conceptual model for implementation. Descriptive analysis of selected papers shows that this research stream is still in its infancy; nonetheless, the growth has been impressive and is expected to advance faster in the near future.

The study suggests IA theories as a legitimate approach to understanding and guiding the implementation of Blockchain. A novel, conceptual framework for implementing Blockchain in FSCs was developed using the lenses of IA theories. Therefore, this framework can be used as a reference by academics and practitioners in examining Blockchain use in the food industry.

Some implications for companies and regulatory bodies can be drawn from this study. First, managers gain an overview of the Blockchain development in the FSC and fundamental understandings about the implementation activities, potential, and challenges of a Blockchain application. Moreover, although conceptual, the framework can help managers plan their implementation process, utilizing the insights provided. For policymakers, it is possible to help leverage the use of Blockchain in the FSC by eliminating regulatory inhibitors, such as the lack of legal frameworks in recognizing smart contracts and, consequently, companies can adhere better to other regulations such as food traceability and food safety.

There are a few limitations to this study. A limited number of papers were used to derive insights. Future empirical work can advance the conceptual framework by testing it in an industry setting. The review was limited to the FSC context, thus generalizing the study's results to other SCM areas may be constrained. Although the keywords for the data search were carefully formulated, there is a possibility that several relevant studies may have been overlooked. Even though the 'grey literature' such as conference papers or book chapters were excluded to make our review procedure replicable and rigorous, we acknowledge that certain insights about the subject can be gained from examining such a stream of research. Nevertheless, this SLR provides evidence-based future avenues and contributes by providing a novel conceptual framework for implementing Blockchain in FSCs.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Notes on contributors



**Mr. Nam Vu** is a PhD Researcher at Centre of Logistics and Supply Chain Management at Cranfield University, UK. He is researching on the use of Blockchain technology in food supply chains. Nam obtained bachelor's degree in finance from Washington State University, USA and MSc in Logistics and Supply chain management with Distinction at Heriot-Watt University, Edinburgh, UK. After graduation, he spent the next 5 years working as a business analyst in one of the largest banks of Vietnam, specialising in Information technology implementation projects.



**Dr. Abhijeet Ghadge** is a Senior Lecturer in Logistics and Supply Chain Management at Cranfield School of Management, UK. He holds PhD in Operations and Supply Chain Management from Loughborough University, UK, and MTech in Industrial Engineering and Management from Indian Institute of Technology, India. He has several years of industrial, academic and consulting experience working with a wide range of UK, European and Asian organizations.

Dr Ghadge has published widely in leading operations, logistics and supply chain management journals. He follows practice-driven approach to problems across the broad domains of supply chain risk, sustainability and Industry 4.0.



**Professor Michael Bourlakis** is the Director of Research for Cranfield School of Management and the Head of the Logistics, Procurement and Supply Chain Management Group. Michael is an internationally renowned and established authority in logistics and supply chain management especially in food, retail and sustainable supply chains and supply chain technologies. He has been very successful in winning substantial external funding. Specifically, he won more than 33 research and consulting projects (as PI or Co-I), he has generated more than 265 publications including 76 journal papers and 5 edited books and he sits on the Editorial Board of 15 journals.

## ORCID

Nam Vu <http://orcid.org/0000-0003-4791-550X>  
 Abhijeet Ghadge <http://orcid.org/0000-0002-0310-2761>  
 Michael Bourlakis <http://orcid.org/0000-0001-5093-5398>

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