Conceptualising data driven food supply chains: creating integrity and resilience

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Abstract

This research aims to explore the potential of data and data driven technologies in achieving greater control in the food supply chain and in creating a data rich relationship between customers and suppliers. A plethora of data (both open and closed) already exists across the various nodes in the supply chain. The paper presents a brief literature review along with an analysis of case studies and interview data from a small sample of supply chain entities within the food sector. The paper provides a conceptual framework to create integrity and resilience within the food supply chain.

Keywords: Food Supply chains, Supply chain integrity, Supply chain Resilience

Introduction

One of the important developments within the food supply chain to harness data is the rapid progress in the development of active product labels. Active product labels have the potential to enhance the end-customer experience and also disrupt food supply chain design and operations. In particular, labels that are able to supply information via smartphones offer considerable potential to provide a range of value-add services that augment the customer experience. According to Charlebois et al (2016) there is a lack of trust across consumer networks in both policy creation and supply networks to deliver authentic food supply chains. Their research also supports the use of technology by consumers to bridge the gap between supply chain actors and end users. Improvement in data exchange technology will facilitate active engagement by the end-customer with the food supply chain. One of the aspects of the paper is to explore the potential of offering end-customers greater personal control and power and also in creating a data rich relationship between customers and suppliers.

However, one could argue that data in large numbers (Big data) already exists across the supply chain actors, with larger retailers retaining detailed information on each consumer through the use of loyalty schemes and online purchasing. The use of data to create authenticity in the food supply chain is a growing concern and hence the

requirement to link this information across the food supply chain. One of the mechanisms as proposed in the professional literature is the use of new technology such as the blockchain and or use of predictive analytics using Big data. Introducing data using Internet of Things (IoT) processes with existing consumer technology such as smart phones, wearables or RFID can foster connected supply chain with bi-directional information flows to support greater integrity and authenticity for all actors. Government reports, such as Elliott (2014) propose the need for data sharing across food chains to create better resilience and to retain food integrity. The Food standards agency proposes the need to create a better consumer understanding of the origin of food in the chain, and clearer metrics around food authenticity, criminality, safety and sustainability (FSA, 2016). However SME's within the food supply chains do not possess the ability, funds and networks to integrate, interpret and utilise supply chain data to manage their operations effectively and efficiently. The convergence of a range of technologies (such as sensor-based technologies, wearables, advances in human genomics and advanced data analytics) now offer a platform to further enhance these experiences by addressing knowledge deficits (e.g. genomic, food requirements), time famines and budgetary constraints.

This research address two key questions: (i) what are the underlying processes within data driven food supply chains? (ii) what are the challenges and enablers for operating data driven food supply chains?

Challenges to Food Supply Chains

Since the Horsemeat scandal, there is an extensive visibility of food fraud and contamination events in the UK. The Milk scare, Peanut Butter scare and the Horsemeat scandal showed the vulnerability and the expanse of food risks within food supply chains. Food contamination and other risks are not focused around one country or product supply chain but are spread across the world and are caused sometimes by negligence but in many cases have been intentional fraud. The global nature of food supply chains provides a channel for the risks to flow rapidly through the supply chains across continents. The Horsemeat scandal depicted the complexity of the supply chain and the issues with visibility. The Milk scare in China (2008) depicted that the responsibility and accountability for limiting the contamination was very important to avoid losses in the chain (Dani and Deep, 2010). According to Spink and Moyer (2011), food fraud is: "*the deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients, or food packaging, or false or misleading statement made about a product, for economic gain*". Lotta and Bogue (2015) discuss that the definition of food fraud will encompass events of food adulteration and food misrepresentation including incorrect or misleading labelling (Fassam and Dani, 2017). Agiwal and Mohatadi (2008) have identified that there will be both intentional causes and unintentional causes for risks in the food supply chain. Terrorism is at the farthest end of the spectrum of intentional causes and relates to contamination with the intention of causing harm and fatality to the final consumer. As seen in the recent cases (Horsemeat, Chinese Milk Scare) the intention for the contamination was to commit fraud for monetary gains.

Food supply chain risks can be classified on the basis of those risks occurring on account of limitations in 'sales and operations planning' or due to causes leading to supply disruptions. Sheffi (2005) proposes that to effectively handle contamination incidents and increase the risk management capability of the firm in the wake of an event, systems should be robust and flexible. Sheffi and Rice Jr (2005) discuss about internal safety measures and propose that supply chain resilience can be developed by creating a proactive safety culture. The food supply chain is primarily vulnerable due to the

perishable nature of the products and the high levels of risk associated with food from a consumer perspective. International food supply chains are fragile due to the geographical spread of its entities, varied economic status between countries and size of entities, and the difference in legislation across boundaries.

There are two approaches to managing supply chain risks: *proactive*, referring to taking precautionary measures to tackle risks, and *reactive*, referring to reacting once the risk materialises (Dani, 2015). Both approaches have to work hand-in-hand. It is important for organisations to invest in building proactive risk management systems. However these proactive systems should be prepared to react in a crisis scenario. In a report for DEFRA, Peck (2006) suggested that the rise in food safety incidents and the risks from environmental uncertainty showed that food businesses were ill prepared to manage business resilience and has inadequate proactive methods.

Supply Chain Resilience

Tukamuhabwa et al., 2015: pp. 5599) define supply chain resilience as "The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than prior to the disruption". Considering supply chain disruptions and the link to resilience, Sheffi and Rice Jr (2005) suggest that supply chains should be designed for redundancy and flexibility. They suggest 'redundancy' as additional resources (for example safety stock) or multiple suppliers, whereas 'flexibility' is the presence of certain capabilities and characteristics such as responsive manufacturing practices, agility or supplier relationships to respond effectively to disruptions. Zsidisin and Wagner (2010) explain that flexibility can mitigate the impact of the disruption whereas redundancy can help delay the disruption. Christopher and Peck (2004) suggest that an organisation culture that has a positive and forward looking attitude to managing supply chain risks with an agility focus can help to achieve supply chain resilience. Working collaboratively with supply chain partners is also important to develop supply chain wide resilience.

Wieland and Wallenburg (2013) however do not agree to the view on 'redundancy' and 'flexibility' and in turn propose that robustness and agility are the two main requirements to develop supply chain resilience. Robustness is a characteristics of the supply chain in which future disruptions are anticipated and the ability to cope with these events is built into the supply chain using proactive strategies. Agility is the ability to react quickly to the unexpected event and cope with changes by adapting quickly to the new requirements.

Hohenstein et al., (2015) have suggested various strategies both proactive and reactive for supply chain resilience: [supply chain collaboration, building redundant inventory and dual sourcing (proactive)], [agility, manufacturing flexibility, and employing back-up suppliers (reactive)]. The mixed approach of using both proactive and reactive strategies to manage disruptions has also been proposed by Chowdhury and Quaddus (2017). Ali et al., (2017, pp 16) outline the stages of achieving supply chain resilience- "the ability to anticipate, to adapt, to respond, to recover and to learn from disruptions". These phases highlight the need to be able to plan for, adapt and respond to disruptions.

Methodology

This work utilises a dual approach. The first phase involves a review of the literature within academic journals and professional publications. This review focuses on challenges within food supply chains, data proliferation and the use of data to manage supply chains. The second phase involves an analysis of case studies and interview data

from a small sample of supply chain entities within the food sector. This qualitative data is analysed using a 'thematic analysis' method. The literature review and thematic analysis provides a conceptual framework to create resilience within the food supply chain using various data sources.

Table 1 shows some of the literature sources studied to understand the various fraudulent activities within Food supply chains.

Table 1: Literature sources for fraud cases

Meat (Horsemeat Scandal)	Addy (2014), Lawrence (2013), Press Association (2013)
Dairy (Chinese Milk Scare)	Coghlan, 2008; Reuters, 2008; Fairclough, 2008).
Wine	Gallagher, Thomas (2010)
Fish	Gallagher, Thomas (2010)
Wheat (Bread)	Barling, et al. (2009)
Types of fraudulent activities across various products	Shears (2010), FSA(2016)
Olive Oil	Lord, et.al. (2017)

The data for exploring supply chain resilience was sought from various cases in the academic and professional literature (for example: the Milk scare, Peanut Corporation of America, Walmart and Hurricane Katrina, Cadburys chocolate recall, etc.). Interviews were conducted with a small group (6) of food industry representatives to understand the challenges with using data. These respondents represented technology SME companies and food companies. Notes were taken at the interviews and analysed to explore themes for improving the effective use of data.

Data driven food supply chains

Food Supply chains are complex systems with complex data requirements. Data can be collected at various nodes and operational points of the food supply chain using sensors, Internet of Things (IoT), GPS technologies, and cloud computing (Yu et al., 2001; Kelepouris et al., 2007; Manzini and Accorsi, 2013; Yu and Nagurney, 2013). Big Data is another emerging trend which provides processes and capabilities for dealing with large and complex data sets (Tan et al., 2015; Zhong et al., 2016). Zhong et al., (2015) suggest that food supply chains need to enhance their capabilities for data processing, data visualization, data-driven decision models, and decision support systems to make effective use of the data. The analysis of the literature and various cases from the food sector provide the following types of data that are relevant for managing food supply chains.

Traceability: data associated with the origin of raw materials within the food supply chain. The traceability data will be mapped out from producer to retailer and in the case of the producer- the traceability of seeds and fertilisers too.

Environmental: data about the environment- weather data, country specific information, etc.

Cold Chain: data associated with the storage and movement of food products in the supply chain, for example temperature, humidity, fridge/ freezer conditions, etc.

Operational: data associated with food processing and movement- data from shop floor processing, warehousing, etc.

Quality: data associated with quality of the food at producer, processor and retailer stages of the supply chain. Although this should be collected at all stages, the bulk of the data is collected from processing or as an entry into the processing stage.

Demand: data from forecasting, retailer environments, social media, IoT (consumer wearables, smart homes, etc.). Data from systems that can help in understanding demand patterns and help in optimising 'sales and operations planning'.

Farming related: data related to food production- soil data, disease data, seed data, etc.

Food waste and consumption patterns: this data is not readily available however the trend to harness this data both in the supply chain and at the consumer level is on the rise.

A process view of Data driven Food Supply chains

The previous sections have discussed the concepts of resilience, food integrity, and food fraud. The discussion has been food sector centric with an emphasis on food supply chains. Figure 1 represents a process model of the discussion in the earlier sections with the aim to show the connections between the various elements both in terms of affecting food supply chain resilience as well as the use of data effectively to develop resilience. Food supply chains are affected by various sources of risks. These risk influencers can be external to the chain- for example environmental sources of risks, infrastructure challenges, and demand changes. Food supply chains can be influenced by internal factors to the operations of the chain, for example: machine breakdowns, fires, etc. Food Fraud and integrity are considered as separate factors in the figure as they affect food supply chains in a more serious way. The figure proposes that data from these factors and operations can be collected using a number of innovative technological enablers and this data once captured can be analysed to provide effective information to take appropriate decisions. The management of resilience is both a proactive process as well as a reactive one.

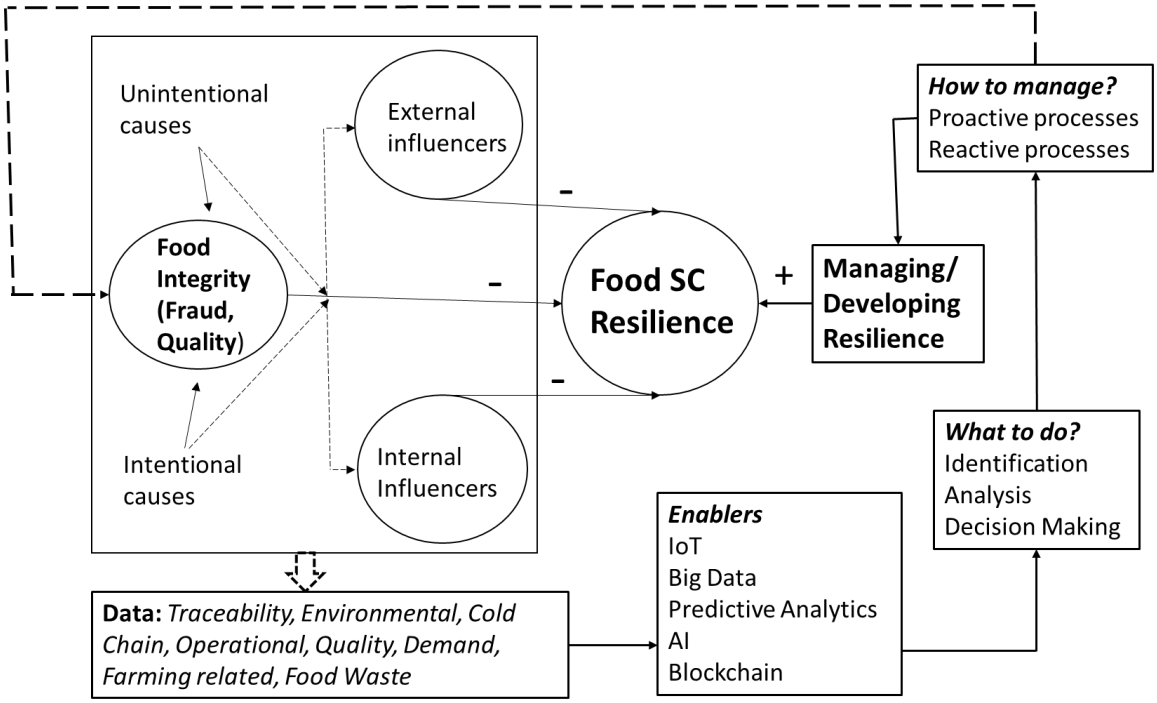

Figure 1 –Data and data driven processes to manage food integrity and develop food sc resilience

Thematic analysis

A number of food fraud cases and cases of food supply chain risks were analysed using the Thematic approach. The focus of the analysis was to explore the use of data within these cases and the factors to consider for effective use of the data for developing food supply chain resilience. Figure 2 represents how these factors interact with supply chain resilience.

1. Collaboration

Food supply chains have a greater challenge of upstream visibility due to the nature of the outcome of the final product. Tang and Zimmerman (2013) have suggested the use of Information and communication technologies to increase visibility and coordination amongst supply chain partners. However this can be achieved only through collaboration, and collaboration will happen through the appropriate supply chain relationship. Ring and Van den Ven, (1992) have suggested that effective communication, information sharing and joint pay-offs will help build trust within the collaboration. However for Data sharing between supply chain entities collaboration will be very important, both in terms of the relationship and the use of appropriate technology.

2. Appropriate Contracting

Traceability and transparency are achievable in food supply chains through the use of data sharing and integrated systems. This will require appropriate technology and resources. With closer vertical coordination and collaboration, contracts could be more strategic and build in the requirement to share and access data across the supply chain. Addy (2014) has suggested sometimes the role of sampling and traceability should be increased (with the appropriate use of data), although trust within the contractual agreement will still continue to play a focal role.

3. Adherence to ethical codes of conduct

Large food companies and their supply chains will follow ethics codes of conduct based on the principles of the UN Global Compact (UNGC, online). They will also follow the laws on labour and Modern slavery and in general laws associated with sustainability. However, the challenge is maintaining the governance of these beyond a certain tier upstream and downstream. Data plays an important role in providing this vital information. However it is also essential that strict ethical codes are followed by the supply chain entities for accessing and using the data.

4. Data Security

Integrated supply chains, sharing of data, information visibility, etc. are all important and useful processes for managing risks within food supply chains. However it is important that important security systems are in place to secure this data flow. All food supply chain entities in the UK and Europe will be required to follow General Data Protection Regulation (GDPR).

5. Appropriate Data and systems

An important aspect of using data effectively is to access the appropriate kind of data for the analysis. Data must be authentic, timely with the appropriate quality. This will require appropriate systems in place to generate and transfer data. Currently IoT systems, Big Data systems, Enterprise systems are being developed to facilitate both data generation and sharing for analysis and decision making.

6. Investment

One of the key challenges and hence the enablers within this paradigm of using data across the food supply chain is the inability of small and medium entities with the food supply chain to invest in appropriate technologies. Lack of investment and or supply chain financing could cause major hurdles in the seamless transfer of data across food supply chains.

Figure 1

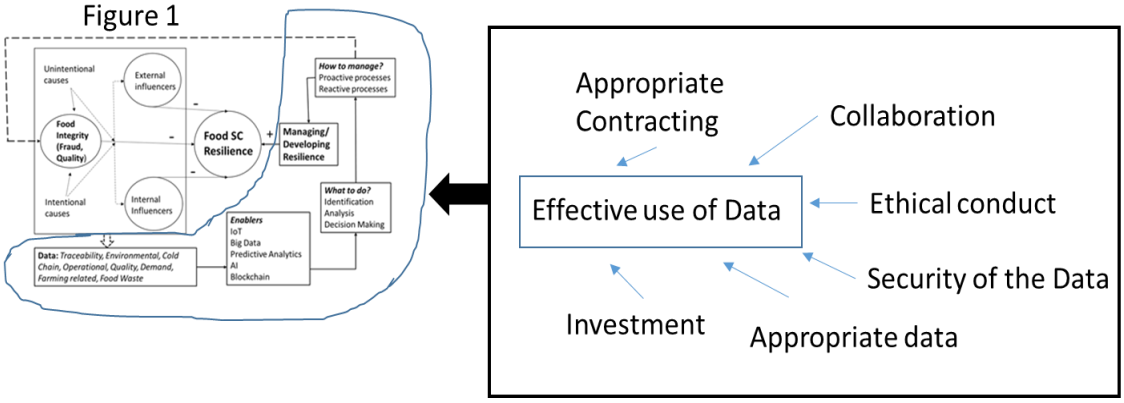

Figure 2 –The factors influencing effective use of Data for Food SC resilience

Conclusions

This paper has explored the topic of data driven food supply chains. The research used a qualitative design to explore the challenges and the processes linked with the effective use of data within food supply chains. The research questioned the idea that effective use of data will be useful to manage both food fraud and integrity as well as provide the

systems to develop supply chain resilience. The paper presented a process view of this activity both from a proactive and reactive perspective. Finally the paper explored the themes that affect the effective use of data and proposed a framework that will enable data effectiveness to manage supply chain resilience.

It is proposed to test the factors affecting data effectiveness within the food supply chain empirically. It will be important to understand the flows for both proactive and reactive strategies separately. Future research will utilise a mixed-method technique to understand the data utilisation process in detail as well as influence of each factor on the process.

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