A Sustainable Blockchain Framework for the Halal Food Supply Chain: Lessons from Malaysia

Abstract

This study proposes a sustainable blockchain framework for the halal food supply chain. As is widely acknowledged, blockchain could enhance supply chain integrity, but its impacts on the halal food supply chain are unknown. Disruptive technologies for Industry 4.0 can improve transparency, which is desperately needed in the food supply chain; however, various challenges are also incurred. Based on five in-depth halal food supply chain case studies, this paper reveals a practical framework for overcoming the challenges faced by the halal food supply chain pertaining to blockchain implementation. The framework comprises five key challenges that are vital to small and medium enterprises in halal food supply chain blockchain implementation. The findings also indicate that the halal food supply chain can gain a congruent and fresh perspective in inducing or superseding blockchain technology. In addition, the roles of supply chain integration and food regulations as the key enablers on the success of blockchain technology in the halal food supply chain are also discussed in this study. Additionally, the limitations and future research directions are also discussed.

Keywords: blockchain technology, halal, food supply chain, SMEs

1.0 Introduction

Blockchain is argued to be the panacea of the current issues in multiple industries and supply chains (Hastig and Sodhi, 2019; Kamble, Gunasekaran and Gawankar, 2020). Previous studies found that a supply chain (SC) benefits from blockchain adoption because it improves the transparency (Kittipanya-ngam and Tan, 2020; Sunny, Undralla and Madhusudanan Pillai, 2020), traceability (Rejeb, 2018; Qian, Dai, *et al.*, 2020; Tan, Gligor and Ngah, 2020), firm performance (Kamble, Gunasekaran and Gawankar, 2020), and business model (Weking *et al.*, 2020). The food industry has observed the great potential of blockchain technology and considers its adoption a top priority (Edmund, 2018). Considering the advantages of blockchain, the food SC and industries have decided to adopt it for multiple aims, such as food safety, transparency, quality, and traceability (Kamilaris, Fonts and Prenafeta-Boldú, 2019; Wong *et al.*, 2020). Zwitter and Boisse-Despiaux (2018) argued that the concept of blockchain as a magic bullet in the SC is misleading. Even though a global and complex food SC intensifies the need for blockchain adoption, implementation and monitoring, Rogerson and Parry (2020) systematically reviewed studies on food SC blockchain and found that studies on the blockchain implementation challenges are scarce.

Disruptive technology has been implemented in the food SC to address the industrial problems, as depicted in Table 1. On this basis, introducing new technologies such as blockchain into the industry is a viable option. Nevertheless, blockchain technology still has unresolved issues and challenges beyond technicality that warrant more exploration and investigation (Kamilaris, Fonts and Prenafeta-Boldú, 2019). The immutable nature of blockchain (Treiblmaier, 2018; Queiroz, Telles and Bonilla, 2019; Köhler and Pizzol, 2020) may enhance SC performance and complicate fraudulent acts in the halal SC, which involve intangible values that are unable to be evaluated physically, such as slaughtering, contamination, and product purity. Halal food represents more than 17% of the total world

food production (Tan et al., 2017), and the absence of blockchain studies focusing on this sector leaves a significant gap in the knowledge. Tan et al. (2020) highlighted that empirical studies on the implementation of blockchain technology in the context of the halal food SC are available. Even though some research exists in this discourse, the majority of the literature on the blockchain and halal food SC nexus is theoretical in nature; for instance, regarding the conceptual understanding, applicability, and opportunities, no theoretical framework has been developed from a real case scenario (Tieman *et al.*, 2019; Tan, Gligor and Ngah, 2020). The absence of empirical research connecting the halal food SC and blockchain is also limiting (Duan *et al.*, 2020); therefore, reaping the benefits of blockchain remains difficult and complex for players in the SC and policymakers.

The previous literature on conceptual blockchain benefits to the total SC assumed application to a simplified SC. The generalizability of blockchain adoption into the food SC is daunting when the firm/farm size, exporters, and business environment vary. Although Kamilaris et al (2019) claimed that small players in the SC could benefit from investing in blockchain adoption, the majority of the studies on blockchain adoption have scrutinized the context of larger corporations and complete SCs and have generalized the findings to the context of small and medium enterprises (SMEs) (e.g., Hastig and Sodhi, 2019; Kamilaris et al., 2019). Especially for the halal food industry, the myriad of standards, regulations and requirements increase the technicality of blockchain adoption. Thus, a novel extension to the opportunities and challenges encountered by SMEs, the halal food SC and their key enablers is needed to understand the debate on the blockchain adoption and implementation. Specifically, the aims of this study are as follows:

1. To investigate blockchain opportunities and their potential impacts on the current halal SC business model.
2. To investigate the halal food SME SC's current practices and the challenges faced in embracing and adopting blockchain.
3. To propose a halal food SME blockchain challenges framework.

The findings of this study contribute to halal and blockchain knowledge by proposing an SME challenge framework. In addition, the key enablers for leveraging blockchain technology in halal food SMEs are provided. The results allow owners, managers, and policymakers to understand and identify the factors and challenges that are involved in successfully deploying blockchain technology in the food SC.

This research is presented as follows. Section 2 discusses and identifies the existing theories and gaps in the blockchain knowledge base concerning the halal food SC. The methodology is described in Section 3, including an explanation of the case studies involved in this research. Section 4 proposes a framework for the blockchain challenges faced by the SME halal food SC, followed by research and practice implications. Section 5 concludes with the findings, study limitations, and suggestions for future research opportunities.

2.0 Blockchain as Disruptive Technology in SC Management

Industry 4.0 is a new era of ICT where information about real products is linked to web-based applications and integrated into the production process. The technologies that provide better solutions and have the ability to replace the traditional methods in the SC can be regarded as disruptive (Abdel-Basset, Chang and Nabeeh, 2020). Table 1 exemplifies a list of disruptive technologies that are used in addressing the issues in the food SC. The interrelatedness and complexity of the food attributes in the SC (i.e., food traceability, food integrity, food safety,

food delivery, food quality, food security, and food recall) exacerbate the development and implementation of a capstone technology that has the potential to address all of the food concepts.

Even though a myriad of disruptive technologies has been introduced in the food SC, these technologies aim to address specific food issues and work in a silo and standalone with some spillover effect on the adjacent food attributes. For example, the smart-packaging that can either be used as a tracking device (Shoue Chen *et al.*, 2020) or an anti-counterfeiting mechanism is used as a stand-alone system (Soon and Manning, 2019). In addition, the listed disruptive technology is developed for one way communication; the consumption of the user with limited interaction between actors in the SC. The shortfall of the non-reciprocal relationship and communication limits the interface between the actors in the SC. As food is a fusion-type product, the production cannot be physically modulated once it is being processed. Therefore, a disruptive technology that allows mutual development among the SC stakeholders, as well as the incorporation of other existing technologies is novel. As argued by Kamilaris, Fonts and Prenafeta-Boldú (2019), blockchain technology has the ability to address the incorporation of the existing technologies and opening-up the horizon for more SC collaborations on its platforms.

*****TABLE 1 to be inserted somewhere here*****

According to Weking et al. (2020), the application of blockchain in the production process to provide better services to customers in the key part of Industry 4.0. Technically, Industry 4.0 refers to the interconnected dynamic global network (Kshetri, 2018; Ben-Daya, Hassini and Bahroun, 2019). In a broader scope, it is used to connect people, goods, and operations through a global network and to increase global competitiveness and provides network connectivity in the SC (Shankar *et al.*, no date; Chandra, Liaqat and Sharma, 2019; Kamilaris). Evidence exists showing that Industry 4.0 has fostered the use of blockchain technology applications in SC management (Kshetri, 2018; Zhao *et al.*, 2019; Qian, Dai, *et al.*, 2020). Blockchain application in SC management is forecasted to reach the value of $3,314.6 million by 2023, with an increasing annual rate of 87% (Chang, Iakovou and Shi, 2020). Learning from the opportunities and potential of blockchain application in the food agriculture and food SC, the industry and its stakeholders aim to capitalize on the technology, for example, by increasing the transparency in the SC, which is prone to fraudulent acts of untrusted actors (Kamilaris, Fonts and Prenafeta-Boldú, 2019; Kittipanya-ngam and Tan, 2020; Rogerson and Parry, 2020). Accordingly, Kittipanya-ngam and Tan (2020) developed a food SC digitalization conceptual framework, and the relationships between key opportunities and challenges are posited. However, the limited studies and guidance on blockchain in developing countries and firms of different sizes have been unable to address the technology dynamic impact (Mavilia and Pisani, 2020; Wong *et al.*, 2020).

2.1 Blockchain-based Halal Food SC

Traditional SCs face challenges at every point of the chain, for instance, delayed delivery, fraudulent acts, such as theft and spoilage, mishandling, contamination, and issues that are not easily captured using visual checks (Zailani *et al.*, 2019). Concerning the halal food SC, issues such as cross-contamination, halal counterfeiting, halal fraud, logistics issues and no development towards a standardized halal standard that is applicable around the world have always been at the forefront of the public debate (Tan *et al.*, 2017; Ali and Suleiman, 2018). The halal industry encounters inaccuracy and inauthenticity issues, as control over the whole

system is quite difficult to achieve because not everyone has access to information, which can greatly diminish the integrity of the food SC (Abidin and Perdana, 2019). All stakeholders and industry players have in-house ledgers for storing information, a system that does not truly embrace transparency.

Blockchain is expected to ensure transparency, real-time information on any product, fraud circumvention, manipulation resistance, reduced operational costs, auditability, enhanced product quality, safe and healthy consumption and a more structured halal certification process (Hew *et al.*, 2020; Tan, Gligor and Ngah, 2020). Normally, a halal food item is certified by halal certification at the country of origin by the halal authority, with some relevant data having been entered into a block of the blockchain. These data are updated as the food item moves along the SC, for instance, to a storage location, a warehouse or to an intermediary party. The procedure is repeated until the item reaches its destination, at which point it is verified by the blockchain applications before the halal authority approves its receipt. These processes are captured in blockchain applications, and consumers can verify all the information related to a product at any point.

Typically, transparency is the key to a successful halal food chain, as the presence of transparency improves both the authenticity and trust regarding a halal-certified product (Ali and Suleiman, 2018). Thus, blockchain itself is a technology that allows a shared database equipped with an open, safe, and verifiable system that does not require the presence of a central operator; therefore, the information flow cannot be easily manipulated (Rejeb, 2018). The application of blockchain allows multilevel SC players to communicate effectively and efficiently for better and outstanding decision-making and is believed to be an effective business tool to uplift the performance of the halal SC and increase the quality of halal products. In other words, leveraging blockchain technology in the halal food industry holds the potential to restructure the conventional ways of managing halal food traceability, promote credibility and trust, and boost the Islamic economy at large (Chandra, Liaqat and Sharma, 2019).

As the halal industry addresses further religious needs and requirements, blockchain can ensure the traceability of goods from their origin to the destination, minimizing the trust invested in intermediary third parties in the halal SC for product viability and integrity authentication, thus establishing the significance of this technology to the halal food market. The incorporation of blockchain in the halal food SC can serve as a platform for a tangible relationship between globally distributed trading partners via a transparent networking base, a vital component of the Shariah screening process to ensure that the product offered is truly halal. For example, each critical activity in the halal food supply chain identified in Tan et al. (2017) can be recorded and the information can be transacted between players in the supply chain. For halal food, these critical elements are currently represented by the halal logo. In current practice, blockchain technologies are used to perform several transactions and functions, such as sensing activity, motion, and temperature; actuating and collecting; and processing, storing, and sharing data (Rejeb, 2018). For instance, in halal logistics, halal packaging was equipped with sensors are that relay information such as temperature, humidity, light levels and the movement, enabling the monitoring and tracking of the physical condition of the entire shipment or an individual product. All of this information is post-processed, and blockchain technology can address the intangible information that resides within the halal supply chain. Devices can now even be customized and by having instant data regarding a shipment's physical condition enables real-time SC visibility (Rezaei et al., 2017),

and the incorporation of the purity elements of the halal food supply chain is equally important as added value.

3.0 Research Methodology

This research aims to determine 'how blockchain affects the halal food SC' and 'how halal food SMEs view the emergence of blockchain technology'. Firms are the unit of analysis in the study of the perception of the blockchain effect on the SME SC, as well as its impending challenges. This research follows the methodology applied in the work of Kittipanya-ngam and Tan (2020).

The research is designed to understand the opportunities and key challenges related to blockchain technology from the nexus of halal food SMEs and the SC. Qualitative data contains rich information for defining the dimensions of blockchain opportunities and halal food SME challenges; hence, this research adopted an exploratory approach that enables the authors to determine the important factors for further analysis (Marshall and Rossman, 2016). Three phases of key research activities were design to determine the main challenges of blockchain technology faced by halal food SMEs. First, this research identified the factors that can be used as a base for providing understanding and guidance during the exploration, data collection, and analysis. The literature was scrutinized to develop a sound comprehension of the blockchain opportunities and its adoption challenges in the food supply, definitions and interpretations. Second, triangulation of the data obtained from the cases studied, as shown in Table 2, was performed with the insights gained from phase one. The second phase enables this research to contextualize relevant blockchain opportunities and challenge dimensions from the angle of the SMEs in the halal industry, as shown in Figure 1. Finally, the data obtained from the case study was utilized to explain and consider the dimensions, as stipulated in Table 3. Thematic analysis was applied to generalize the complex challenges of the blockchain in the halal food SC settings.

3.1 Case study

Based on the research questions, this research opted to use case study methods following the three criteria of research approaches by Yin (2009). This research aims to understand how blockchain impacts the halal food SC and the rationale behind it. Since the blockchain research is in the embryonic stage and limited numbers of firms are adopting the technology, survey and archival analysis are deemed to be inappropriate to provide sufficient data to carry out a solid and in-depth discussion. The limited number of halal food SMEs applying blockchain technology impedes the experimental approach. This research focuses on blockchain, which is currently a phenomenon and contemporary event; therefore, the historical research approach is limited, as scarce historical information is available. Therefore, a more holistic approach is needed, and close contact with the firm being investigated provides a better understanding of blockchain technology in the halal food context. A multiple case study design is adopted in this study to yield a better understanding of the complex halal food SC. Furthermore, as highlighted by Voss, Tsikriktsis and Frohlich (2002), the multiple case study approach can safeguard this research from researcher bias and enhance external validity when the findings are generalized based on research findings, and more accurate conclusions can be postulated.

3.2 Data collection

Due to the scarcity of literature discussing blockchain in the halal food context (Duan *et al.*, 2020; Tan, Gligor and Ngah, 2020), this research is designed to begin with the literature from many corpuses of knowledge. The amalgamation of literature comprises the food SC, halal, SMEs, blockchain technology, and adoption to identify the research gaps and existing theory regarding the impact of blockchain on halal food SMEs. Then, the research questions of 'how does blockchain affect the halal food SC' and 'how do halal food SMEs anticipate and embrace the emergence of blockchain technology' are established to fill in this gap. Adopting the work of Kittipanya-ngam and Tan (2020) on digitalization in the food SC, the following sub-questions are inserted in the interview protocol and are valuable in drawing conclusions.

1. How do you see blockchain impacting the food SC, especially regarding halal food?
2. In what aspects do you think that blockchain will impact the halal food SC? How do you think it is affecting it now? [Can you elaborate from the aspects of technology, organization, and the environment?]
3. Could you share the opportunities/key challenges you perceive/face regarding adopting or embracing the growing trend of blockchain? How does your firm address these opportunities/challenges?
4. Are there any external pressures in the SC (among the stakeholders), i.e., customers, competitors, or regulators, with regard to blockchain [the growing trend of blockchain]? What are the pressures? How does your firm handle the pressures?
5. Is there any part of the SC or your internal business settings that can be improved to prepare your firm for blockchain integration? Are there any impending challenges that will cause you to continue using the traditional methods?
6. Are there any upcoming technologies that will impact your businesses?
7. What are your predictions about your business in the next five-ten years?

During the case study, the informants were asked and answered the key research questions and sub-questions. Despite the small number of respondents or cases, the case study method enriches the data collected (Eisenhardt, 1989). As per Yin (2009), the triangulation of the data obtained during the case study will enhance the validity, quality, and reliability of the study. Three semi-structured interviews were conducted in the case studies, as depicted in Table 2, with the management of SME food manufacturers in Malaysia. The management level was selected for this research to allow the researcher to have access to strategic information, especially in the context of anticipating and embracing blockchain technology. All of the companies were interviewed, and site visits were conducted (Case 1: between 1.5 to 2 hours; Case 2: between 2 to 2.5 hours; Case 3: 1.5 to 2 hours, Case 4: 1.5 hours; Case 5: 1 hour). Follow-up telephone calls were made when further clarification and explanation were needed.

3.3 Case sampling and selection

To ensure research validity, case sampling is carefully conducted. This research aims to build a theory that adopts theoretical sampling to enable the collection of diversified data (Glaser and Strauss 1967). Variance exists in the data, allowing this research to identify different categories that explain the characteristics and dimensions (Corbin and Strauss, 2014). This research applies four criteria for case selection to enhance the internal validity and generalizability (Mena, Humphries and Wilding, 2009; Kittipanya-ngam and Tan, 2020). This research focuses on SME firms in the halal food industry that are halal certified. The reason

for selecting halal-certified SME firms is to facilitate comparisons between cases that fall under similar parameters and contexts. All of the firms selected in this research are based in Malaysia. This criterion is set because Malaysia is known as a leading country supporting halal industries. The research on halal is predominantly being performed Malaysia (Mostafa, 2020); therefore, a relatively new study of blockchain in this context is provided. In addition, lessons learned from Malaysia's cases may represent the best understanding of halal best practices. The firms that inform this research represent different mixes of product types, allowing contrasting differences that are valuable for framework development. All of the companies fall under the characteristic stipulated by the Malaysia governing body known as SMECorp. Following these criteria, the selected cases and their details are as shown in Table 2.

*****TABLE 2 to be inserted somewhere here*****

3.4. Data analysis

Within-case and cross-case analyses are adopted in this study. First, each case is analysed individually, facilitating the insights to the second phase of the analysis; then, cross-case analysis is carried out to find the variance in the data. The two phases of data analysis are designed in this study according to Eisenhardt (1989) to prevent a premature conclusion, which can be caused by information and researcher bias. During the within-case analysis, the following key dimensions are used as a base:

1. Blockchain opportunities – investigates, explains, and clarifies the rationale behind the blockchain opportunities for the SME halal firm and its SC.
2. Blockchain implementation and adoption challenges – investigates, explains, and clarifies the rationale behind the blockchain adoption and implementation challenges for the SME halal firm and its SC.
3. Blockchain key enabler – investigates, explains, and clarifies key factors that can increase blockchain technology adoption within the SME halal food SC.

A conceptual framework of blockchain challenges of the SME halal food SC is proposed as the result of the cross-case analysis, as depicted in Figure 1. The framework is developed to elucidate the relationship between blockchain opportunities and key challenges that impede blockchain adoption and implementation among SMEs in the halal food SC. The theoretical and practical implications are embedded in the discussion and concluded. The limitations of this research design are noted, and thus, further research suggestions are provided. In summary, three distinctive research activities are conducted in this case-study-based research following the suggestion of Eisenhardt (1989) and Yin (2009).

*****TABLE 3 to be inserted somewhere here*****

4.0 Results, Discussion, and Implications

Figure 1 depicts the simplified blockchain that is applied in the halal food supply chain and is followed by an explanation of the opportunities that emerge from using blockchain technology in the halal food SC. Additionally, the key challenges of blockchain implementation and adoption from the perspective of halal food SMEs are brought forward and simplified in Figure 2. Furthermore, the key enablers of blockchain adoption for halal food SMEs are

brought forward. The theoretical and practical implications are discussed at the end of this section.

4.1 Blockchain opportunities in the halal food SC

Theoretically, the parties that participate in blockchain can benefit from information sharing, which is currently being practised in the halal food industry using halal certificates. In other words, blockchain can simply be achieved through the digitalization of halal certificates, which can assure consumers of the full-scale halal integrity (Tieman *et al.*, 2019; Keogh *et al.*, 2020). Blockchain may address the key aims of SC management, for instance, risk mitigation flexibility, quality, and sustainability (Kshetri, 2018) and, thus, may benefit the halal food SC. Specifically, the goal of the halal industry is to address the SC integrity, which is concerned with issues beyond those related to food safety and quality that are commonly being examined in the conventional food SC. Therefore, halal research related to food fraud, traceability, and transparency is commonly investigated when considering blockchain technology (e.g., Hew et al., 2020; Rejeb et al., 2020; Tan et al., 2020). The most likely explanation for this is that trends regarding the impacts of these research themes pose serious impacts, such as health and religious concerns for consumers. This research and the cases studied (Cases A-E) acknowledge the capability of blockchain in addressing this pressing need for traceability to improve food safety, food quality and food integrity in relation to the halal SC.

All the cases studied in this SC showed that blockchain technology is still new and that its adoption and the enjoyment of its benefits are not easy to achieve, especially for SMEs. The cases suggest that blockchain can be easily applied by capitalizing on the maturity of halal certification and the uniformity of the data. However, a careful application of this approach is needed for a few reasons. Case B highlighted some players in the SC that are considered non-critical and are able to trade in the halal industry without certification. Therefore, non-certified firms may be the missing link in fully integrating blockchain technology into the halal SC if this measure is adhered to. Case C highlighted that the verification of halal certification is currently done through manual disparity checks between halal certificates and local label descriptions, which are prone to tampering. Hence, the ultimate aim of the halal food industry may be defeated. This insight is visualized in Figure 1, which indicates that successful implementation and adoption of the blockchain technology will enhance visibility, transparency, and traceability. However, the figure also shows that when missing links exist in the SC (i.e., a non-certified firm), which will further affect the blockchain system, achieving halal food traceability, transparency, and integrity will become more complicated. Moreover, the overreliance on halal certification in carrying out information unification and feeding information to the chain yields little incentive to completely adopt blockchain technology in the industry.

*****FIGURE 1 to be inserted somewhere here*****

4.2 A blockchain framework for halal food SMEs

The adoption and implementation of blockchain technology in the food SC is in the embryonic phase and is suffering from many obstacles (Si Chen *et al.*, 2020). Moreover, through a consolidation of the literature and case studies, this study postulates five distinct dimensions of challenges faced by halal food SMEs in making blockchain viable, which are as follows:

complexity and capability, cost and competitive advantages, change management and external pressure, halal sustainable production and consumption, and regulatory culpability, as shown in Figure 2. The five dimensions reflect the challenges that reside within and beyond firm control, which is important for SMEs in the halal food SC to consider before embracing and adopting blockchains. It is important to note that the findings are derived from the thematic analysis from the case study and are not ranked in terms of their importance. The arrows in Figure 2 represent the repelling effects between the opportunities and impeding challenges, where the darker downward-pointing arrows indicate more problematic issues to be addressed in embracing blockchain technology.

4.2.1 Complexity and capability

Technology complexity has always been a pivotal topic in the innovation adoption literature (Hew *et al.*, 2020; Maroufkhani *et al.*, 2020). The literature reveals that firms prefer innovation that is simple, user-friendly, useful, and able to provide relative advantages (Clohessy and Acton, 2019; Yunan, Ali and Alam, 2020). SMEs have difficulties adopting blockchain technology (Kamilaris, Fonts and Prenafeta-Boldú, 2019; Wong *et al.*, 2020). Sophisticated knowledge of IT and equipment is essential when adopting blockchain technologies (Zhao *et al.*, 2019), which is not common among SMEs in the halal food industry. Moreover, digital devices must be available to all SC actors involved for data entry into the network chain (Kamble, Gunasekaran and Gawankar, 2020). However, for SMEs, this practice is not common, as data are still recorded using pen and paper. As an example, in Case C, all incoming stocks are checked manually. Another common practice is the reliance of firms on the halal labelling and certification of a product. Moreover, the materials used for production are standard with little variability; therefore, replacing traditional paper and pen with digital devices can be costly (Si Chen *et al.*, 2020). In all cases, homemade monitoring and control systems are used. As observed, all three systems are unique and different, which has made transferring information to a blockchain a serious problem (Nash, 2018). Consequently, the readiness of halal food SME firms regarding the complete adoption and implementation of blockchain technology in the food SC is questionable.

The halal food SC comprises firms of many sizes. Without a uniform standard of information, these firms are unable to share data and cannot share data that will result in information gaps, and technical compatibility between firms in the SC is almost impossible to achieve (Zhao *et al.*, 2019; Dutta *et al.*, 2020). All cases also highlighted the absence of a standard information format shared with suppliers, except for the information available regarding halal certification. Negotiations with the actors in the SC to unify the data formats can be conducted as a solution (Si Chen *et al.*, 2020); however, the economic scales of SMEs are too limited, thus influencing the negotiations. This limitation significantly hinders a firm's ability to adopt the blockchain strategy. The offshoring of difficult and costly SC activities by a firm is a sound strategy. Complex blockchain adoption can be overcome through the appointment of blockchain-based service providers. In the halal food context, many emerging blockchain service providers exist, such as Halal Digital Chain in Malaysia and HalalChain in the United Arab Emirates (Hew *et al.*, 2020). However, the imminent risk of non-ethical issues, such as Halachic vague data ownership and information leakage, arises when shared with a compromised third party in the blockchain (Chang, 2021; Kamilaris, Fonts and Prenafeta-Boldú, 2019). Consequently, the capability of halal food SMEs to control their blockchain adoption is limited.

4.2.2 Cost and competitive advantages

While halal food is produced to fulfil the expanding Islamic religious dietary market, one notable risk is that the food may be fraudulently produced. Islam is one of the fastest-growing religions, and a higher demand for halal food is anticipated (Ali and Suleiman, 2018). Furthermore, halal food is also consumable by other religions; this increase in the number of consumers will also impact the production of halal food. By contrast, food production is still catching up with the demand, a challenge that halal food is not exempt from. Furthermore, the literature has found that the usefulness of blockchain technology among SMEs in the halal food industry has yielded mixed findings. Although promising opportunities have been mentioned, the extensiveness of the application of blockchain is still limited.

For SMEs, which are commonly limited in their resources, the return on investment in technology adoption is critical. As highlighted by Ji *et al.* (2020), the uncertainty circling the return of the investment in blockchain technology casts more doubts about its implementation and adoption. For instance, developing a blockchain-based halal traceability system requires significant investment in multi-resources that are expensive for the firm and ultimately stop the stakeholders from participating (Hew *et al.*, 2020). Instead, blockchain adoption for food traceability has slim profit margins, especially for grocers and restaurants (Kim and Laskowski, 2018; Nash, 2018). This issue was present in all cases studied in this research. For example, Case B raises the following questions: Halal requires wholesomeness in its SC. Can blockchain fulfil this? Can it offer a better control mechanism than the existing one? The firms spent more than 7 years establishing their current control mechanisms in their SCs by aligning all the processes and activities suitable for halal standards and requirements laid out by the halal regulatory body. Another example is Case A, which is a member of the restaurant chain and produces OEM food products; it developed a closed-loop system business model that required more than 15 years to accomplish. All of the material supplies are produced either by the central kitchen or by the OEM factory, and the distribution is done in house. The control measures that ensure that the halal requirement is met with strict supplier selection have been a competitive weapon for the firm. Hence, the competitive advantages provided by blockchain require establishing its cost-effectiveness and a higher return on investment for the firm.

The halal food industry depends on halal certification, which has been tested for blockchain applicability (Tieman *et al.*, 2019; Keogh *et al.*, 2020). Each of the case study firms are aware of this effort and monitors it closely. However, they noted that the blockchain application will take much time to implement in the halal food industry because more than 70% of the total halal food market is composed of SMEs. For example, in Case C, their main raw materials are sourced from key suppliers that are distributors, and the information is passed along through halal certificates. They indicate that due to the small sizes of orders, an agreement with the main supplier is not achievable where data integration beyond halal certification is impossible, impeding blockchain viability. Similarly, Case A highlighted that suppliers are not keen to share any data other than that stipulated in the halal certificates. Limited data sharing may lead to missing information (Dutta *et al.*, 2020); therefore, the application value proposition of blockchain in the halal food context will be limited to the digitalization of halal certification. SME SCs are commonly shorter, and the number of products is small, making them less complex and manageable, therefore hindering SMEs from jumping on the blockchain bandwagon. In addition, the blockchain advantage of eliminating intermediaries (Saurabh and Dey, no date; Hastig and Sodhi, 2019) is not that appealing for the SME halal food SC.

Digitalization has improved transparency in the SC (Kittipanya-ngam and Tan, 2020). Conceptually, when all players in the SC put information up on the chain, the members of the chain can develop a strategic alliance and choose their business partners freely (Treiblmaier, 2018; Kamble, Gunasekaran and Gawankar, 2020). Relative to conventional digital technologies, blockchain technology enables all of the SC actors to have full access to the transactions (Ølnes, Ubacht and Janssen, 2017). Tracing this concept back to the period before the existence of blockchain, transparency was previously achieved through SC integration. SC integration argues that a firm with more extensive integration of its SC members is better off in terms of its performance (Frohlich and Westbrook, 2001; Tan *et al.*, 2017). Correspondingly, a myriad of research has provided empirical evidence of the impact of SC integration on firm performance. However, from the context of the food SC, the findings on SC integration yield mixed results in terms of the performance achieved. The dominant explanation for this inconsistent result is that players in the SME food SC reluctantly share information (Tan *et al.*, 2017). This reluctance is due to the nature of the SME food business, which allows the easy replication of information. As noted in Case B, a few occasions of larger firms trying to emulate their product due to some information leakage during a transaction can be observed. A substantial number of resources are required to mitigate the issue. Although blockchain may establish a trusted source of information for all transactions, making digitalized information available to anyone in the system may cause uneasiness for the SMEs in the halal food industry (Kaur *et al.*, 2018). Similarly, in Case C, the supplier information was mishandled, resulting in the creation of a few competitors in the marketplace. Since the number of credible suppliers with halal certification is scarce in the industry, each firm has to redevelop its products to obtain a greener marketplace. Hence, until blockchain technology sets some parameters to ensure the privacy and security of sensitive information (Kaur *et al.*, 2018), the SME halal food SC will lag in its adoption.

4.2.3 Change management and external pressure

Generally, the awareness of and skills related to blockchain are limited in the food SC (Zhao *et al.*, 2019). However, blockchain professionals and experts who can provide training platforms for the food SC are still scarce and are actually still gaining new knowledge themselves (Chang *et al.*, 2020; Dutta *et al.*, 2020; Mavilia and Pisani, 2020). All cases in this research showed that they are aware of blockchain technology. However, the understanding of blockchain technology in the food SC is still at the conceptual level due to the limited references and guidance regarding blockchain implementation in practice (Tan, Gligor and Ngah, 2020). SMEs commonly implement flatter organizations and have centralized decision-making processes. The adoption of blockchain depends on the knowledge and skills of upper management. Case C shows that the decision regarding technological inducement and automation within firms belongs to upper management, typically the owner of the firm. Halal food SMEs commonly see halal certification as a market qualifier; hence, additional changes to the existing system, i.e., to accommodate blockchain, are deemed not timely or appropriate. This situation is exemplified in Case A, where the restaurant chain and OEM food products were impacted by online viral cases that show the production of food products containing swine, which is not permissible for Muslim consumption. After a quick and careful investigation by the halal regulatory body, the viral cases were rebutted later that same day. The efficiency of the current halal mechanism may outweigh the benefits of blockchain application in terms of traceability because the cost of the technology is higher than the value of the food itself. Investment in blockchain-based systems, i.e., enhancing traceability in food

SC, incurs raised costs without necessarily increasing revenue (Kim and Laskowski, 2018; Erol *et al.*, 2020; Ji *et al.*, 2020).

Blockchain technology adoption and implementation require firms to have a holistic understanding of the related infrastructure and setup necessary to support the technology within each firm. Most likely, the existing infrastructure and support systems of firms will be outdated and thus not aligned with blockchain technology. In addition, a new business model may also be needed, and business models and operations may suffer from incompatibility with blockchain technology (Hastig and Sodhi, 2019; Urbano *et al.*, 2020; Weking *et al.*, 2020). Blockchain adoption by a firm may require a major overhaul, which will impact change management. The greatest challenge in change management is commonly related to human resource management; firms are expected to encourage employees to accept blockchain technology (Shankar *et al.*, no date). For instance, Case B presented the difficulty faced in managing employees and operations during efforts to achieve Hazard Analysis and Critical Control Point (HACCP) certification, with major changes being required within the firm. Moreover, the food industry is flooded with meta-systems and certifications (Ali and Suleiman, 2018). These meta-systems are overlapping, conflicting and demanding, bringing about more challenges for blockchain-related regulations and laws that will require daunting changes within firms to make them ready to adopt the technology (Galvez, Mejuto and Simal-Gandara, 2018).

4.2.4 Halal sustainable production

Firms are now more inclined towards being sustainable and socially responsible (Kittipanya-ngam and Tan, 2020). Halal production is regarded as sustainable because of its specific processes (Ali and Suleiman, 2016; Tan *et al.*, 2017). Because the goal of halal production is to produce products that are safe, high quality, and with intact integrity for consumers, incorporating the dynamism of the food concept into blockchain application implementation should be considered. In addition, not all of the food parameters can be monitored using analytical methods (Kamilaris, Fonts and Prenafeta-Boldύ, 2019). Some of the food concepts and parameters, such as safety, quality, integrity, and purity, are very difficult to measure and establish analytically, as they encompass and involve many aspects of production at every echelon of the SC (Ali and Suleiman, 2018).

Zhao *et al.* (2019) argued blockchain technology to be beneficial in reducing food safety risks, which relates to social impact. Case B and Case C provide important examples that refute this argument. Both cases imply that limited information regarding, e.g., the pesticides and fertilizers used to grow plants is made available. They further argue that farmers cannot update information regarding, e.g., the type, amount, frequency, and potency of pesticides and fertilizers used over the typically long periods of cultivation. Some available information is commonly given as blanket information for the whole process, such as sustainability certificates (Köhler and Pizzol, 2020). Even if proper information input is available when blockchain technology is adopted, the process is tedious, exhaustive, and costly for SMEs in the halal food SC (Wong *et al.*, 2020). Economically, Case D indicated a similar concern regarding the unwillingness of employees who are established, experienced and knowledgeable to embrace the blockchain into their business practices. They presume that the current operations are sustainable enough and are yet to observe a success story from blockchain adoption into the business. Similarly, Case E hinted that including blockchain as part of sustainable efforts is confusing and unrelatable. They further highlighted that their supply chain members still relate the blockchain with transaction and communication that

has minimal impact on sustaining the firms. Commonly, halal food SMEs, unlike other premium food producers, cannot transfer these costs to the end customer by setting higher prices and therefore satisfy the existing mechanisms that are argued to be highly related to sustainable efforts.

4.2.5 Regulatory culpability

Blockchain will eventually benefit the SC; however, it is highly dependent upon the regulatory bodies that govern the industry. Common legal requirements and standardization of the blockchain technology have yet to be agreed upon and established (Duan *et al.*, 2020; Keogh *et al.*, 2020), requiring a substantial amount of policy underwriting by the regulatory bodies that play a significant role in the halal food industry, such as JAKIM and the Ministry of Health. Blockchain policy and regulation are necessary for determining the feasibility of adoption. Furthermore, voluntary-based and underutilized international halal standards complicate the smart contracts between two parties in the halal SC. As mentioned, halal food relies upon governmental/certification bodies that have their own interpretations of Islamic divine sources, i.e., the Quran and practices of the prophet Muhammad, which may slightly differ from one another.

Nonuniformity and voluntary-based certification leave some uncritical players in the SC, i.e., vegetable farmers, distributors, and logistic providers, without halal certification, which may further complicate data sharing on the blockchain. The transition to wider adoption of the blockchain technology should be led and governed by a higher industry authority (Ølnes, Ubacht and Janssen, 2017; Hew *et al.*, 2020). However, efforts are being made to realize and trace physical data using blockchain through hazard and critical control point systems, which may apply to the halal food industry (Tian, 2017; Creydt and Fischer, 2019). However, the risk to halal food products exists at all levels, which is beyond the reach of the critical point. For the halal concept, the blockchain policy and regulations are anticipated to be tied with the current panacea for the halal industry and halal certification. Following this logic, to ensure the successfulness of blockchain implementation, uncritical players should also be certified, which will impact the small farmers residing within the SME SC. This scenario is exemplified by Case B regarding the difficulties in finding a halal-certified farmer as a supplier. Extending halal certification to uncritical players will impose a stricter requirement within the existing halal SC and further hinder the absolute application of blockchain technology. For SMEs that belong to uncritical points, blockchain technology can be viewed as another voluntary certification that they will not implement when the benefits are not obvious. This issue has been highlighted by Case C and E, who state that involving a third-party halal logistic provider is challenging and does not provide additional value to their finished product. Further, halal logistic providers are not largely available and are used on a voluntary basis, which complicates the blockchain implementation of the complete halal SME supply chain.

4.3 Key enablers for halal blockchain in the SME SC

Informed by dynamic capabilities theory, to adapt with the changing environments, the firms should be able to integrate, build and reconfigure internal and external competencies (Teece et al. 1997). Correspondingly, to obtain success in blockchain adoption in halal food SMEs, integrating internal and external competencies is crucial. Following Tecce's (2018) operationalization of the dynamic capabilities (i.e., sensing, seizing, and transform), the cases

studied have indicated that blockchain is regarded as a disruptive technology with great potential if it is adopted and applied in the halal food SC. However, the adoption and implementation of blockchain technology in the halal food industry, particularly in SMEs in this industry, is low. The perplexing situation of the mismatch between opportunities and the adoption of blockchain has been identified in this research and suggests that internal and external factors are needed to reduce the impact and seize blockchain opportunities in the halal food SME SC. From the findings, this research postulates extensive SC integration and regulatory intervention (internal and external competencies respectively) as universal enablers, as shown in Figure 3.

The fostering of SC integration between firms is mandatory. Blockchain remains a technology that aims to simplify and enhance the collaboration between two parties in the SC. Without more extensive SC integration, regardless of the form, how advanced, and how simple the implementation and application are, the potential and benefits of blockchain can never be achieved. The component of trust in the halal industry should extend beyond halal certification. As exemplified in Case A, a closed system was established within the firms that successfully safeguarded the halal issues in the firm and regarded them as competitive advantages. This system was developed with strategic SC partners by sharing data even more sensitive than halal certificates. Being able to take risks through information sharing with suppliers, for instance, is a daunting task, as it demands the utmost trust between parties. Furthermore, as blockchain does not allow the 'Control Z' options, the information is permanently available in the chain. Several uncontrollable factors also exist, such as foul play by some players of the SC, and strategic and trusted alliances can never be discovered if a firm does not gradually become more welcoming in terms of data sharing and being digitally connected. Hence, the readiness of a halal SME firm for blockchain integration strongly affects the implementation of blockchain in the overall SC.

*****FIGURE 3 to be inserted somewhere here*****

Regulations, halal standards, and halal regulatory bodies have been the backbone of the halal industry. Stricter regulations, revised halal standards, and proactive regulatory bodies in the halal industry can play a large role in blockchain adoption. Case B, for example, values halal integrity and calls for non-critical players in its SC to be halal certified. Blockchain cannot work at the optimum level when missing links/information occur in the SC. The halal industry/product values wholesomeness and integrity; therefore, a formative approach should adhere to blockchain implementation and adoption. Therefore, the halal industry requires a body that not only governs but also champions any innovation that contributes to the betterment of the industry. Moreover, halal governing bodies could play an important role in improving the ethical issues surrounding issues that have been of concern by the case firms studied, hence ensuring privacy, fairness and regulation for SMEs who are willing to commit to blockchain technology (Chang, 2021). In particular, SMEs in the halal food SC face challenges that limit the ability to adopt blockchain technology and are the largest segment in the halal food industry. In summary, the governmental and regulatory role are important in assisting SMEs (Ølnes, Ubacht and Janssen, 2017; Veronica *et al.*, 2020), especially in the case of the adoption non-eminent benefits technology such as blockchain.

These two enablers are interrelated, and the synergetic value between these enablers can address some of the challenges. For example, extensive SC integration is needed for system customization if halal regulations/standards are revisited and a decision is made to

incorporate blockchain technology. In another example raised by Cases C and D, the lack of significant value attached to blockchain technology in the SME SC may be due to a lack of knowledge and awareness. This issue could be mitigated by halal governance body intervention through training or self-experience regarding the benefits of more extensive SC integration.

4.4 Theoretical Contribution and Practical Implications

This research has contributed to theory in many different ways. First, the proposed framework addresses the gap highlighted in the halal food SC literature regarding the scarce amount of research investigating blockchain, as argued by Tieman et al. (2019). The proposed conceptual framework offers five key dimensions for practitioners to revisit the challenges and opportunities that can be achieved after adopting blockchain technology. Second, the adoption of the case study method in this research for framework development addresses the lack of empirical blockchain studies, especially concerning the halal food SC (Tan, Gligor and Ngah, 2020). Three SME firms participated in this research, enabling an in-depth explanation of and reasoning regarding the diffusion of blockchain technology. Third, this research responds to the call of Duan et al. (2020) for a real-life investigation of blockchain adoption and its application in the halal industry. Fourth, this study focuses on unresolved non-technical issues surrounding blockchain, as suggested by Kamilaris et al. (2019). Fifth, SMEs constitute the main discussion topic of this research, which extends the research by Wong et al., (2020) by investigating blockchain within the halal food context.

In practice, this research sheds light on the different players in the halal food SC. First, practising managers can use this research as a guideline to understand the relationship between the opportunities and challenges for blockchain adoption through the conceptual framework developed. Moreover, firms that have characteristics similar to those of the cases studied in this research can become aware of similar challenges that lie within their SC on blockchain adoption. Thus, firms should be more ready and proactive when preparing for blockchain adoption in the future. In addition, this research unravels the challenges that halal food SMEs face in reality. Through a detailed discussion and examination of the blockchain opportunities and challenges provided, this research offers important information pertinent to governmental policy underwriting.

5.0 Conclusion

In summary, our findings indicated that blockchain, as disruptive technology, can help halal food SMEs achieve food SC transparency. However, some challenges may hinder its adoption. An investigation of blockchain in the context of halal SCs that is supported by empirical evidence is urgently needed. Hence, the objective of this research is to address the research gap through the development of a conceptual framework using a case-based approach as guidance for determining the blockchain challenges among SMEs in the halal food SC. Extending the research on blockchain from the context of the halal food SC, SMEs and non-technical aspects using empirical case studies, a framework is proposed regarding halal food SME blockchain challenges that comprise five main dimensions (complexity and capability, cost and competitive advantages, change management and external pressure, halal sustainable production, and regulatory culpability) underpinning the challenges of halal food SMEs in terms of blockchain opportunities. In light of the key enablers, this research provides blanket solutions for overcoming the challenges of blockchain adoption.

Some limitations are associated with this research. The impacts of blockchain on the SME halal food SC are postulated in a framework that collapses into five dimensions. However, the dimensions are equally important in the context of the halal food SC. Corroborating the literature indicating that the halal food SC is a formative concept, these dimensions are interrelated. In other words, the absence of one dimension will shatter the absolute meaning of halal. However, the interrelations between the dimensions have yet to be explored in the context of blockchain. In addition, blockchain technology is highly associated with the contemporary decrease in halal traceability of other important food aspects, such as food quality, safety, and integrity. Future research on the blockchain that encompasses more food aspects under a single study would yield a more in-depth understanding of the applicability of the framework. Furthermore, a detailed practical guide for explaining the framework is needed, as SMEs are bound not only to traceability as their SCs become shorter and less complex.

As this research is limited to identifying the challenges of blockchain technology adoptions and probable solutions based on the dynamic capability's perspective, there are many others ways of seizing the opportunities from blockchain technology. It is important to ensure that the technology adopted by the halal SMEs are reflected and aligned with the current and future needs. Therefore, sustainability notions, such as green supply chain management, are argued to be important future research avenues. Following this research highlights the overlapping challenges, practices, perspectives and enablers, which are important gaps that warrant investigation. For example, future research can strategically identify the priority and ranks of the challenges/practices of blockchain technology faced by the halal food supply chain that need to be addressed (e.g., Abdel-Baset et al., 2019), hence, providing important insights to the food industry, SMEs, and the complex SC discourse.

SC complexity differs from one firm/product to another; thus, validation of the generalizability and universality of the framework should be attempted in future research. This research is exploratory in nature, and further research with more cases involving firms of similar/different sizes (i.e., micro-firms and multi-national corporations) or more food product types can result in theoretical validation and replication of this study (Yin, 2009). Further research may consider expanding the interviewee list to other roles in the SC, such as the government, food regulators, customers, suppliers, farmers, distributors and retailers, which may enrich the data and provide new insights into the blockchain technology. This will become more necessary in the future, as at the time this article was written, blockchain technology had yet to be implemented in the halal food SME context. Halal-related research is predominantly conducted in Malaysia (Mostafa, 2020). The findings of the halal food research in Malaysia could be argued to be advanced, and this research may suffer from bias because the understanding and awareness of halal food production in Malaysia are high. Halal food is a global dietary phenomenon, and similar industries in other parts of the world may differ significantly in regard to their technological and environmental readiness for blockchain adoption. Different nations and industrial settings may provide different contexts for halal SC industrial and governance structures that could influence blockchain implementation and adoption.

Acknowledgement

We would like to thank Ministry of Higher Education Malaysia for funding the research via grant number: FRGS/1/2018/SS03/UKM/02/ 1. We would also like to thank anonymous

reviewers for their helpfulcomments and suggestions, which have resulted considerable improvement of this manuscript.

References

Abdel-Basset, M., Chang, V. and Nabeeh, N. A. (2020) 'An intelligent framework using disruptive technologies for COVID-19 analysis', *Technological Forecasting and Social Change*. Elsevier Inc., (July), p. 120431. doi: 10.1016/j.techfore.2020.120431.

Abidin, N. Z. and Perdana, F. F. . (2019) 'A Proposed Conceptual Framework for Blockchain Technology in Halal Food Product Verification', *Journal of Halal Industry and Services*, 3, pp. 1–5.

Adeyeye, S. A. O. (2019) 'Food packaging and nanotechnology: safeguarding consumer health and safety', *Nutrition and Food Science*, 49(6), pp. 1164–1179. doi: 10.1108/NFS-01-2019-0020.

Ahmed, S. and Broek, N. (2017) 'Blockchain could boost food security', *Nature*, 550(7674), p. 43. doi: 10.1038/550043e.

Alfian, G. *et al.* (2020) 'Improving efficiency of RFID-based traceability system for perishable food by utilizing IoT sensors and machine learning model', *Food Control*, 110(October 2019). doi: 10.1016/j.foodcont.2019.107016.

Ali, M. H. and Suleiman, N. (2016) 'Sustainable food production: Insights of Malaysian halal small and medium sized enterprises', *International Journal of Production Economics*, 181, pp. 303–314. doi: 10.1016/j.ijpe.2016.06.003.

Ali, M. H. and Suleiman, N. (2018) 'Eleven shades of food integrity: A halal supply chain perspective', *Trends in Food Science and Technology*, 71, pp. 216–224. doi: 10.1016/j.tifs.2017.11.016.

Ben-Daya, M., Hassini, E. and Bahroun, Z. (2019) 'Internet of things and supply chain management: a literature review', *International Journal of Production Research*, 57(15–16), pp. 4719–4742. doi: 10.1080/00207543.2017.1402140.

Bouzembrak, Y. *et al.* (2019) 'Internet of Things in food safety: Literature review and a bibliometric analysis', *Trends in Food Science and Technology*. Elsevier, 94(October), pp. 54–64. doi: 10.1016/j.tifs.2019.11.002.

Bumblauskas, D. *et al.* (2020) 'A blockchain use case in food distribution: Do you know where your food has been?', *International Journal of Information Management*. Elsevier, 52(October 2019), p. 102008. doi: 10.1016/j.ijinfomgt.2019.09.004.

Chandra, G. R., Liaqat, I. A. and Sharma, B. (2019) 'Blockchain Redefining: The Halal Food Sector', *Proceedings - 2019 Amity International Conference on Artificial Intelligence, AICAI 2019*. IEEE, pp. 349–354. doi: 10.1109/AICAI.2019.8701321.

Chang, V. (2021) 'An ethical framework for big data and smart cities', *Technological Forecasting and Social Change,* 165(120559), pp. 1-11. doi: 10.1016/j.techfore.2020.120559.

Chang, V. *et al.* (2020) 'How Blockchain can impact financial services – The overview, challenges and recommendations from expert interviewees', *Technological Forecasting and Social Change*, 158(120166), pp. 1–12. doi: 10.1016/j.techfore.2020.120166.

Chang, Y., Iakovou, E. and Shi, W. (2020) 'Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities', *International Journal of Production Research*, 58(7), pp. 2082–2099. doi: 10.1080/00207543.2019.1651946.

Chen, Si *et al.* (2020) 'Processes, benefits, and challenges for adoption of blockchain technologies in

food supply chains: a thematic analysis', *Information Systems and e-Business Management*. Springer Berlin Heidelberg. doi: 10.1007/s10257-020-00467-3.

Chen, Shoue *et al.* (2020) 'The role of smart packaging system in food supply chain', *Journal of Food Science*, 85(3), pp. 517–525. doi: 10.1111/1750-3841.15046.

Clohessy, T. and Acton, T. (2019) 'Blockchain Adoption: Technological, Organisational and Environmental Considerations', in Treiblmaier, H. and Beck, R. (eds) *Business Transformation through Blockchain*. Switzerland: Palgrave Macmillan, pp. 47–76. doi: 10.1007/978-3-319-98911-2.

Corbin, J. and Strauss, A. (2014) *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications.

Creydt, M. and Fischer, M. (2019) 'Blockchain and more - Algorithm driven food traceability', *Food Control*, 105, pp. 45–51. doi: 10.1016/j.foodcont.2019.05.019.

Duan, J. *et al.* (2020) 'A content-analysis based literature review in blockchain adoption within food supply chain', *International Journal of Environmental Research and Public Health*, 17(5). doi: 10.3390/ijerph17051784.

Dutta, P. *et al.* (2020) 'Blockchain technology in supply chain operations: Applications, challenges and research opportunities', *Transportation Research Part E: Logistics and Transportation Review*, 142(102067), pp. 1–33. doi: 10.1016/j.tre.2020.102067.

Edmund, M. (2018) 'On the fast track?', *Quality Progress*, pp. 10–12.

Eisenhardt, K. (1989) 'Building theories from case study research', *The Academy of Management Review*, 14(4), pp. 532–550. doi: 10.2307/258557.

Erol, I. *et al.* (2020) 'Assessing the feasibility of blockchain technology in industries: evidence from Turkey', *Journal of Enterprise Information Management*. doi: 10.1108/JEIM-09-2019-0309.

Frohlich, M. T. and Westbrook, R. (2001) 'Arcs of integration: An international study of supply chain strategies', *Journal of Operations Management*, 19(2), pp. 185–200. doi: 10.1016/S0272-6963(00)00055-3.

Galvez, J. F., Mejuto, J. C. and Simal-Gandara, J. (2018) 'Future challenges on the use of blockchain for food traceability analysis', *Trends in Analytical Chemistry*, 107, pp. 222–232. doi: 10.1016/j.trac.2018.08.011.

Hackett, R. (2017) 'Walmart and 9 Food Giants Team Up on IBM Blockchain Plans', *Fortune*, p. 1. Available at: http://fortune.com/2017/08/22/walmart-blockchain-ibm-food-nestle-unilever-tyson-dole/.

Haji, M. *et al.* (2020) 'Roles of Technology in Improving Perishable Food Supply Chains', *Logistics*, 4(33), pp. 1–24.

Hastig, G. M. and Sodhi, M. M. S. (2019) 'Blockchain for Supply Chain Traceability: Business Requirements and Critical Success Factors', *Production and Operations Management*, 29(4), pp. 935–954. doi: 10.1111/poms.13147.

Hew, J. J. *et al.* (2020) 'The blockchain-based Halal traceability systems: a hype or reality?', *Supply Chain Management*, 25(6), pp. 863–879. doi: 10.1108/SCM-01-2020-0044.

How, M. L., Chan, Y. J. and Cheah, S. M. (2020) 'Predictive insights for improving the resilience of global food security using artificial intelligence', *Sustainability (Switzerland)*, 12(15). doi: 10.3390/SU12156272.

824 Hwang, J., Kim, J. J. and Lee, K. W. (2020) 'Investigating consumer innovativeness in the context of
825 drone food delivery services: Its impact on attitude and behavioral intentions', *Technological*
826 *Forecasting and Social Change*. Elsevier Inc., (October), p. 120433. doi:
827 10.1016/j.techfore.2020.120433.

828 Ji, Z. *et al.* (2020) 'Empirical research on the fama-french three-factor model and a sentiment-related
829 four-factor model in the chinese blockchain industry', *Sustainability (Switzerland)*, 12(5170), pp. 1–
830 22. doi: 10.3390/su12125170.

831 Kamble, S. S., Gunasekaran, A. and Gawankar, S. A. (2020) 'Achieving sustainable performance in a
832 data-driven agriculture supply chain: A review for research and applications', *International Journal of*
833 *Production Economics*, 219, pp. 179–194. doi: 10.1016/j.ijpe.2019.05.022.

834 Kamilaris, A., Fonts, A. and Prenafeta-Boldú, F. X. (2019) 'The rise of blockchain technology in
835 agriculture and food supply chains', *Trends in Food Science and Technology*, 91, pp. 640–652. doi:
836 10.1016/j.tifs.2019.07.034.

837 Kandel, C., Klumpp, M. and Keusgen, T. (2011) 'GPS based track and trace for transparent and
838 sustainable global supply chains', in Thoben, K., Stich, V., and Imtiaz, A. (eds) *2011 17th International*
839 *Conference on Concurrent Enterprising, ICE 2011 - Conference Proceedings*. Aachen, Germany: IEEE,
840 pp. 1–8.

841 Kaur, H. *et al.* (2018) 'A Proposed Solution and Future Direction for Blockchain-Based Heterogeneous
842 Medicare Data in Cloud Environment', *Journal of Medical Systems*. Journal of Medical Systems,
843 42(156), pp. 1–11. doi: 10.1007/s10916-018-1007-5.

844 Kelepouris, T., Pramatari, K. and Doukidis, G. (2007) 'RFID-enabled traceability in the food supply
845 chain', *Industrial Management & Data Systems*, 107(2), pp. 183–200. doi:
846 10.1108/02635570710723804.

847 Keogh, J. G. *et al.* (2020) 'Chapter 17 - Optimizing global food supply chains: The case for blockchain
848 and GSI standards', in Datwiler, D. (ed.) *Building the Future of Food Safety Technology: Blockchain*
849 *and Beyond*. London: Academic Press, pp. 43–54.

850 Kim, H. and Laskowski, M. (2018) 'Sustainable Solutions for Food , Farmers , and Financing', in
851 Tapscoot, D. (ed.) *Supply Chain Revolution*. Barrow Books. Available at:
852 https://ssrn.com/abstract=3028164.

853 Kim, Y. G. and Woo, E. (2016) 'Consumer acceptance of a quick response (QR) code for the food
854 traceability system: Application of an extended technology acceptance model (TAM)', *Food Research*
855 *International*. Elsevier Ltd, 85, pp. 266–272. doi: 10.1016/j.foodres.2016.05.002.

856 Kittipanya-ngam, P. and Tan, K. H. (2020) 'A framework for food supply chain digitalization: lessons
857 from Thailand', *Production Planning and Control*, 31(2–3), pp. 158–172. doi:
858 10.1080/09537287.2019.1631462.

859 Köhler, S. and Pizzol, M. (2020) 'Technology assessment of blockchain-based technologies in the
860 food supply chain', *Journal of Cleaner Production*, 269(122193), pp. 1–10. doi:
861 10.1016/j.jclepro.2020.122193.

862 Kshetri, N. (2018) '1 Blockchain's roles in meeting key supply chain management objectives',
863 *International Journal of Information Management*, 39, pp. 80–89. doi:
864 10.1016/j.ijinfomgt.2017.12.005.

865 Li, T. *et al.* (2020) 'A quantitative survey of consumer perceptions of smart food packaging in China',
866 *Food Science and Nutrition*, 8(8), pp. 3977–3988. doi: 10.1002/fsn3.1563.

Mantihal, S., Kobun, R. and Lee, B. B. (2020) '3D food printing of as the new way of preparing food: A review', *International Journal of Gastronomy and Food Science*. Elsevier B.V., 22(September), p. 100260. doi: 10.1016/j.ijgfs.2020.100260.

Maroufkhani, P. *et al.* (2020) 'Big data analytics adoption: Determinants and performances among small to medium-sized enterprises', *International Journal of Information Management*, 54, p. 102190. doi: 10.1016/j.ijinfomgt.2020.102190.

Marshall, C. and Rossman, G. B. (2016) *Designing qualitative research*. 6th Editio. California: Thousand Oaks, CA: Sage.

Mavilia, R. and Pisani, R. (2020) 'Blockchain and catching-up in developing countries: The case of financial inclusion in Africa', *African Journal of Science, Technology, Innovation and Development*, 12(2), pp. 151–163. doi: 10.1080/20421338.2019.1624009.

Mena, C., Humphries, A. and Wilding, R. (2009) 'A comparison of inter- and intra-organizational relationships: Two case studies from UK food and drink industry', *International Journal of Physical Distribution and Logistics Management*, 39(9), pp. 762–784. doi: 10.1108/09600030911008193.

Mercier, S. *et al.* (2017) 'Time–Temperature Management Along the Food Cold Chain: A Review of Recent Developments', *Comprehensive Reviews in Food Science and Food Safety*, 16(4), pp. 647–667. doi: 10.1111/1541-4337.12269.

Mostafa, M. M. (2020) 'A knowledge domain visualization review of thirty years of halal food research: Themes, trends and knowledge structure', *Trends in Food Science and Technology*, 99, pp. 660–677. doi: 10.1016/j.tifs.2020.03.022.

Nash, K. S. (2018) 'Farm to Cradle: Nestlé Experiments with Tracking Gerber Baby Food on the Blockchain', *Wall Street Journal*, pp. 1–4.

Nugraha, G. T. *et al.* (2018) 'The Implementation of Halal Supply Chain With Private Blockchain in Indonesia', *Advances in Transportation and Logistics Research*, 1(1), pp. 174–186. Available at: http://proceedings.itltrisakti.ac.id/index.php/ATLR/article/view/18/162.

Ølnes, S., Ubacht, J. and Janssen, M. (2017) 'Blockchain in government: Benefits and implications of distributed ledger technology for information sharing', *Government Information Quarterly*, 34(3), pp. 355–364. doi: 10.1016/j.giq.2017.09.007.

Qian, J., Ruiz-Garcia, L., *et al.* (2020) 'Food traceability system from governmental, corporate, and consumer perspectives in the European Union and China: A comparative review', *Trends in Food Science and Technology*. Elsevier, 99(January), pp. 402–412. doi: 10.1016/j.tifs.2020.03.025.

Qian, J., Dai, B., *et al.* (2020) 'Traceability in food processing: problems, methods, and performance evaluations—a review', *Critical Reviews in Food Science and Nutrition*. doi: 10.1080/10408398.2020.1825925.

Queiroz, M. M., Telles, R. and Bonilla, S. H. (2019) 'Blockchain and supply chain management integration: a systematic review of the literature', *Supply Chain Management*, 25(2), pp. 241–254. doi: 10.1108/SCM-03-2018-0143.

Rejeb, A. (2018) 'Halal Meat Supply Chain Traceability based on HACCP, Blockchain and Internet of Things', *Acta Technica Jaurinensis*, 11(4), pp. 218–247. doi: 10.14513/actatechjaur.v11.n4.467.

Rejeb, A. *et al.* (2020) 'Blockchain Technology in the Food Industry: A Review of Potentials, Challenges and Future Research Directions', *Logistics*, 4(0027), pp. 1–26. doi: 10.3390/logistics4040027.

Rogerson, M. and Parry, G. C. (2020) 'Blockchain: case studies in food supply chain visibility', *Supply*

Chain Management, 25(5), pp. 601–614. doi: 10.1108/SCM-08-2019-0300.

Saurabh, S. and Dey, K. (no date) 'Blockchain technology adoption, architecture, and sustainable agri-food supply chains', *Journal of Cleaner Production*. Elsevier Ltd. doi: 10.1016/j.jclepro.2020.124731.

Shankar, V. *et al.* (no date) 'How Technology is Changing Retail', *Journal of Retailing*. doi: 10.1016/j.jretai.2020.10.006.

Soon, J. M. and Manning, L. (2019) 'Developing anti-counterfeiting measures: The role of smart packaging', *Food Research International*. Elsevier, 123(December 2018), pp. 135–143. doi: 10.1016/j.foodres.2019.04.049.

Spence, M. *et al.* (2018) 'Exploring consumer purchase intentions towards traceable minced beef and beef steak using the theory of planned behavior', *Food Control*. Elsevier Ltd, 91, pp. 138–147. doi: 10.1016/j.foodcont.2018.03.035.

Stranieri, S. *et al.* (2021) 'Exploring the impact of blockchain on the performance of agri-food supply chains', *Food Control*. Elsevier Ltd, 119(May 2020), p. 107495. doi: 10.1016/j.foodcont.2020.107495.

Sun, J. *et al.* (2015) 'A Review on 3D Printing for Customized Food Fabrication', *Procedia Manufacturing*. The Authors, 1, pp. 308–319. doi: 10.1016/j.promfg.2015.09.057.

Sunny, J., Undralla, N. and Madhusudanan Pillai, V. (2020) 'Supply chain transparency through blockchain-based traceability: An overview with demonstration', *Computers and Industrial Engineering*. Elsevier Ltd, 150(106895), pp. 1–13. doi: 10.1016/j.cie.2020.106895.

Tan, A., Gligor, D. and Ngah, A. (2020) 'Applying Blockchain for Halal food traceability', *International Journal of Logistics Research and Applications*. Taylor & Francis, 0(0), pp. 1–18. doi: 10.1080/13675567.2020.1825653.

Tan, A. and Ngan, P. T. (2020) 'A proposed framework model for dairy supply chain traceability', *Sustainable Futures*. Elsevier Ltd, 2(December 2019), p. 100034. doi: 10.1016/j.sftr.2020.100034.

Tan, K. H. *et al.* (2017) 'The impact of external integration on halal food integrity', *Supply Chain Management: An International Journal*, 22(2), pp. 186–199. doi: 10.1108/SCM-05-2016-0171.

Teece D. J. Pisano G. Shuen A. (1997). 'Dynamic capabilities and strategic management', *Strategic Management Journal*, 18(7), pp. 509–533. doi: 10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Teece D.J. (2018). 'Business Models and Dynamic Capabilities', *Long Range Planning,* 51, pp. 40-49. doi: 10.1016/j.lrp.2017.06.007

Tian, F. (2017) 'A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things', in *14th International Conference on Services Systems and Services Management, ICSSSM 2017 - Proceedings*. Guangzhao, China: IEEE, pp. 1–6. doi: 10.1109/ICSSSM.2017.7996119.

Tieman, M. *et al.* (2019) *Utilizing blockchain technology to enhance halal integrity: The perspectives of halal certification bodies*, *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. Springer International Publishing. doi: 10.1007/978-3-030-23381-5_9.

Treiblmaier, H. (2018) 'The impact of the blockchain on the supply chain: a theory-based research framework and a call for action', *Supply Chain Management*, 23(6), pp. 545–559. doi: 10.1108/SCM-01-2018-0029.

952 Urbano, O. *et al.* (2020) 'Cost-effective implementation of a temperature traceability system based
953 on smart rfid tags and iot services', *Sensors (Switzerland)*, 20(1163), pp. 1–19. doi:
954 10.3390/s20041163.

955 Di Vaio, A. *et al.* (2020) 'Artificial intelligence in the agri-food system: Rethinking sustainable
956 business models in the COVID-19 scenario', *Sustainability (Switzerland)*, 12(12). doi:
957 10.3390/SU12124851.

958 Veronica, S. *et al.* (2020) 'International social SMEs in emerging countries: Do governments support
959 their international growth?', *Journal of World Business*. Elsevier, 55(100995), pp. 1–13. doi:
960 10.1016/j.jwb.2019.05.002.

961 Voss, C., Tsikriktsis, N. and Frohlich, M. (2002) 'Case research in operations management',
962 *International Journal of Operations and Production Management*, 22(2), pp. 195–219. doi:
963 10.1108/01443570210414329.

964 Weking, J. *et al.* (2020) 'The impact of blockchain technology on business models – a taxonomy and
965 archetypal patterns', *Electronic Markets*. Electronic Markets, 30(2), pp. 285–305. doi:
966 10.1007/s12525-019-00386-3.

967 Wong, L. W. *et al.* (2020) 'Time to seize the digital evolution: Adoption of blockchain in operations
968 and supply chain management among Malaysian SMEs', *International Journal of Information
969 Management*, 52(101997), pp. 1–19. doi: 10.1016/j.ijinfomgt.2019.08.005.

970 Yin, R. K. (2009) 'Case study research: Design and methods', in *Applied Social Research Methods
971 Series*. 4th Editio. London: Thousand Oaks, CA: Sage.

972 Yunan, Y. S. M., Ali, M. H. and Alam, S. S. (2020) 'Safeguarding halal integrity through halal logistics
973 adoption: A case of food manufacturers', *Institutions and Economies*, 12(3), pp. 18–40.

974 Zailani, S. *et al.* (2019) 'The influence of halal orientation strategy on financial performance of halal
975 food firms: Halal culture as a moderator', *Journal of Islamic Marketing*, 11(1), pp. 31–49. doi:
976 10.1108/JIMA-01-2018-0023.

977 Zhang, C., Brown, S. and Li, Z. (2019) 'A content based literature review on the application of
978 blockchain in food supply chain management', *The 26th EurOMA Conference*, 2018(Wto 2015), pp.
979 1–10. Available at:
980 https://eprints.soton.ac.uk/432491/%0Ahttps://eprints.soton.ac.uk/432491/1/Zhang_et_al._2019_c
981 onference_paper.pdf.

982 Zhao, G. *et al.* (2019) 'Blockchain technology in agri-food value chain management: A synthesis of
983 applications, challenges and future research directions', *Computers in Industry*. Elsevier B.V., 109, pp.
984 83–99. doi: 10.1016/j.compind.2019.04.002.

985 Zhao, X. *et al.* (2015) 'The Design of the Internet of Things Solution for Food Supply Chain', in *5th
986 International Conference on Education, Management, Information and Medicine (EMIM2015)*.
987 Shenyamg, China, pp. 314–318. doi: 10.2991/emim-15.2015.61.

988 Zhong, R., Xu, X. and Wang, L. (2017) 'Food supply chain management: systems, implementations,
989 and future research', *Industrial Management & Data Systems*, 117(9), pp. 2085–2114. doi:
990 10.1108/IMDS-09-2016-0391.

991 Zwitter, A. and Boisse-Despiaux, M. (2018) 'Blockchain for humanitarian action and development
992 aid', *Journal of International Humanitarian Action*. Journal of International Humanitarian Action,
993 3(16), pp. 1–7. doi: 10.1186/s41018-018-0044-5.

994 Table 1: Examples of disruptive technologies in food SC management

	Technologies	Description	Authors
Food traceability	Quick Response (QR) Code	QR Code is a cheap and effective way of providing the consumers with needed information (i.e., country of origins) beyond conventional pre-packaged food labelling complexity.	(Kim and Woo, 2016; Spence *et al.*, 2018; Tan and Ngan, 2020).
	Radio Frequency Identification (RFID)	An RFID tag is attached to the pre-packaged food packaging, which contains a certain amount of information to identify leaks in the distribution network.	(Kelepouris, Pramatari and Doukidis, 2007; Alfian *et al.*, 2020; Urbano *et al.*, 2020)
	Smart packaging	Smart-packaging is integrated with wireless communication and cloud service, which enables food product real-time monitoring, thus providing transparency regarding the product movement in the SC.	(Shoue Chen *et al.*, 2020).
	Big data	Big data analysis services could be used for competitiveness advantage maximization through transparency.	Navickas & Gruzauskas (2016)
	Internet of Things (IoT)	IoT-based business solutions enabled tracking and tracing platform through real-time visibility.	(Zhao *et al.*, 2015)
	GPS tracking system	A GPS track and trace system can be utilized in the logistic process to, e.g., detect delays in the transportation system, which may prevent food counterfeiting.	(Kandel, Klumpp and Keusgen, 2011)
	Blockchain	The shared data in blockchain technology enhances the efficiencies of data extraction of essential data in tracing the information of a food product.	(Hackett, 2017; Bumblauskas *et al.*, 2020).
Food integrity	Anti-counterfeiting	The overt and covert approach in anti-counterfeiting technology can enhance food integrity. Overt allows the users to verify the product authenticity visually (e.g., barcodes, holograms, watermarks, RFID, tamper-proof). Covert requires more advanced applications, such as intaglio printing, invisible ink, and mobile applications, that have higher technological interference and are more difficult to replicate.	(Soon and Manning, 2019)
	Internet of Things	Internet of Things allows controlling and food fraud mitigation in the SC. IoT can	(Bouzembrak *et al.*, 2019)

		ensure food adulteration, contamination, and degradation.	
	Blockchain	Blockchain is able to assure business integrity, for instance, sustainably sourced, organic or faith-based, and certification. Blockchain data is immutable and unchangeable, thus reducing the risk of food fraud in the SC.	(Köhler and Pizzol, 2020; Rejeb *et al.*, 2020).
Food safety	Smart packaging	Smart packaging enhances the traceability and its effects spill over on the overall quality and safety of the food supply.	(Shoue Chen *et al.*, 2020)
	Drone technology	Drones can help to provide information about individual animals, such as temperature and location of lost stock.	(Haji *et al.*, 2020)
	Internet of Things	IoT enables collaboration among SC actors, including food producers, transportation and hospitality/retail companies, ensuring efficient delivery and food safety.	(Zhao *et al.*, 2015)
	Blockchain	Blockchain enables the firm to identify products suffering from food-borne illnesses in seconds instead of weeks. Blockchain enhances food safety and provides consumers with the nutritional information of all edible items through digitized information.	(Hackett, 2017; Tian, 2017; Creydt and Fischer, 2019)
Food delivery	Robotic	Speeds up the most repetitive tasks in agriculture, food processing, and packaging.	(Rejeb *et al.*, 2020)
	Drone technology	Drones will operate along one predetermined delivery route, connecting a distribution canter with a single delivery point. Drones are expected to replace current delivery methods, which suffer from traffic congestion, and reduce the use of multimodal transportation.	(Haji *et al.*, 2020; Hwang, Kim and Lee, 2020)
	Internet of Things	IoT-based fleet management enhances the continuous visibility of intermodal transportation and provides transportation alternatives and on-time delivery.	(Zhao *et al.*, 2015)
Food security	Artificial Intelligence	Artificial intelligence enables food resilience through early identification of disease, maximizing agriculture inputs and return based on supply and demand.	(How, Chan and Cheah, 2020)
	Big Data	Data-driven systems will be the future for more sustainable food production and consumption.	(Zhong, Xu and Wang, 2017)

	Internet of Things	IoT integrates the food SC ecosystems and reproduces the production flows from the market demand.	(Zhao *et al.*, 2015)
	Blockchain	Blockchain can enhance the visibility of food and commodities and its related environmental footprint. Blockchain might also be used to identify food surplus for distribution to beneficiary bodies.	(Ahmed and Broek, 2017)
Food Quality	3D food printing	With 3D printing technology, firms can personalize food based on customer demand, for instance, allowing them to choose the ingredients and nutrition, flavours, and shapes.	(Sun *et al.*, 2015; Mantihal, Kobun and Lee, 2020)
	Artificial intelligence	Artificial intelligence can be used in food quality prediction and control.	(Qian, Ruiz-Garcia, *et al.*, 2020)
	Internet of Things	IoT-based testing equipment can be used to confirm the food quality when it leaves the factory or warehouse, for instance, a mobile application could be used to test the freshness of food.	(Zhao *et al.*, 2015)
	Temperature and Moisture Sensor	For perishable goods that are temperature-sensitive in transit can be controlled through sensor-enabled refrigeration systems.	(Mercier *et al.*, 2017)
	Smart packaging	Smart packaging solutions are beneficial to the overall quality and safety of the food supply by enhancing product traceability and reducing the amount of food loss and waste.	(Shoue Chen *et al.*, 2020)
	Blockchain	Blockchain impacted extrinsic product quality characteristic (associated with food but not part of the food product).	(Tian, 2017; Stranieri *et al.*, 2021)
Food sustainability	Artificial Intelligence	Artificial intelligence capable of providing alternatives to complex problems, saving valuable resources and reducing environmental damage	(Di Vaio *et al.*, 2020)
	Smart packaging	Smart-packaging provides accurate data regarding the product condition, reduces food loss and waste, prevents theft and provides brand protection. Recyclable and bio-based packaging is environmentally friendly and reduces material waste, elongates the shelf life and enhances the food quality.	(Adeyeye, 2019; Li *et al.*, 2020; Shoue Chen *et al.*, 2020)

	Blockchain	This technology allows farmers to reduce the use of chemical inputs, machinery, and water by using the information on soil, temperature, humidity, agricultural equipment, livestock, fertilizers, soil, and sown crops.	(Rejeb *et al.*, 2020)
Food recall	Blockchain	Blockchain enables efficient and effective product recall through more detailed transaction data, hence preventing economical, reputational, and social loss.	(Zhang, Brown and Li, 2019; Duan *et al.*, 2020; Rejeb *et al.*, 2020)

Table 2: Summary of the cases studied in this research

Case	**Type of Business**	**Turnover in 2018 (USD)**	**Employees**	**Informant**	**Interview Duration**
A	Restaurant Chain and OEM Food Product	800,000	70	Managing Director	Between 1.5 to 2 hours
B	Beverages	250,000	20	Owner	Between 2 to 2.5 hours
C	Confectionary	200,000	30	Owner	Between 1.5 to 2 hours
D	Livestock and food processing	1,000,000	30	Chief Executive Officer	Between 1.5 to 2 hours
E	Snacks	500,000	50	Operation Manager	1 hour

Table 3: Summary of cross-case analysis of the key challenges of blockchain adoption in the SME halal food SC

	Key Challenges of Blockchain Adoption among Halal Food SMEs				
	Complexity and Capability	Cost and Competitive Advantages	Change Management and External Pressure	Halal Sustainable Production	Regulatory Culpability
Case A	///	///	//	//	///
Case B	//	///	//	///	/
Case C	//	///	/	/	//
Case D	//	//	//	///	//
Case E	///	//	//	//	///

Notes: ///: heavy impact; //: moderate impact; /: light impact

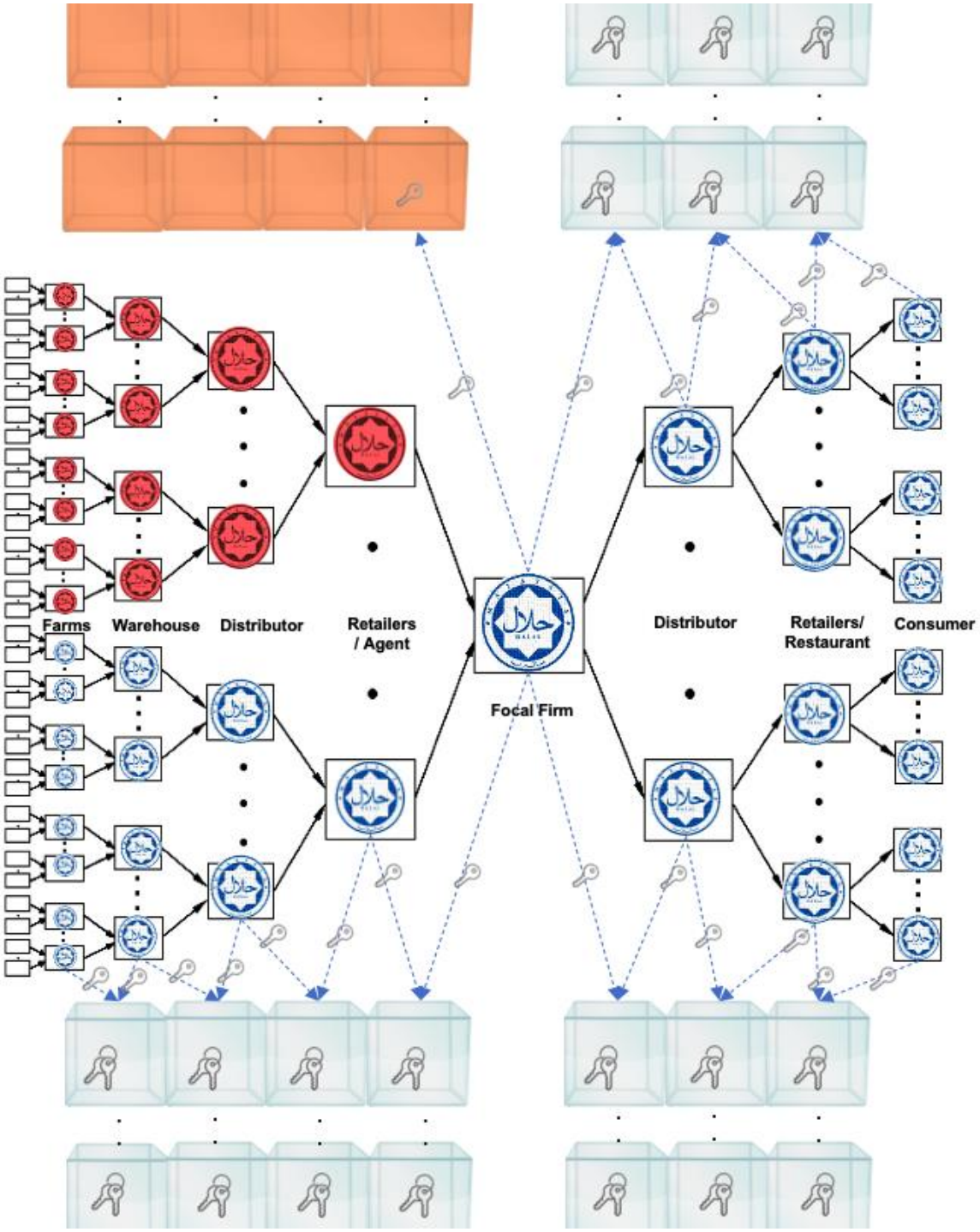

Figure 1: Simplified blockchain-based halal SC

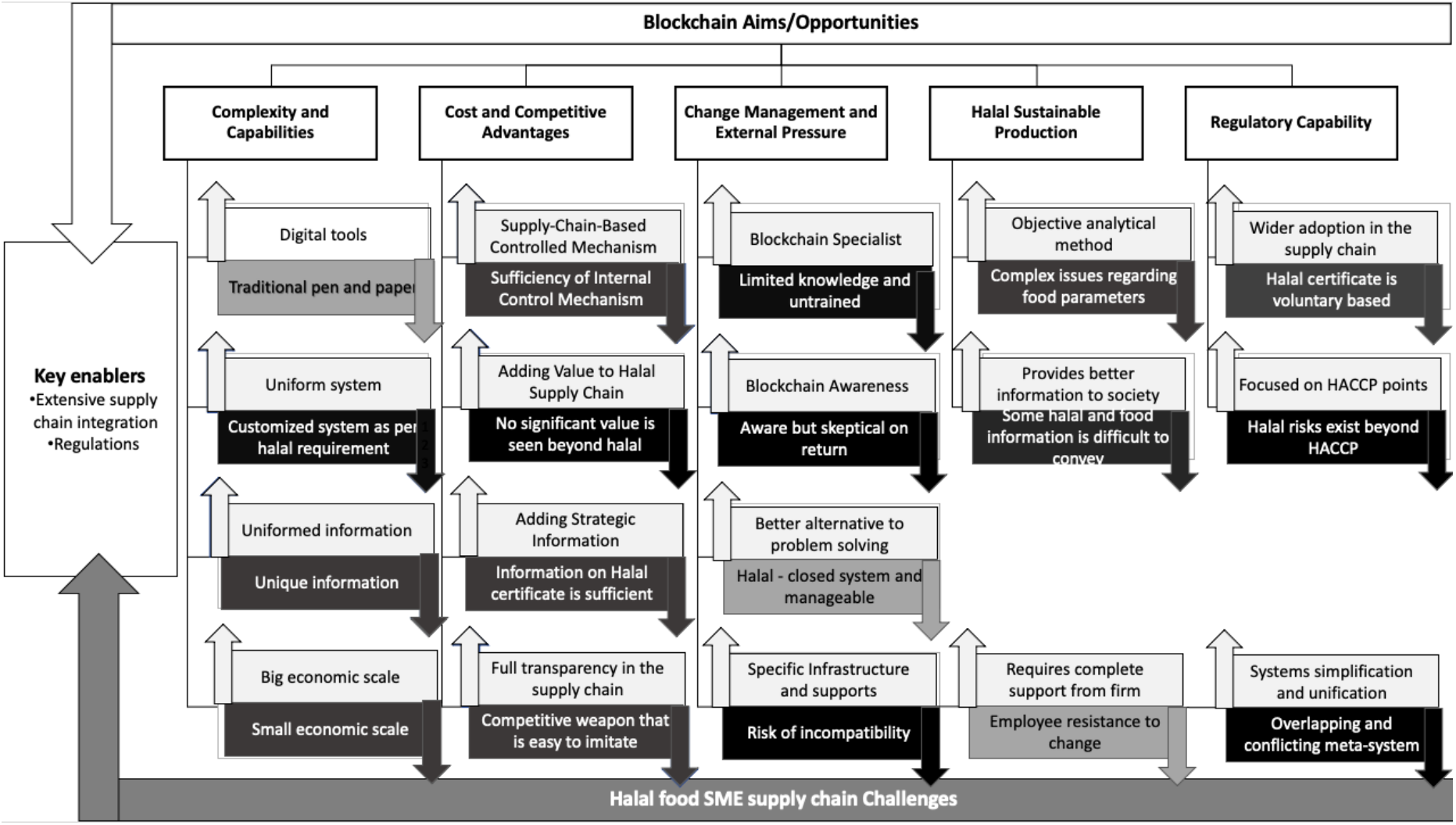

Figure 2: Proposed halal food SME blockchain challenge framework embedded with the within-case analysis

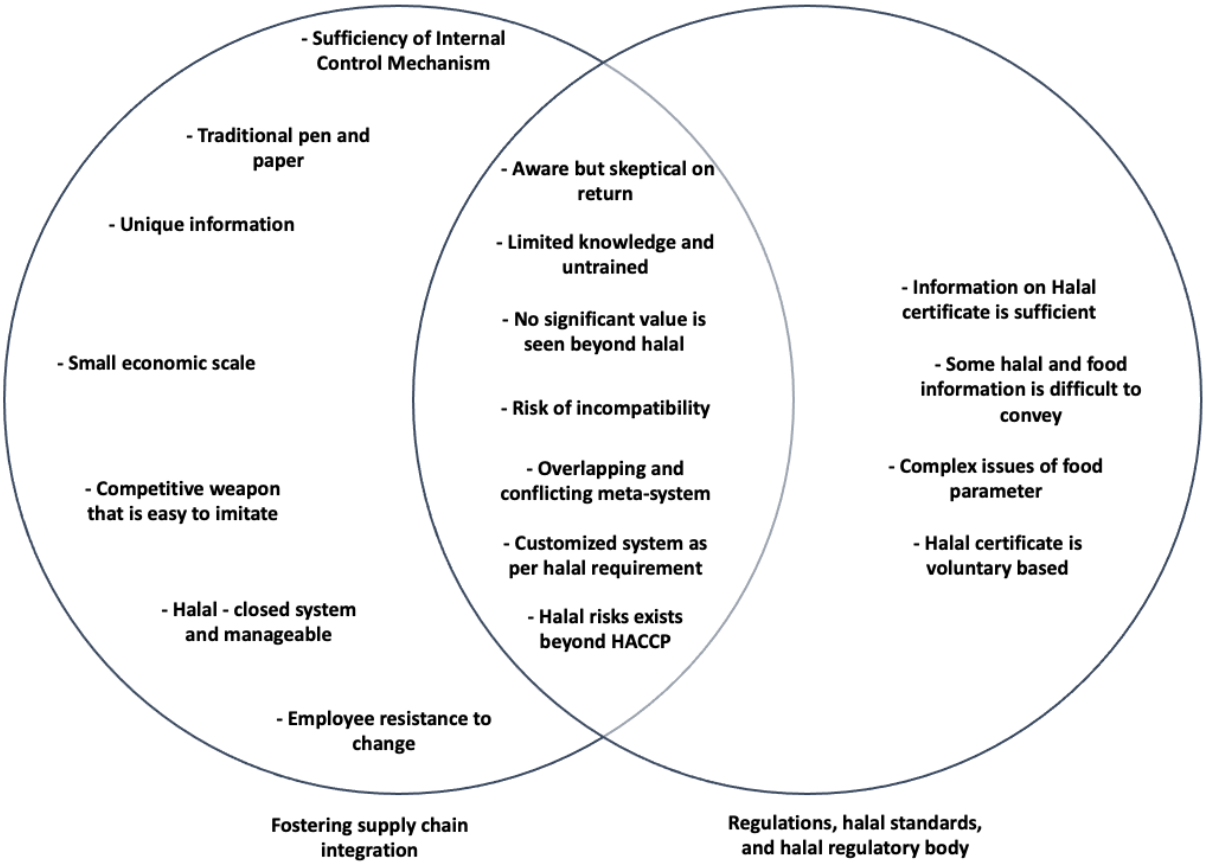

Figure 3: Key enablers for halal SME food SC blockchain challenges