

Title: A Framework for Food Supply Chain Digitalisation: Lessons from Thailand

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Abstract

The promise of digitalisation is enormous and nowhere is it more critical than in its potential to transform food supply chain. Consumers have become more educated and are demanding real-time updated information on foods they consumed through digital media. They are also increasingly demanding to know if the foods they consuming are environmentally and socially sustainable or not. As a result, food product traceability, safety, and sustainability issues have become crucial concerns to food retailers, distributors, processors, and farmers. Digitalisation allow food supply chains to be highly connected, efficient, and responsive to customer needs and regulation requirements. However, digitalising a traditional food supply chain is challenging and resource demanding. This is more so for developing countries where moving food from farms to consumers can take months as it travels through an array of middlemen. Unfortunately, little is available in the existing literature on food supply chain digitalisation. So far, current researchers mainly explore the benefits of digitalisation. Using cases in three companies, this paper explores the practices, challenges, and opportunities faced by Thailand food manufacturers in digitalising their food supply chains. A framework for food supply chain digitalisation is proposed and its implications for research and practices are discussed.

Keywords: Food supply chain, supply chain digitalisation, transparency; visibility; blockchain

1.0 Introduction

Thailand has been significantly contributing to and playing an important role in the world's food trade. In other words, Thailand has been a lead global producer and exporter of tuna, poultry, rice, cassava, shrimps and pineapple products. Statistically, Thailand's food exports have been consistently ranked among the top in the world in terms of export value. In 2017, its food exports were ranked 14th largest in the world (NFI, 2018). In particular, Table 1 shows that the export value of Thai canned tuna, cassava starch, and pineapple was ranked the 1st in the world whereas the export value of rice and poultry meat was ranked the 2nd and the 4th in the world, respectively (NFI, 2018). The growth rate of Thai food exports was 11.4% in 2017 and is expected to grow 16.5% in 2018 (ibid.). As a result, Thai food industry has been updating and improving themselves to meet world food standards and quality as well as upcoming requirements from end consumers, overseas customers, and governments in different countries around the world. These standards and requirements include, for example, traceability, sustainability, and safety issues. Hence, Thailand's food supply chains have been adapting to be more efficient and sustainable in order to maintain the country's leadership in world food exports, for example, applying the traceability issue up until the feed mill of their poultry meat's chain as well as adopting the broilers' welfare policy by allowing the broilers be unconscious before slaughtering, according to one of the UK customers' requirements (Kittipanya-ngam, 2010). One of the new practices and trends, which has been increasingly placing new challenges to Thai food supply chains (FSC), is the rise of digitalisation (eFoodChain, 2017; Gharehgozli et al., 2017; Savastano et al., 2018).

[Table 1 - Thailand's world food export market share in 2017]

Though digitalisation has recently been increasingly emphasized as a key factor to bring supply chains into the new era (Buck and Minvielle, 2013; Lewis, 2017), digitalisation itself is not new. The food industry has already been using several digital technologies and data systems decades ago. The continual development of food production technologies and the implementation of ERP systems in FSC has enabled the streamlining of supply chain operations from upstream to downstream, improving efficiency (Gharehgozli et al., 2017). In addition, technology developments in smart farming such as sensors to help detect diseases, record weather conditions, and yield predictions are also increasingly available, thanks to the data-rich systems in agricultural sectors. Even traditional transportation modes are being reevaluated, from rail, roads, and ships to drones and four-to-six-wheeled robots for last mile deliveries (Robinson, 2017).

However, despite their benefits, advanced technologies and the availability of big data systems have placed several new challenges to FSC. For example, end consumers have become more educated and expect real-time news and information through digital media. They are increasingly demanding to know if the foods they are consuming are environmentally and socially sustainable (Song et al 2018). As a result, food product traceability, safety, and sustainability issues have become a crucial concern to food retailers, distributors, processors, and farmers (Gharehgozli et al., 2017), whose digital and technology skills are still lacking. Additionally, there are also tensions amongst supply chain players to drive down the costs by taking advantages of the digitalisation of supply chain to make more efficient decisions based on rich-data analytics (eFoodChain, 2017), or the digital integration of supply chain operations to reduce waste, labour,

and excess inventories (Song et al 2018). With digital integration, FSC will be more connected across the globe. This implies that each nation will be more dependent on each other in terms of food supplies, which would create even more challenges when there are disruptions in FSC.

All these challenges are yet to be explored and understood empirically and academically in order to allow food industry practitioners to be better prepared for the upcoming issues concerning digitalisation. Therefore, this research aims to answer the research question *“how is Food Supply Chain (FSC) effected by the rise of digitalisation?”* by exploring *the practices and challenges to digitalisation of FSC and production processes in Thailand*. Thai food products hold strong and growing leadership roles in meeting global demand, hence, lessons learned from their FSC, which have demonstrated swift adaptation to *digitalisation* would be beneficial to other food practitioners and academics.

This research begins with the literature on supply chain integration, food supply chain, and digitalisation in order to identify the research gaps and the existing theories on digitalisation implications on FSC. Then, research methodology is described, followed by empirical studies of three FSC cases in Thailand. A framework for food supply chain digitalisation is then proposed and its implications for research and practices are discussed. This research ends with the conclusion and limitations for future research in FSC digitalisation.

2.0 Literature Review

To ensure product integrity and consumer safety, regulators have been imposing various regulations, standards and certifications upon food manufacturers. Many researchers (Maruchek et al., 2011; Premanandh, 2013; Swinnen and Vandemoortele, 2009) point out the needs and benefits of these standards and certifications especially in managing transparency, quality and safety in the food industry. However, responsibility on food integrity should not be limited to an individual firm, but covering all actors within the supply chain (Elliott, 2013). Lately, many researchers have advocated the integration of digital tools in the global food supply chain which could bring following benefits: a) better traceability system (Aung and Chang, 2014; Maruchek et al., 2011; Rosenzweig and Roth, 2007); and, b) better legal culpability (Barratt and Oke, 2007; Tse and Tan, 2011). Tan et al (2017) pointed out the importance of Supply Chain Integration (SCI) in ensuring food integrity in the complex global supply chain operations. SCI is defined as a strategic collaboration of both intra-organizational and inter-organizational processes and firms that carefully link their activities with external parties will perform better (Frohlich and Westbrook, 2001).

SCI in the food industry has been increasingly prominent due to the increasing traceability requirement, the issue of product perishability, as well as the pressure to improve productivity due to its low margin (as compared to many other products in other industries). With better SCI, food products will be managed more efficiently. For example, less excess inventory of food products via better SCI helps reduce excess inventory costs and obsolete products. An example of a close-loop food supply chain (CLSC) can help reducing the wastes of perishable foods along supply chains (Sgarbossa and Russo, 2017). With support from digital technologies, SCI plays an even higher important role in improving food supply chains in terms of efficiency through automated systems and AI (Artificial Intelligence), precision and accuracy through big data analytics (Omid et al., 2013; Pang et al., 2015), better traceability via RFID, Internet of Things (IoT) and block chain (Costa et al., 2013; Pang et al., 2015; Ruiz-Garcia et al., 2009), better logistics

decisions (Bosona and Gebresenbet, 2013), for example. In the following we discuss how digitalisation has impacted food supply chain integration.

Food Supply Chain & Digitalisation

The advancement of digital technologies and the availability of big data have been increasingly enabled international supply chains to be more efficient (Khajavi & Holmström, 2015). With highly-integrated digital platforms, supply chains become more cost effective with less labour needs and mistakes along the chain while increasing the responsiveness to market demands. For example, food product information traceability and supply chain information transparency can be improved alongside the higher food product safety and quality (Roth et al., 2008). PriceWaterhouseCoopers (PWC) suggested eight emerging technologies that will transform the traditional supply chain into a digitalised one (see Table 2) i.e. Artificial Intelligence (AI), Internet of Things (IoT), Augmented Reality (AR), Virtual Reality (VR), Robots, Blockchain, 3D printing, and drones (Eckert et al., 2016). For example, a make-to-stock business model starts to fade away while a more responsive business model, i.e. distributed manufacturing, allows products to be manufactured close to the final consumers (Meyerson, 2015). An example of distributed manufacturing in the food industry is that consumers can print their own foods at home with their 3D printers. 3D printing of food products is increasingly evident in the food industry and in the near future as pointed out by MIT's Tangible Media Group. Food products can be programmed i.e. 2D pizza can be printed to reduce transportation costs. 2D pizza can be soaked in water to become 3D pizza ready to eat for consumer at the end of food supply chain (Wehberg et al., 2017; Savastano et al., 2018). In addition, the availability of real-time information through digitally integrated supply chains also provides opportunities for informed decisions and flexibility in operations and supply chains. However, the benefits of digitalisation come with new challenges to supply chains. The rise of IoT (Internet of Things) and cloud database has placed requirements on new infrastructure along with new standards and practices in supply chain operations (Kumar *et al*, 2016; Verdouw et al., 2016). These effects of digitalisation will increasingly appear in most industries, even in the food industry where products cannot be digitalised and most foods can only be grown in a certain geographical location and climate condition. There is no single/generic technology for digitalization process in the food supply chain. The food industry will need to take into account of various factors in identifying the suitable technology leads for the digitalization process, which may vary according to the scope of implementation. In other words, technology provides the means for which the competitive advantages of digitalization is delivered.

[Table 2 - A summary of existing applications in food supply chain digitalisation]

Though digitalisation has recently been increasingly emphasized as a key factor to bring supply chains into the new era, digitalisation itself is not new. The food industry has already been using digital technologies and data systems, which were developed decades ago. The implementation of MRP I and MRP II in supply chains can be seen as the starting point of the digitalisation of SC operations. The software then, helped reduce inventory and ordering costs, reduce human errors and paper-based work, as well as increase the efficiency of supply chains.

Recently, the implementation of ERP within and across the firms along FSC is increasingly evident as it helps improve communication precisions and efficiency (Gharehgozli et al., 2017) as well as reducing excessive inventories along the chain. Food production technologies to improve productivity and reduce defects have also been developed alongside ICT (Information, Communication, and Technologies) developments. In addition, in the upstream FSC, technology developments in smart farming such as sensors to help detect diseases, record weather conditions, and yield predictions are also increasingly available.

Lately, the rise of blockchain (Lewis, 2017; Wehberg et al., 2017) has put more pressure on firms to digitalise their FSC in order to stay competitive globally. Already most farmers in Kenya are using mobile payment instead of cash for their business transactions. Clearly, to address the complexities, vulnerabilities, and inefficiencies of current FSC – digitalisation (i.e. blockchain, bitcoin etc) is the only way forward. Nonetheless, digitalisation is much more than an investment in technology; it is a long-term strategic commitment that requires sound business value propositions, skills and availability of resources. Firms need clear guidelines for implementing a successful digitalisation strategy.

This is more so for developing countries where current transactions are mainly done manually and moving food from farms to consumers can take months as it travels through an array of middlemen. Unfortunately, little is available in the existing literature on food supply chain digitalisation (Pang et al., 2015; Verdouw et al., 2016). So far, current researchers have only explored the technologies, their applications, the key benefits, and the key enablers of supply chain digitalisation within isolated areas of interest (Büyüközkan and Göçer, 2018). At present, “there is a limited number of studies regarding digital supply chain and there are no academic studies that explicitly focus on the digital supply chain concept.” (ibid.) Though there has been an increase in digital supply chain publications since 2010, the publications remain still ‘industrial reports’. Therefore, there is a need for more theoretical publications, particularly to provide “guidance for digital supply chain adoption in a context with clear guidelines and roadmaps” (ibid.). To fill these research gaps, by using the cases in three companies, this paper aims to explore the practices, key challenges, and opportunities faced by leading food manufacturers in adopting food supply chain digitalisation.

3.0 Research Methodology

This research is exploratory in nature with the aim to answer the research question “*how is Food Supply Chain (FSC) effected by the rise of digitalisation?*” by understanding the key challenges and opportunities related to digitalisation of FSC and production processes through case studies in Thailand. Food supply chain as the unit of analysis, from a food processor’s perspective, encompasses the key components, mechanisms, and processes that work together to enable the flow of a particular product and information to be delivered to a particular market, from upstream SC players (feed mill and farmers) to downstream SC players (retailers and final consumers). However, there are many ways to identify particular product-market SC and there is no consensus in the literature regarding this matter. Hence, this research allowed case companies to define particular product-market SC in their own terms as long as their SCs require different ways to manage and configure.

Case study as a research method Research questions determine the research methods and strategies available for researchers. This research aims to answer the question “*how is Food Supply Chain (FSC) effected by the rise of digitalisation?*” by understanding the key challenges and opportunities related to digitalisation of FSC and production processes through case studies in Thailand. Hence, Yin (2009) suggested three criteria in the selection of research approaches . Accordingly, case study has been chosen in this research because:

- First, this research aims to understand how FSC is affected from the rise of digitalisation and the rationale behind it. This is a question about *how*. Hence, survey and archival analysis do not fit the research aim as they cannot provide enough depth or richness of the necessary data.
- Second, the researcher has no control over the organization or management decisions of any FSC. Therefore, experimental approach appears impractical in this research.
- Third, this research aims to provide a better understanding of FSC in digitalistion era. Thus, the focus of this research is on the contemporary events and that historical approach cannot provide such data.

This research aims to conduct multiple-case studies instead of a single-case study as multiple-case studies can help guard against researcher’s bias (Voss, 2009) as well as it increase external validity whereby a single-case study limits the generalizability of research findings and conclusion drawn from the data (Voss et al., 2002).

Data collection methods

This research begins with the literature on supply chain integration, food supply chain, and digitalisation in order to identify the research gaps and the existing theories on digitalisation implications on FSC. Then, the key research question “*how is Food Supply Chain (FSC) effected by the rise of digitalisation?*” is set to fill in the research gaps. In addition, a set of sub-questions is identified for data collection as follows:

1. What are the key challenges/opportunities you are facing in terms of supplying/producing, particularly with the growing trend of digitalisation? How do you proceed with the challenges/opportunities?
2. Are there any pressures from competitors/customers with the growing trend of digitalisation? If so, what are they and how do you handle them?
3. Are there any upcoming regulations/standards emerging with the digitalisation trend?
4. Where in your supply chains/operations do you think you can make improvements to take advantage of the digitalisation platform?
5. What do you think of blockchain/upcoming technologies and their impact on your business now and in the future?
6. What do you see your organization in the next 5-10 years?

To answer the key research question and sub-questions, case study method is chosen. Case study method allows the richness of the case data despite a small number of cases (Eisenhardt, 1989). In addition, to ensure the validity, quality, and reliability of the research, triangulation of data collection through semi-structured interviews, direct observations, and

documentation is adopted in this research (Yin, 2009). Triangulating by conducting direct observations and documentation helps reducing bias from the interviews.

Four semi-structured interviews with three leading food manufacturers in Thailand (shown in Table 3) were conducted with the management level of each case company in order to allow the access to strategic information regarding implications of digitalisation on each case company's supply chain as well as the vision of each case company. The first company required two semi-structured interviews (1.5 hour and 1-hour interviews, respectively) due to the large size and complexity of the case company. The second interview was mainly for clarification and additional information. However, the second and third case companies only required one semi-structured interview each. Multiple phone calls to follow up and clarify the collected data were adopted in the second and third case companies.

Direct observations were conducted at the case companies themselves, mainly in their operations from procurement, production, distribution, to sales and marketing divisions. Documentations were conducted by gathering public information as well as documents provided by the case companies. The collected data was cross-checked amongst three sources of information to ensure the data validity during the case data collection period (McCutcheon and Meredith, 1993; Yin, 2009).

Case sampling and selection

For multiple-case study research, case sampling strategy is critical for research validity. The sampling of theory building research is based on *theoretical sampling*, rather than statistical sampling (Glaser and Strauss, 1967). Theoretical sampling aims to gather diversified data in order to maximize opportunities to discover variations amongst the evidence and to identify categories in terms of their characteristics and dimensions (Strauss and Corbin, 1998).

There are criteria in case selection, which provide both the internal validity and the generalizability of the research (Mena et al., 2009). First, food industry is selected in order to help the ease of compare and contrast across cases within similar context. Second, all case companies are based in Thailand because it has been significantly contributing to and playing an important role in the world's food trade. Its food exports have been consistently ranked among the top in the world in terms of export value (NFI, 2018). As a result, the key opportunities and challenges learned from the Thailand's cases can be good representatives as one of the world's leading best practices in the food industry. Third, case companies are chosen based upon their perceived leadership in the business environment either at the national level or international level. Fourth, different food product types across different cases allow differences to be shown in the case data in terms of the implications of digitalisation in FSC to be observed. Three selected food products are amongst those that Thailand exported the most to the world market. Finally, different size of the case companies can result in different key challenges and opportunities from the FSC digitalisation (Savastano et al., 2018). As a result, this research selects different case company's sizes to allow differences of the results. Table 3 presents the selected cases and their details.

[Table 3 - Case Details]

With-in case analysis and cross-case analysis

This research adopted two approaches in data analysis: with-in case analysis and cross-case analysis. With-in case analysis provides detailed investigation within the cases whereas cross-case analysis gives insightful comparison across cases. A combination of the two prevents the researcher from information bias and forming premature conclusions (Eisenhardt, 1989). With-in case analysis of this research is based upon the key data dimensions as follow:

- *Key challenges* - it explores, describes, and explains the reasons and rationale behind the current and future FSC digitalisation challenges of the firm in both upstream and downstream supply chains
- *Key opportunities* - it explores, describes, and explains the reasons and rationale behind the current and future FSC digitalisation opportunities of the firm in both upstream and downstream supply chains
- *Key enablers and obstacles* - it explores and describes the key factors both positively and negatively influencing FSC digitalisation of the firm
- *Future digitalisation plans* - it explores and describes the ways the firm plans to digitalise their supply chains both in upstream and downstream supply chains as well as explains the reason and rationale behind the plans.

As new cases were added, *cross-case analysis* was conducted to observe different series of data from different cases and look for patterns across cases (Eisenhardt, 1989). Based on the cross-case analysis tabulation and examination of the tabulation complexity and their relationships (Yin, 2009), the conceptual framework of FSC digitalisation (Figure 1) was proposed to explain the relationships of key challenges and opportunities in FSC digitalisation. Its implications for research and practices are discussed and concluded. Case studies were used to develop the framework. Due to a small number of cases, the limitation of this research design on reliability and generalizability is recognized. This research ends with the conclusion and limitations for future research in FSC digitalisation.

As previously described, the key activities of this research can be summarized into 3 key stages as demonstrated in Table 4 along with the suggested key research activities of case study proposed by Eisenhardt (1989) and Yin (2009).

[Table 4 – Key research activities]

4.0 Empirical Studies

The three cases of food supply chains conducted in this research focuses three food products as follows: frozen and cooked poultry meat (ready to eat), canned tuna, rice, as shown in Table 3. Each food product is mainly sourced and produced in Thailand and exported to world markets and comply with world food standards and requirements. The details of each case are described below.

Case 1: Poultry cooked meat (ready-to-eat meal)

Case 1's product is poultry cooked meat as a ready-to-eat meal, owned by a big conglomerate who runs a whole poultry chain starting from feed mills to food processing plants. Their poultry meat's supply chain can be traced back to the cereal suppliers and maize farms in the north of Thailand and neighboring countries i.e. Laos, Cambodia, Myanmar. These cereals

and maize are the key supplies of the feed mills for live birds' farms. After the feed is produced locally in Thailand, they are transported to live birds' farms and broilers' farms. When broilers are ready to be slaughtered, they are sent to the slaughterhouses and then further processing plants to process the poultry meat into ready-to-eat products i.e. grilled chicken meat, chicken tikka masala, etc. Then, the finished products are frozen and transported to the UK and EU markets under the private labels of UK and EU retailers.

In order to supply to the UK and EU markets, this poultry supply chain must comply with strict and ever-changing import standards and requirements requested by the UK and EU governments. However, the food standards and quality requirements requested by their customers (i.e. local retailers) tend to always be higher and stricter than those requested by governments. This could be because the retailers are pressured by the ever-changing consumer demands. At present, with the possibility of digitalisation, consumers have become even more demanding, particularly in terms of traceability, safety, and sustainability issues. In addition, consumers are becoming more educated and are able to gain access to online information easily and quickly, particularly consumers in the UK & EU, key markets of the firm. Hence, there has been increasing pressure on UK & EU retailers (i.e. Iceland, M&S, Sainsbury, and Tesco), who order poultry products (frozen grilled chicken, breaded chicken Kiev, etc.) from the firm to provide traceable products that are sourced sustainably.

Tracing the products only up to the chicken feed composition and how the broilers are farmed and fed will soon no longer be enough. Details will also be required on where the feeds are produced and sourced, and how those sourced materials impact the environment and society. For example, the deforestation problem from maize farms in the very upstream chain of poultry meat is becoming a crucial issue that the UK and EU retailers and consumers are raising concerns about. Even though this issue is not regulated by retailers or governments yet, the firm had already foreseen it. Coupled with the rise of digitalisation, which enables tracing and tracking at reasonable costs, the firm was pressured to prepare for such an issue a year ago.

Currently, the firm is only able to trace back to the feed composition and how broilers are fed and farmed through barcodes and QR codes as well as through their fragmented ERP system across different players in the chain. The firm is aware of the increasing demand from end consumers regarding further traceability in its upstream chain, i.e. the deforestation problems from maize farms. It is in the process of preparing for afforestation and has already stopped purchases from several maize farms who were its subcontractors. An example can be seen in the north of Thailand (Monjam, Chiang Mai) whereby there are plans to replace maize farms with bamboo forests. However, this is a long-term plan as it takes several years for bamboo to grow and become viable commercial plants for farmers. In the short run, farmers still have loans to pay off and are struggling to find enough cash flow on a day-to-day basis, given the stop in revenue from maize. This problem is recognized by the firm and has yet to be resolved.

The rise of block chain also gives the firm concern. Digitalisation, particularly block chain, could be seen as threats and opportunities to the firm concurrently. An instance of a threat is where the firm's feed sourcing does not meet environmental and socially sustainable standards and such information can be verified easily through the digital platform. Hence, the firm tries to avoid being trapped in this situation. Instances of opportunities are (1) the firm can verify information of their supplies in a more efficient way and (2) the firm can also verify their products to overseas customers easily as long as their customers' system can support the blockchain, (3)

in case the firm can meet environmental and socially sustainable standards before its competitors, the information can be made available to the customers and consumers, granting the firm a competitive advantage. However, the firm still thinks blockchain applications across international supply chains still have several years to go as they require international collaboration and support.

Another concern on FSC digitalisation of the firm is that it needs to catch up with technologies and data analytics to help measure and improve the efficiency of its operations as well as make informed decisions based on the predictions from big data. Currently, the firm still cannot make the best use of their big data though it has ownership of all data along the whole chain starting from the feed mills to further processing plants. This is because the firm's structure is still fragmented. However, the firm has high potential to integrate all data and make the best use of it and it is already in the firm's strategic plan to become digitally integrated. By then, it aims to achieve, for example, precision food production, precision agriculture and predictions, truly optimized inventory and logistics decisions, etc.

In terms of technologies to automate supply chain operations, to begin with, feed mills, which are almost automated as it only requires 2-3 people to operate the machines, perform best utilizing data analytics for efficiency improvement. Broiler farms currently have sensors to detect real-time temperature and humidity to ensure the livelihoods and health of live birds. However, the farms are yet to implement sensors to detect diseases and other conditions that impact the real-time conditions and farming of live birds i.e. weight and stress of the live birds, water portion of the live birds. The firm is aware that it is important to have such sensors, hence, it is in collaboration with several research centers to develop affordable sensors to be used in its farms. At the moment, data on feeding and nutrition, as well as weight of live birds are collected manually and are manually used to optimize the farming conditions and feeding patterns.

Case 2: Canned tuna

Case 2's product is canned tuna, whose raw materials (frozen raw tuna) are caught in the Western Pacific i.e. Solomon sea, Coral sea, Bismarck sea, and the surroundings. The caught tuna are then transshipped to a particular point on land for further transport to the processing plants, be it in China or Thailand. China plants only focus on the primary processing of tuna, then the semi-processed tuna is shipped to Thailand for further process i.e. further filleting and packing. Meanwhile, Thailand plants perform all processing activities. Then, all products are exported from Thailand's ports to the worldwide markets. The firm does not have any particular market that they focus, their customers are scattered around the world including Asia, Africa, EU, Middle East, North America, South America. Their products are in 2 forms: OEM in bulk for retailers or food processor, and bulk size for food service industry i.e. hotels, restaurants, and airlines.

Since the firm supplies to the world market, the food product standards vary widely from one market to another. As a result, the firm sets its supply chains to meet the highest standards and requirements in the market so that it can ensure compliance to all requirements, no matter which market they are exporting to. One of the most restricted standards is the EU market standards. EU government has IUU regulations (Illegal, Unreported, and Unregulated fishing) and ANNEX 4 (catch certificate), which require all traceability of fish products up to the level of which ship fished the tuna, where the tuna was fished, how it was fished, who was the captain and the observer of the ship, what time it was fished, how the tuna was transshipped from a small ship

to a bigger one or from a ship to an in-land location, where transshipment took place, and how it was transported to the end processor. This set of information is strictly required and validated by each country's local authorities. This is because the EU governments are highly sensitive about illegal fishing and fish welfare. For example, one of their concerns is to make sure that only larger fish are caught, leaving the smaller fish to grow at their pace so that future generations will have enough fish to consume. Another concern is also to prevent international environmental crimes i.e. pirate fisheries.

The most challenging issue in this supply chain is the validity of the traced information. Currently, all traced information is paper-based with local authority's signatures to ensure its validity. However, once the documents are scanned, information in them may be unclear, which could lead to suspicions on whether the documents are authentic or not. The increase application of digital platforms including Internet of Things (IoT) and blockchain will definitely help to ascertain the validity and improve the efficiency of traced information being collected from different authorities along the international fish supply chains. However, the possibility of seeing it happen may still be many years away as it requires each local authority and government to utilize digital platforms within their systems first.

In terms of productivity improvement, with better technologies and support in digitalisation, the firm finds that it opens doors for them to electronically source new suppliers easily and efficiently. In addition, in terms of fish production, many fish processors have increasingly adopted automation in their processing plants to help reduce processing costs while increasing the hygiene level of the products. However, the firm does not think its processing plants can be fully automated. This is because the fish shape and internal organs/bones are still unique for each tuna, which also varies depending on the breed, age and size, area of fishing, etc. As a result, the yield of fish will vary significantly if full automation is applied in the tuna filleting process at the moment. Currently, the firm is labour intensive due to the low labour cost and short training time required for workers to learn how to properly fillet tuna (1 month).

Case 3: Rice

Case 3's product is Thai Jasmine rice and organic rice being grown and milled in Thailand. The rice is then packed and exported mainly to China, ASEAN countries, and the US. To export rice, there are a few basic standards of rice products to follow globally, which are ISO 9001, ISO22000, HACCP and GMP. Most countries only require these standards, which typically request for product name, quantity, date, name of buyer/seller, and information necessary for identifying the linkages between purchased product(s) and sold product(s). The standards of rice import in each country are not strict, compared to other food products. This could be because most of the countries who import and consume a lot of rice are not the western countries where concerns about traceability and sustainability are high. Hence, the standards of rice export still only focus around the quality and basic levels of traceability issues with little focus on social and environmental sustainability.

The firm's traceability of rice supply chain, currently, can only provide the information on rice breed, quantity, date of processing/packing, name of each seller and buyer. The information of each farmer and their rice quality/quantity is difficult to obtain at the moment. This is because a miller would typically process 500 tons of rice a day whereby each farmer would on average only provide 2 tons of rice/day, meaning there are too many farmers providing rice to the miller

a day and it is not economically feasible for the miller collect all the data and trace back to the farmers when there is no need or pressure from customers to do so. Hence, the firm does not see much impact of digitalisation in their upstream chain in terms of traceability. Though the traceability system of organic rice is not done by the firm, it sets the QC system by sending samples of rice from every batch to a lab to test the organic quality.

Lately, the Chinese government has issued a new standard, AQSIO, for Thai importers as there are many importers attempting to export low quality of rice under the banner of higher quality rice i.e. rice contaminated with dust, rice brans, or excess composition of broken rice. Hence, the Chinese government has recently sent their representatives to work together with the Thai MAFF (Ministry of Agriculture, Forestry, and Fisheries) to screen through the rice product quality and has come up with a list of qualified distributors to the China market. Those who are not on the list would not be able to export rice to China. The firm does not think digitalisation to improve traceability would help much in this instance. Instead it sees more collaboration to identify and remedy weak spots in the chain to meet AQSIO standards. The general sentiment among Thai rice exporters is that even if they can consistently meet AQSIO standards, the Chinese government will not easily these standards as they are a mechanism to regulate trade.

In the downstream rice supply chain, there seems to have higher potential for digitalisation. First, the online updated price of rice trades helps traders and exporters to optimize their trade margins. Second, digitalisation such as e-commerce and online shopping has opened the doors to overseas markets, particularly the China, ASEAN countries, US, and EU markets, which are the key markets of the firm. However, the key challenge of this opportunity is the rice import quota, particularly in countries where rice is the main food staple i.e. China and ASEAN countries. As a result, Thai rice exporters, including the firm, still need to trade with local distributors instead of directly selling to local consumers as they require local distributors who have quota licenses to import rice from Thailand. Without the local distributors, their rice products cannot make it into China and ASEAN markets. An example can be found in April 2018; Alibaba signed a deal with the Thai government to start online trading of Thai food products for Chinese consumers online (B2C) on their websites (Tmall.com). Within 1 minute after the online trade began, 80,000 Thai durians were sold. This cannot happen to Thai rice exporters as Thai rice products are still restricted by the import quota regulations. As a result, they can only trade electronically with local distributors (B2B) on Tmall.com, though it's better than not having Tmall.com at all. At least they have market access to local distributors in China. On the other hand, in the countries where rice is not the main food staple, online trading for B2C and B2B has become big opportunities, particularly in the US markets where there is no import quota of rice.

[Table 5 - A summary of with-in case data]

Table 5 summarises the key challenges and opportunities drawn from the three case studies in an organized format. The table categorized the key challenges and opportunities in upstream and downstream chains due to the different requirements and characteristics between suppliers and customers, as well as between raw materials and finished goods.

5.0 Results and Discussion

The findings from the three case studies mentioned above in Table 5 help answering the key research questions and sub-questions accordingly. Below are the key challenges and opportunities emerged from the rise of digitalisation in their supply chains from upstream and downstream perspectives.

Upstream challenges and opportunities

One of the key challenges that all food supply chain cases face is the issue of traceability, safety, and sustainability. The depth and length of traceability may vary depending on the food products and the requirements from the downstream customers/consumers and governments, resulting in different digitalisation challenges and opportunities in each supply chain.

Rice supply chain does not require high traceability, safety, and sustainability, compared to that of poultry meat and canned tuna. This could be because, firstly, the customers and local authorities of poultry meat and canned tuna in the EU and UK markets are more concerned about what they are eating and how their food consumption affect society and the environment in the long run. If their consumption damages the world, they are willing to switch to something else that has less impact. However, major consumers of rice are in the Asian countries where there are less concerns on sustainability. Hence, they are only concerned about quality and safety issues, and less about the sustainability issue. Secondly, the reason that rice supply chain does not require high traceability, safety, and sustainability, compared to that of poultry meat and canned tuna, is because poultry meat and canned tuna supply chain involve the lives of animals whereas rice does not. Hence, there are additional issues that concern regarding the lifecycle and welfare of the animal. These result in less digitalisation implications on rice supply chain, compared to poultry meat and canned tuna, in terms of traceability, safety, and sustainability. The digitalisation platforms such as block chain and Internet of Things (IoT) hence play a more important role in canned tuna and poultry meat to allow their supplies and upstream operations to be validated swiftly and efficiently. The upstream information becomes more transparent through the digital platform, which challenges their upstream operations to be truly sustainable. An example can be seen in Case 1 whereby the poultry supply chain creates deforestation from their maize farms. The firm needs to solve this problem before environmentally concerned consumers develop a negative perception of the firm and its products.

In terms of productivity improvement via digital technologies, poultry supply chain and canned tuna supply chain gain higher benefits than rice supply chain. This could be because poultry and canned tuna supply chains involve more processing activities than rice supply chain. Rice supply chain processes are simple, starting from rice farming, drying, milling, and packing whereas, for example, poultry supply chain processes are more complicated. The process begins from the feed mills down to live birds' farms (3 generations of live birds), slaughterhouses to further processing plants. As a result, the role of digital technologies in improving productivity is higher in poultry and canned tuna supply chains. Poultry and canned tuna supply chains see the benefits of applying big data analytics in their upstream operations to achieve optimized decisions in precision agriculture, precision food production, self-learning shelf life prediction of food products and real-time supply chain re-planning of food processing. In addition, canned tuna supply chain also reports of the benefits of e-commerce platforms on its sourcing activity.

Meanwhile, rice supply chain only sees the benefits of data analytics in smart farming and optimized yield. However, currently, these technologies are not yet economically viable for

farmers. Their primary benefit from digitalisation in rice supply chain now is the accessibility of real-time updated price of rice trade so that rice exporters can optimize their trade decisions.

Downstream challenges and opportunities

The increasingly demanding customers and consumers in downstream chains are the key drivers to challenge existing practices in food supply chains as technological advancements become accessible. For instance, with ICT (Information and Communication Technologies) advancement, customers and consumers can cross-check any information quickly. This has enabled customers who are social conscious and environmentally aware, in particular from the EU and UK, to place demands on food supply chain traceability, safety, and sustainability on all food manufacturers. It can be seen in the Case 1-2 of poultry and canned tuna where both the private sector (customers and consumers) as well as governments request high levels of traceability, safety, and sustainability. However, the rice supply chain that supplies mainly to Asian countries only has concerns over safety and quality issues.

One of the big opportunities that come with the digitalisation of downstream food supply chain is the e-commerce channel. E-commerce has opened doors of opportunity to food exporters to cut out the middlemen and directly sell to their end consumers. Rice supply chain benefits the most from this channel, compared to poultry and canned tuna. The reason could be because rice is a commodity and relatively easily can be traded whereas poultry cooked meat and canned tuna in several flavours are specially differentiated products developed to meet the specific preferences of end consumers. Although e-commerce allows the rice supply chain to gain easy access to many markets electronically, access to the key China and ASEAN markets is still limited by trade barriers such as import quotas to protect local rice growers. As a result, rice exporters to these protected markets can only trade electronically with authorized local distributors, and not directly with local consumers.

[Table 6 – A cross-case analysis of key challenges and opportunities of FSC digitalisation]

To conclude, both the upstream and downstream key challenges and opportunities on FSC digitalisation can be summarized in Table 6 altogether with their impact levels. In all cases, efficiency improvements are observed at different levels of impact and is one of the key challenges FSC faces with digitalisation. Efficiency improvements through digitalisation has the highest impact in Case 1 due to higher complexity of its FSC processes, compared to other cases. Traceability and traceability are also emphasized, particularly in Cases 1-2, possibly because their products are based on animal meat, which requires more processing and hence a longer supply chain than that of rice. In terms of environmental and social impacts (sustainability), Cases 1-2 are observed to face more challenges from digitalisation platforms as they serve a more demanding group of consumers who are more concerned more about sustainability, compared to Case 3. In terms of legal culpability, each FSC acknowledges that government standards and requirements are their prime concerns, as these are mandatory requirements that each FSC must comply with. Though Case 1 sees less impact of regulated legislations on its FSC digitalisation, this is because its FSC already serves world leading retailers, who demand higher standards than the governments. Lastly, digitalisation platforms are reported to have impact on electronic

sourcing and market access, as seen in Case 2 and Case 3 whereby Case 2 (canned tuna) gains access to more choices of supplies and Case 3 (rice) gains more access to overseas markets.

The findings in this section help answering the key research question and sub-questions 1-3, which are the key challenges and opportunities in FSC digitalisation, the management of such changes in digitalisation, as well as the key regulations and standards emerging in the digitalisation of FSC. Next sections will help answer the rest of the sub-research questions on key improvement areas and technological impacts from FSC digitalisation through the developed framework, as well as the future of FSC digitalisation.

5.1 Framework for Food Supply Chain Digitalisation

In our analysis of the cases, we identified five main dimensions which are vital to FSC digitalisation; efficiency, transparency and traceability, environmental and social impacts, legal culpability, and e-market/supply accessibility. These dimensions, with the support of technology capability and infrastructure, would create high value proposition for food supply chains. A framework that captures the five dimensions is shown in Figure 1. In the following, we discuss the framework in-depth.

[Figure 1 - A framework for FSC digitalisation]

Efficiency

With the support of digital technologies and platforms such as IoT, block chain, AI, FSC is expected to become more efficient via big data analytics and a better system of verification through block chains (Koonce, 2017; Lewis, 2017; Wehberg et al., 2017), for example. Economic loss in FSC processes will shrink tremendously. For example, distribution networks can be optimized. Food processing can also be fully automated, increasing productivity and higher food safety due to less human errors and human touch, respectively (Gharehgozli et al., 2017; Wehberg et al., 2017). Integrated information system on ICT also helps improving communication time and reduce communication errors when there are many parties involved in using the same set of data (Kumar et al., 2016; Ruiz-Garcia et al., 2009). Paper-based systems between firms will become electronic, enabling faster inter-organisation documentation processes and higher accuracy of information as sometimes unclear scanned documents are at risk of being fraudulent. An example can be seen in Case 2, canned tuna supply chain, whereby several documents of its upstream chain are all provided in the form of scanned documents from local authorities worldwide.

Transparency & Traceability

The advancement of digital technologies, for example blockchain technologies, has enabled the transparency and traceability via the availability and verification of upstream information in FSC regarding suppliers, materials and their origins, as well as the processes such materials had gone through (Koonce, 2017; Lewis, 2017; Wehberg et al., 2017). More examples can be seen in the development of IoT (Internet of Things) such as sensors linking with mobile devices to help with smart farming (Kumar et al., 2016; Wehberg et al., 2019). When these digital technologies are widely available and are economically feasible in the industry, full transparency and traceability of FSC will become one of the first concerns that consumers and customers will request from FSC. This is because of the importance of the food safety issue. In case there is a problem with a food

product in the downstream chain, FSC should be able to tell where the problem is in particular in the upstream chain and pinpoint the problem ingredient, from where did it come from and when was it used, in order to remedy the problem before it grows. Transparency and traceability provide benefits to end consumers in terms of safety and trust (Gharehgozli et al., 2017; Wehberg et al., 2017) although they place challenges on FSC, according to all case studies. Particularly in Case 1 where poultry meat supply chain foresees that in the near future, end consumers and customers will be asking for available information on the deforestation caused by maize farms, or in other words, how much deforestation that 1 KG of poultry meat creates from the amount of maize that live birds have consumed before being slaughtered. Hence, when everything in FSC is transparent, FSC needs to become reliable and environmentally and socially sustainable to maintain the end consumers' trust and loyalty.

Environmental & Social Impacts

Whilst expanding markets and trade activities may have positive development outcomes, there is also a risk that they come at the expense of local natural resources and livelihoods. The faster the economic growth in a country, the higher the environmental and social risks it could create if each FSC is risk prone. With the increasing adoption of digital technologies in FSC, full transparency and traceability will soon be possible (Kumar et al., 2016; Pang et al., 2015). This will eventually allow in-depth environmental and social impact assessment of FSC. Each FSC is now working hard to become environmentally and socially sustainable. This is because it takes time to reduce the negative environmental and social impact of FSC. An example can be seen in the Case 1 of poultry meat product. Its upstream chain creates deforestation from maize farms, which are key suppliers in producing chicken feed. To mitigate the detrimental impact of deforestation, the firm needs to embark on afforestation efforts, which can take up to 10 years. Another example is Case 2 where tuna are the key supplies of FSC. The use of fishing net to catch tuna is strictly prohibited as it would also catch small tuna altogether with big ones, resulting in the inability of the tuna populations to rejuvenate itself in the long run. If this occurs, it will take several years for tuna populations to recover. Hence, the issues of environmental and social impacts will definitely be highly emphasized when full transparency and traceability is made possible.

Legal Culpability

Digitalisation will eventually allow the feasible implementation of certain legal requirements and regulations. Legal requirements on FSC traceability are evident from all case studies, but at different level of impact. FSC that exports to the countries where consumers are highly sensitive against social and environmental issues will face a stricter set of regulations. For example, Case 2 of canned tuna faces traceability regulations that allow identification of which ship fished the tuna, where the tuna was fished, how it was fished, who was the captain and the observer of the ship, what time it was fished, where transshipment took place, and how it was transported to the end processor. These legal requirements will only get stricter, supported by ever-improving digitalisation.

E-market/supply Accessibility

Digitalisation does not only place challenges to FSC, but also creates opportunities to explore new markets as well as new supply availability worldwide at little cost. Case 3 of rice supply chain experienced the expansion of its markets through e-commerce platforms with Chinese customers, meaning the firm does not have to rely only on their existing distributors anymore. This will cut the middlemen out of the picture in FSC and will enhance the profit margin for both the exporters and distributors. With the increasing availability and advancement of technology capability and digital infrastructure such as IoT, block chain, AI, robots, drones, VR and AR, for example, these five dimensions becomes even more crucial to the transformation of FSC digitalisation to the food industry 4.0 (Kumar et al., 2016; Pang et al., 2015; Verdous et al., 2016; Koonce et al., 2017; Savastano et al., 2018).

These five dimensions altogether with the technological support would create high value proposition for food supply chains to be able to compete more efficiently and effectively. Each FSC may not place the same level of importance or invest in each dimension equally in order to increase their value proposition, due to differences in raw material and product characteristics, customers/consumer preferences in each region, the level of technological adaptation of their suppliers and customers or even their end consumers, who eventually place the requirements back in the upstream chain. Hence, each FSC needs to strategically prioritise their five dimensions and to allocate more resources to dimensions that require more attention and deliver greater gains.

5.2 Key enablers, and obstacles of FSC digitalisation

It is shown from the case studies that digital transformation in food supply chain comes with benefits in all means including the improvements in food product information traceability and information transparency, increases in food product safety and quality as a whole, for example. To make these benefits happened does require several factors.

To begin with, *inter-firm collaboration and partnerships* as well as *government-to-government partnerships*, in case of international food supply chains, are mandatorily required. Without such collaboration or partnerships, no matter how advanced the technologies are to support the supply chain operations, such benefits will never happen. An example can be seen in Case 2 whereby tuna fish are caught in Western Pacific i.e. Solomon sea, Coral sea, Bismarck sea, and the surroundings. The fish then are processed in China, mainly. Afterwards, they are shipped to be further processed and packed in Thailand before exporting to different parts of the world including EU, Middle East, Arctica, North America, or even in Asia. To be able to digitalise the supply chain in upstream, for example, is already difficult as it requires each country of origin's authorities to be on digital platforms and digitally connect to the firm in Thailand. There are several uncontrollable factors such as government policies for each authority in each country on digitalisation within their organization. Once their organizations are on digital platform, then each party can be digitally connected. Hence, the readiness to digitalisation of each party in FSC strongly effect the final outcomes of FSC as a whole.

Regulations such as import/export quota of each country can be an obstacle to some countries and also can be an opportunity to some countries when FSC is digitalised. Case 3, for example, exports Thai rice to several countries around the world. Digitlisation of FSC hence opens up several doors of opportunities to the world market at low cost of connections both in terms of B2B and B2C markets. However, this opportunity only happens in the countries whereby its

regulations do not have rice import quota. However, to some countries where the regulations on import/export quotas are set, such as Case 3, the import quota of rice from China is set. As a result, despite the availability of digital platform between Thailand and China, FSC is limited to be only in Thailand.

Conclusion

Büyüközkan and Göçer (2018) had conducted a thorough review on supply chain digitalisation and argued that there is an urgent need, given the current pace of technology development and implementations, to develop a framework as a “guidance for digital supply chain adoption in a context with clear guidelines.” Hence, this research aims to fill such research gaps by providing the case-based conceptual framework on supply chain digitalisation in the food industry. The conceptual framework, as shown in Figure 1, offers five key dimensions for practitioners to explore their specific key challenges and opportunities during the adoption of food supply chain digitalisation.

A FSC involves many parties and just one mistake to one batch of products along the chain can create chaos. A simple poultry SC involves multiple ingredients (feeds, vaccine), sourcing from different suppliers, processing through various facilities and distributed via a complicated network of domestic and international logistics. Being able to have a clear visibility of the whole process is critical – both for meeting regulatory requirements and rising customers’ demands. As one of the leading food export countries, Thai food manufacturers are making big strides in tracing food contents by integrating traceability, sustainability, and productivity in the FSC using digital tools.

Interestingly, this study identified that digitalisation platforms such as block chain and Internet of Things (IoT) play a more important role in canned tuna and poultry meat – in which the supplies and upstream operations have to be validated swiftly and efficiently. This is because of the demanding requirements from their western consumers, who are highly concerned about sustainability and traceability. On the other hand, in case of rice supply chain, the digitalisation platforms have more impact on its downstream supply chain instead of its upstream supply chain. The e-commerce platform, in particular, has opened new market opportunities for Thai rice manufacturers. It connects the manufacturers with their customers (local distributors) and their end consumers in a more efficient way. This could be because rice product is a commodity whereas canned tuna (in various flavours) and poultry cooked meat (ready-to-eat meals) are more customized to demands of the customers.

In light of more stringent regulations and pressure from consumers, Thai food manufacturers have adopted and implemented digital tools to digitalise some of their FSC ahead of others. For example, Case 1 has pondered the use of digital tools to create transparency in the poultry supply chain to demonstrate that there was no deforestation impact from their maize farms. Firms that can, need to show their environmental responsibility and credentials to address the environmental concerns of consumers to avoid negative perceptions.

The findings of this study contribute to the literature on FSC and shed light for further research on issues relating to the digitalisation in the Far East. Based on the literature (Gharehgozli et al., 2017; Wehberg et al., 2017; Büyüközkan and Göçer, 2018) and inputs from three cases, a framework linking five main dimensions (efficiency, transparency and traceability, environmental and social impacts, legal culpability, and e-market/supply accessibility)

underpinning the key issues on FSC digitalisation is proposed. These five dimensions altogether with implications and opportunities afforded by increasing digitisation would create high value proposition for food supply chains to be able to compete more efficiently and effectively. Each FSC needs to strategically prioritise their five dimensions and allocate resources appropriately to maximize gains, given the existing obstacles and enablers identified in this research.

Practically, this research provides practicing managers a set of guidance for the adoption of digitalisation in the context of supply chain through the conceptual framework developed in addition, the lessons learned from each particular case across different food product types can provide food firms to be aware of the upcoming challenges in case of the adoption of FSC digitalisation. Firms whose products have similar characteristics and requirements in supply chain as the case products can also learn from the cases in this paper so that they can be more proactive when it comes to digitalisation adoption in their FSC. Academically, this paper helps researchers better understand FSC digitalisation challenges in the Far East. Researchers do not claim that the framework developed here in the paper is comprehensive, but rather that it is applicable to managerial aspects of FSC digitalisation.

Limitations and Future Research

It is important to bind the conclusions regarding this framework with an understanding of the limitations of this research. The five dimensions in the framework are inter-related. The rise of one dimension may help the improvement in another dimension. For example, the higher level of FSC transparency and traceability will eventually drive down the costs in FSC such as communication costs. However, the inter-relations amongst the five dimensions are yet to be explored. In addition, a detail step-by-step guideline to operationalize the framework is needed. The future research on the inter-relations amongst the five dimensions altogether with the key enablers and obstacles would provide a more comprehensive understanding of the conceptual framework.

Given that the complexity, and uncertainties of other types of food (i.e., organic, vegetarian, kosher), which can differ greatly from the chicken, tuna and rice supply chains, further research can be conducted for validation on the universality of the proposed framework. In order for the framework to have value in these areas it needs to become populated with more cases, both within the similar food product types for the purpose of literal replication and different food product types for the purpose of theoretical replications (Yin, 2009). In addition, the range of interviewees can be expanded across different roles in order to increase data coverage as well as the validity of the research. Also, more case evidence from other roles/players in supply chains, for example food retailers, farmers, or food distributors, would provide different perspectives of key challenges and opportunities in FSC digitalisation and its adoption.

This study was conducted in Thailand where food exports have topped the world rank. Though the findings from the food industry in Thailand could be considered as the practices from the existing global leaders in the food industry, a bias may exist in the cases because the firms were mainly located in Thailand. In addition, Thailand's food industry structure and context may differ from other countries, for example Vietnam and China whereby data privacy is not an issue due to its political governance system. Hence, regulations in terms of FSC digitalisation can be more open, better connected, and better supported by all the parties in FSC. In addition, different

nations may provide different FSC industrial and governance structure which could influence the adoption of FSC digitalisation.

Last but not least, generalizability of the framework should be tested and further enriched in other industries. We intend to further populate this framework for further refinement and would be pleased to have input from other researchers interested in this activity.

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