The role of technology in crisis management/recall in food supply chains

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1. Summary

This chapter considers the advances in governance and how this frames crisis management and product recalls in food supply chains. Effective food recalls following a food safety or legality related incident are supported by traceability systems that range from being paper based to those that apply the newest technology. This chapter is written to consider the value of Distributed Ledger Technologies (DLTs) for the improvements in food supply chain governance structures that are especially tested during product recalls. The focus is on identifying advantages of Blockchain systems within public-private partnerships (PPPs) for food governance. There is a great potential to reduce information asymmetry, which is a key barrier to supply chain development, innovation and efficiency, and effective crisis management and product recalls with the use of DLTs including Blockchain. PPPs for supply chain governance can deliver value at the supply chain and wider stakeholder level including developing Blockchain consortia to improve overall efficiency and integrity in data collection, storage and sharing.

Keywords: food recall, data sharing, Blockchain, food supply chain governance, public-private partnerships (PPPs)

2. Introduction

The first general objective of European Union (EU) food law is to guarantee a high level of protection of human life, health and consumers' (economic) interests. Protection of fair food trade practices is the next priority (Korzycka & Wojciechowski, 2017). Consumer rights in relation to food are enshrined in Article 9 of Regulation (EC) No 178/2002. Current EU labelling legislation intends to help consumers make informed choices, contributing indirectly to effective competition between businesses that are compliant with the law and consistently producing and selling safe, wholesome food and directly to improved consumer health and welfare. The challenge in a complex, food supply chain is to increase consumers' trust in both food regulators and the food industry. Media communication also plays an important and complementary role in governance of food safety and food legality (Zhu, Huang & Manning, 2019). Thus, whilst the safety or legality of food in a given country or region may be seen as being the responsibility of the State to enforce, market mechanisms for food supply, underpinned by definitions of societal, business and individual responsibility, also work together to create a governance structure around food. This governance structure is especially tested during product recalls following a food safety or legality related incident.

Effective food safety management processes are at the core of a food organisation's strategy and, in the event that such controls fail, crisis management protocols must be in place that can be implemented quickly and effectively (Manning, 2007). A food recall is the "action taken by a food business to remove unsafe food from distribution, sale and consumption" (Kaaviya et al. 2019, p. 209). Competent product recall processes must include: timely identification of the food safety or quality problem, clear identification of the batch of product affected or control of the logistics of product return and/or disposal. They also require processes to be in place that embed mechanisms to retain public trust and confidence in the competency of the regulator, the food organisation, the brand and the food product (Manning, 2007; Jianbin & Hooker, 2019). The FDA (2020) defined a recall strategy as "*a planned specific course of action to be taken in conducting a specific recall, which addresses the depth of recall, need for public warnings, and extent of effectiveness checks for the recall"*. The following terms are also defined by the FDA:

- *Market withdrawal* - a firm's removal or correction of a distributed product which involves a minor violation that would not be subject to legal action by the FDA or which involves no violation, e.g., normal stock rotation practices, routine equipment adjustments and repairs, etc.
- *Recall classification* - the numerical designation, i.e., I, II, or III, assigned by the FDA to a particular product recall to indicate the relative degree of health hazard presented by the product being recalled.

    Class I is a situation in which there is a reasonable probability that the use of, or exposure to, a violative product will cause serious adverse health consequences or death.

    Class II is a situation in which use of, or exposure to, a violative product may cause temporary or medically reversible adverse health consequences, or where the probability of serious adverse health consequences is remote.

> Class III is a situation in which use of, or exposure to, a violative product is not likely to cause adverse health consequences.

Article 19 of Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety states: “If a food business operator considers or has reason to believe that a food which it has imported, produced, processed, manufactured or distributed is not in compliance with the food safety requirements, it shall immediately initiate procedures to withdraw the food in question from the market where the food has left the immediate control of that initial food business operator and inform the competent authorities thereof. Where the product may have reached the consumer, the operator shall effectively and accurately inform the consumers of the reason for its withdrawal, and if necessary, recall from consumers products already supplied to them when other measures are not sufficient to achieve a high level of health protection.”

Jianbin and Hooker (2019) identify three indicators that determine the effectiveness of food recalls, these are discovery time (the days from the production incident to the day the recall is initiated), recovery rate (proportion of the recalled material that is recovered), and completion time (the days from starting the recall to the date of completion). Jianbin and Hooker note that discovery time affects recovery rates and completion time, and there is an association between completion time and the recovery rate. Significant and non-targeted food recalls increase food waste and threaten food security (Vågsholm, Arzoomand, & Boqvist, 2020) thus traceability systems are essential to support product recall systems (Sufiyan et al. 2019). Food safety crises with associated recalls can drive improvements in regulatory and market governance systems in order to protect public health (Snyder, 2016). This highlights the focus of this chapter on the advances in governance and how this frames crisis management and product recalls in food supply chains. The next section of the chapter considers emerging structures of food supply governance. The challenges of information asymmetry are then explored both in terms of normal operation and in the event of a recall.

3. Food supply chain governance

Over three decades ago, Lushbough (1980) has rightly stated that it is already too late when the primary system fails and the food business operator confronts a recall or market withdrawal. This is necessary to prevent and plan far ahead for primary system failure. The involvement of entities from both the public and the private sector in food safety governance will improve the effectiveness of a preventive policy for product recalls and market withdrawals.

Public-private partnerships (PPPs) between regulators and industry can provide a model for food supply chain governance of the provision of safe and legal food. PPPs can leverage the benefits of public goods and services when the responsibility for the delivery these public goods and services is shared between the State and the private sector. Hybridisation of the kind that forms PPPs is driven through governance innovation (Pies, Hielscher & Everding, 2020) i.e. PPPs can deliver innovative practices and activities. Hybridisation covers the 'who' (public and private actors) of regulation, the 'how' (command-and-control v. responsive regulation), the 'where' (global, local and intermediate level), and the 'what' (business v. social regulation) of policy initiatives (Verbruggen & Havinga, 2017). When compared to purely governmental instruments, PPPs are a partnership of the public and the private sector, aimed at realising activities and rendering services commonly provided by the public sector. Based on the Guidelines for Successful Public-Private Partnerships (EC, 2003), four principal roles are identified for the private sector in PPP schemes: to provide additional capital; provide alternative management and implementation skills; provide added value to the consumer and the public at large; and to provide better identification of needs and optimal use of resources. Effective PPPs will allow the sharing of resources (financial, human, social and physical), ideas and innovation, reduce duplication and reach a wider audience so activities can be undertaken on a larger scale than individual public and private initiatives (Hernandez-Aguado & Zaragoza, 2016). Further, they argue PPPs allow more diverse communication and marketing channels and wider media access, but conversely there can be a concern over the independence of such approaches where there is an element of industry self-regulation or a misalignment of public and private goals and objectives.

The structure, efficiency and degree of public-private hybridisation of the food governance system is culturally, historically and structurally conditioned, limiting the ability of food markets to develop and implement universal official food control system instruments across national boundaries where regulations may vary from country to country in terms of what is or is not a legal requirement. To address this challenge and also to ensure an organisational food governance culture can be established, transnational corporations have developed common standards across their operating markets especially in countries that lack a State driven food governance system. Indeed, this can lead to transnational corporations operating across multiple governance landscapes with multiple models of food public-private governance depending on the location.

Different PPP governance models co-exist including pure public regulation, and at the other end of the spectrum private organisational and supply chain self-regulation, and then a range of hybrid PPPs in between with the resultant “normative implications” and with the drive for developing PPPs often based on delivering lower regulatory cost (Martinez, Fearne, Caswell & Henson, 2007; Chatzopoulou, 2015). PPP models have been suggested in the academic literature for:

- Assuring food safety and traceability (Rouviere & Royer, 2017; Narrod, Dou, Wychgram & Miller, 2018); public health and nutrition (Clapp & Scrinis, 2017; Greenberg, 2017; Ibrahim, 2018; Gressier, Sassi & Frost, 2020);
- Ensuring food security (Zhong, Si, Crush, Scott & Huang, 2019); healthy lifestyles and food related health promotion (Knai et al. 2015; Hernandez-Aguado & Zaragoza, 2016; Seeuws, 2017; De Pinho et al. 2019);
- Mitigating food fraud (Spink, Moyer & Whelan, 2016); and
- Creating opportunities for innovation in agricultural systems (Kolaj, Osmani, Borisov & Skunca, 2019), cold food chain management (Kendurkar & Tiwari, 2017); agribusiness sustainability (Obayelu, 2018); water allocation and irrigation (Khadra & Sagardoy, 2019; Rafaat, Osman, Georgy & Elsaid, 2020); technology access (Mangeni, 2019) and biotechnology (Lokko et al. 2018).

There are degrees of hybridisation in these proposed models for PPPs and tensions can operate within the structures (Manganelli, Van den Broeck & Moulaert, 2019) including corporate power dynamics (Clapp & Scrinis, 2017; Greenberg, 2017); and especially in food supply chain governance (Kowalska & Manning, 2020).

Non-market drivers, such as regulation and changes to regulatory inspection regimes can affect supply and demand dynamics and influence supply chain interactions. Market failure occurs when markets fail to produce “either economically optimal [efficient] or socially desirable [equitable] outcomes” (Wolf, 1987, p. 46), such as a food safety incident. For a food supply chain to be socially optimal, i.e. the market can consistently supply safe and legal food, it must firstly deliver in practice to consumers and address any negative externalities such as environmental impact and pollution, packaging use and disposal. However the question arises what information it is reasonable to expect a food organisation to share with others both in normal times and in the event of a product recall? It is this understanding of what is competitively important and private information that organisations would not reasonably be expected to share, often providing integral, intangible value in terms of brand equity and what information can be reasonably shared to promote supply chain and market transparency especially during a product recall. Shen, Choi, and Minner (2018, p. 4898) state that "information asymmetry refers to the scenario in which some information (e.g. cost information, demand information, supply information, etc.) is private and not public to all supply chain members." Information asymmetry is of particular interest in food supply chain governance approaches and is now considered more specifically.

4. Information asymmetry

Knowledge may be positioned within information or may be held as tacit knowledge or know-how. The inability to convert tacit knowledge to explicit knowledge leads to knowledge suppression and this can cause gaps in knowledge sharing (Teece, 2000). Information asymmetry is simply where one party is in possession of more information than the other and knowledge asymmetry increases information asymmetry (Nestorowicz, 2014). Information asymmetry occurs "when an imbalance of knowledge exists between two parties, such as a buyer and a seller, a regulator and an operator, and an employer and an employee" (Salhi 2020, p.2983). When sellers have more knowledge than buyers about the integrity of the product, the level of supply chain monitoring and verification associated with products and production processes, or how characteristics such as food safety, product quality, provenance, or traceability are assured, then this can influence the power dynamics in their relationship. It is evident from their contractual position in the supply chain that the retailer or food service organisation can collect more consumer and market demand information, whereas the supplier can provide more supply related information. These two types of information are not always shared openly between all supply chain members. Consumers are the weakest market participants as they are least able to collect and access adequate information. Indeed, consumers bear considerable health and economic risk when purchasing and consuming food (Ozimek, 2012) i.e. they can be vulnerable to being misled by food business operators at any stage of the supply chain. Factors such as resource scarcity, property rights, control of market access, criticality of the exchange relationship, incomplete contracts that lead to information asymmetry, asymmetric lock in, adverse selection, and morale hazard all play a key role in framing market operations (Manning, Soon, Aguiar, Eastham & Higashi, 2017). Wang, Van Fleet and Mishra (2017) argue that "retail gatekeepers" could take advantage of consumers because of information asymmetry, although this risk is reduced by implementing effective traceability and labelling systems (Kendall et al. 2019a; 2019b). The potential consequences of information asymmetry is relevant for a broad group of stakeholders, including honest market competitors and consumers who may be vulnerable to sharp practice or the illicit activity of others (Spink & Moyer, 2011; Kowalczyk, 2015; Kwasek, 2015; Marvin et al. 2016; van Ruth, Huisman & Luning, 2017; van Ruth et al. 2018; Yang et al. 2019).

Information asymmetric provides an incentive for fraud (McCluskey, 2000; Kowalska, Soon & Manning, 2018) and this concern has been linked to organic food (McCluskey, 2000; Giannakas, 2002), and higher animal welfare products (Bitzios, Jack, Krzyzaniak & Xu, 2017). In the organic food supply chain, information asymmetry exists between farmers and processors, processors and retailers, then retailers and consumers (Manning & Monaghan, 2019). In the organic food market, third party certification (TPC) plays a vital role in reducing information asymmetry and increasing signalling. TPC verifies the process of production, the credibility of organic producers, and releases that information to the public through the issuance of a certificate of conformity and organic food labelling cues. TPC might enhance consumers' trust in the integrity of organic food (Manning & Monaghan, 2019). Consumers' trust is an important determinant of purchase of a credence good, like organic food. Based on TPC as an element of food supply chain governance, long-term contracts between suppliers and retailers can further reduce information asymmetry through both parties participating in the normative definition of production methods, especially where, as in the case of organic food the use of production inputs is controlled (Zhao et al., 2020). In recent times, there have been a dynamic development in a multitude of sustainability-related food labels aimed at reducing information asymmetry between food producers, other businesses in the supply chain and consumers, especially regarding the sustainability impact on the food supply chain (Asioli, Aschemann-Witzel, & Nayga Jr., 2020). Organic production is just one example of these standards. TPC often provides assurance that sustainable cues on packaging are associated with a set of normative private standards that are routinely verified at steps in the supply chain to ensure integrity of use (Rees, Tremma, & Manning, 2019).

Supply chain contracts can contribute to overcoming information asymmetry within the supply chain. There are several applications which show that supply chain contracting has been used for solving industrial problems with access to updated information, e.g. quick response (QR) codes, advance selling, vendor-managed inventory (VMI), collaborative planning, forecasting, and replenishment (CPFR), technological advancement for information acquisition, risk management, and sustainable supply chain with demand information updating (Shen, Choi, & Minner, 2018).

Market failure occurs in food supply chains when there is information asymmetry between individual actors in the chain (Verbeke, 2005; Manning, 2018). Over two decades ago, Ritson and Mai (1998) state that a market economy might "fail" in providing safe food, because there is asymmetry in risk knowledge; there are aspects of food safety that are perceived as public goods and the social costs of failures in food safety are not borne by the industry; and there is a divergence between objective scientific evidence and more subjective consumer perceptions of the risks associated with food safety. Information asymmetry can therefore lead to food safety and quality incidents (Louw & van der Merwe, 2020), a motivation for embedding traceability systems (Hobbs, 2004). Despite new forms of information management systems spreading rapidly, the anonymity of those operating in the food chain is a market challenge, and as previously stated, protecting brand value and fierce price competition generates an incentive and pressure to reduce both knowledge sharing and production costs. In summary, PPPs focus on a co-delivery of food supply chain governance through new and emergent institutional arrangements, whereby the arrangements can be either *consultative* (industry being consulted by the regulator), or *contributory* with mutually beneficial collaboration based on trust, shared goals and accountability mechanisms (Rouviere & Royer, 2017). One opportunity for effective cooperation is the ability to share data between public and private actors and emerging technologies can support this interaction and access to data and information. The next section of the chapter considers mechanisms for sharing data and one option in particular distributed ledger technologies or DLTs.

5. Data sharing as a mechanism to underpin PPPs

A product recall can be very expensive and if badly executed can have a detrimental impact on an organisation’s reputation so effective traceability is a key mechanism to reduce liability (Dai, Tseng & Zipkin, 2015). Recalls therefore use traceability information and knowledge of the product life-cycle (Diallo, Henry & Ouzrout, 2014) and this data can be stored on paper, in digital files or in more sophisticated data systems. Granularity is a major consideration here. Each organisation decides the level of granularity in terms of the level of information precision required (Islam & Cullen, 2021). They argue that:

> “Fine granularity decreases the [traceable resource units] TRU size, but increases overall numbers of TRUs thereby increasing information recording. On the other hand, coarse granularity reduces the level of information recording but the resulting TRU size can obscure important product information.” (Islam & Cullen, 2021, p.8).

Traceability in food supply chains therefore requires an information trail that aligns with the products physical movements through the supply chain (Smith et al. 2005). Salampasis, Tektonidis and Kalogianni (2012) consider TraceALL a semantic web ontology-based framework and whether it would provide an infrastructure to enable traceability applications that allow for an information trail associated with the physical trail. They argue that such systems must be “cost effective, easy to manage and applicable within a globalised, networked, interoperable economic environment” (Salampasis et al., 2012; p.302). Whilst traceability data can be collated within software systems it can become outdated as knowledge artefacts lose value (Mills, Escobar-Avila, & Haiduc, 2018) who developed an automatic traceability maintenance system that incorporated machine learning. Blockchain is suggested as a means to ensure information trails are recorded and data integrity is maintained (Agrawal, Sharma & Kumar, 2018).

A Blockchain, quite simply is "a distributed database, which logs an evolving list of transaction records by organising them into a hierarchical chain of blocks." (Zhang, Xue & Liu, 2019). Further, they determine that a Blockchain is developed and maintained using a "peer to peer overlay network" which gains its level of security via "intelligent and decentralised utilisation of cryptography with crowd computing". Blockchain technology has been proposed as being of value in assuring product data traceability (Mattila, Seppälä & Holmström, 2016; Kshetri, 2018; Behnke & Janssen, 2019; George, Harsh, Ray, & Babu, 2019; Pearson et al. 2019); and trust in the integrity and confidentiality of information (Kshetri, 2018; Behnke & Janssen, 2019). Therefore, Blockchain technology has the potential to not only provide a platform to track and trace product, but also to go further to demonstrate provenance via "providing a robust system to trace origin, certifying authenticity, tracking custody, and verifying the integrity of products" (Montecchi, Plangger & Etter, 2019, p.284). This reduces the potential for identity loss and a failure of traceability systems, or more extremely instances of food fraud. Since there may be many supply chain members in DLT-based information systems (1st tier; 2nd tier; 3rd tier etc.) who check the information that they have received, they can raise the alarm immediately if they find the information is incorrect or suggests that the product related to the information may be unsafe or out of specification . Therefore, a successful Early Warning System (EWS) for identification of potential food safety issues that may develop into a crisis might be Blockchain-based (Tian, 2018). Implementing a Blockchain-based solutions should contribute to ensuring quicker recalls along the food supply chain.

Distributed Ledger Technologies (DTLs) with their transparent transactional activity and data retention are proposed to be of value as a digital form of PPP (Tripoli & Schmidhuber, 2018). The basis of DLTs is that there is a digital logbook composed of blocks (Creydt & Fischer, 2019). DTLs, such as Blockchain, "can provide a cryptographically secure and immutable record of transactions and associated metadata (origin, contracts, process steps, environmental variations, microbial records, etc.) linked across whole supply chains" (Pearson et al. 2019; p.145).

A Blockchain is composed of three elements: the block, the chain and the network. The block is composed of a header (a time stamp for when the block was written and a body that records the transaction information and the number of transactions which cannot be modified; and a "hash" which is a link to the previous block (Creydt & Fischer, 2019; Wang, Zhu, Ni, Gu, & Zhu, 2020). Each block is itself protected by cryptography techniques to enable the trusted integrity of the transactions records (Zhang, Xue & Liu, 2019). The "hash value" is thus a cryptographic image that defines this block and the previous block in the chain using a hash pointer. This hash of stored data can be verified so data tampering is ultimately recognisable because there is a single root hash pointer to the initial or genesis block (Zhang, Xue & Liu, 2019). The lowest level of the decentralised infrastructure is the signed transactions between two participants, where one or both sign the transaction (Casino, Dasaklis & Patsakis, 2019). In a transaction between two or multiple parties, the owner of the information retains half of the digital signature (the private key); whilst the other half of the digital signature (the public key) is published to the agreed parties in the network (Cai & Zhu, 2017). However, if the private key of a given party is stolen, it can be very difficult to identify the perpetrator (Efanov & Roschin, 2018). Thus, with appropriate safeguards, Blockchain technologies provide the opportunity to identify in a supply chain what data associated actions have been performed, when, and in what location allowing for greater auditability of data and transactions by different supply chain actors (Kshetri, 2017; 2018). Without an auditable data trail there is a lack of transparency in terms of data integrity from the "point of generation to the point of data use", conversely an auditable trail via Blockchain can deliver visibility and accountability (Kshetri, 2017). The use of DLTs reduces information asymmetry and associated power dynamics as the data is distributed and each actor can access and verify transaction records when needed (Montecchi, Plangger & Etter, 2019, p.284). Whilst private Blockchains have limited access; public Blockchains are open and subject to privacy issues; the third type a consortium or federated Blockchain is a mixture of private and public Blockchains (Casino, Dasaklis & Patsakis, 2019; Creydt & Fischer, 2019; Zhang, Xue & Liu, 2019). It is this latter type of chain that could prove to be of value in developing PPPs. Table 1 compares the characteristics of the three types of Blockchain. Key characteristics to consider is the level of anonymity, the times taken for the transactions to occur and the level of immutability. The benefit of Blockchain is real-time transactions and facilitates auditability for those that have access to the transactions and reduced transaction costs (Kamble, Gunasekaran & Sharma, 2020). In one study, the use of Blockchain technology reduced the time to trace mangoes from seven days to 2.2 seconds (Yiannas, 2018).

Blockchain technology can be linked to Internet of Things (IoT) technology, which is discussed in detail in many chapters of this book. IoT applications can be connected and automatically capture data from sources such as Global Positioning Systems (GPS); Geographic Information Systems (GIS), Wireless sensor networks (WSN) and Radio Frequency Identification (RFID) tags and other barcode systems (Duan et al. 2020). Linking data with GPS can act as a deterrent against theft, and also in the event of theft occurring, materials have the potential to be traced (Bell et al. 2018) or wider provenance (Wallace & Manning, 2020). Others suggest that artificial intelligent applications can support the Blockchain-enabled Intelligent IoT architecture (Singh et al. 2020). Thus, DLTs can secure "the evidence chain" (Pearson et al. 2019) especially via smart contracts. Smart contracts are a specific kind of computer programme that works on all nodes in the network where all active users can create a contract by placing a transaction in the system (Tian, 2017). Smart contracts can be more error-free than manual systems and will automatically "self-execute when specified conditions are met," reducing transaction costs and making the system more "real-time" (Nathan & Jacobs, 2020). Encrypted unique keys provide a reassurance of data integrity: as when tested the data will generate the same key excepting if the data has been amended (Pearson et al. 2019).

Table 1. Definition and main attributes of different Blockchain networks (Adapted from Casino, Dasaklis & Patsakis, 2019; Zhang, Xie & Liu, 2019).

Attribute	**Blockchain type**		
	Public Anyone can participate and is fully accessible and readable.	**Private** Access, read and write permissions are strictly controlled by an organisation.	**Federated or Consortium** Anyone can access and read but only certain participants can have write permissions
Consensus	Costly Proof of Work (PoW)	Light PoW	
Ownership and Management	Public, permissionless	Centralised, permissioned access	Semi-centralised permissioned nodes
Number of trust authorities	0	1	≥1
Mechanism	All miners	Centralised organisations	Leader node set
Identity	(Pseudo) Anonymous	Identified users (writers)	
Anonymity	Opaque	Trusted	
Consensus protocol efficiency	Low (Slow)	Highest (Fastest)	Higher (Faster)
Transaction approval time	Minutes	Milliseconds	
Immutability	Almost impossible	Collusion attacks	

Smart contracts in the event of system or product failure can trigger warnings to prevent a food safety incident minimising the need for product recall and can benefit from not needing human intervention (Duan et al. 2020; Keogh et al. 2020). Wu and Lin (2019) propose that the architecture of the system is on multiple layers which are important in the event of a product recall. The Blockchain level including smart contracts where information is collected; the process level where data is read, issues are detected and actions are taken and the request and validate layer where supply chain actors and regulators and third parties interact with the system. The application of GS1 standards together with Blockchain technology can provide for better regulatory control of the use of the technology and enhanced traceability (Keogh et al. 2020).

Challenges for applying Blockchain technologies are the variations in laws, customs and practice over national and international jurisdictions, the timescale required to agree DLT based solutions and the technology adoption in itself may be a barrier to entry for some organisations along with the need to deliver robust cybersecurity measures (Kshetri, 2018). Indeed, in a data rich supply chain where DLTs are used by some actors and not others, some excluded organisations may be severely disadvantaged by being resource, data and information poor (Arunachalam, Kumar & Kawalek, 2018). Reyna et al. (2018) cite further challenges including anonymity and data privacy vs. transparency, creation of consensus, legal issues, security (weaknesses and threats), issues around smart contracts and storage capacity and scalability. Much of this work is still in its infancy, but there is great potential to reduce information asymmetry and reduce the discovery time and completion time and improve the recovery rate.

6. Concluding thoughts

An advantage of Blockchain systems within PPPs for food supply chain governance is that verification of transactions can be real-time making it more difficult to backdate transactions (Wang & Kogan, 2018) a key need in the event of a food safety incident where a food recall may be required. PPPs for supply chain governance can deliver value at the supply chain and wider stakeholder level including developing Blockchain consortia to improve overall efficiency and integrity in information sharing. However, ownership rights and allocation of permissions, competitive issues that may create challenges for private business partners, and identifying which actors are the guarantors of data quality, and the ethical use of data that is collected and stored in the system all need to be considered (Schwabe, 2019). This is often addressed by the regulator or an independent organisation appointed by the regulator, often termed a data trust. For such PPPs, based on a Blockchain system, to be effective in practice, operating measures need to be in place that address membership criteria, system architecture, data management protocols and governance structures (Nathan & Jacobs, 2020).

Some actors may resist information sharing if they consider that they will impinge on competitive advantage or they have a modus operandi that focuses on information asymmetry as a means to drive personal gain (Chadderton & Norton, 2019). However Chadderton and Norton argue that when implementing PPPs they should not only focus on legislative and technological challenges, but also on factors such as relationships and organisational culture, trust and differentiated risk appetite through long-term commitment, effective governance, collectively agreed strategic direction, shared resources and clear processes to manage data. Further they conclude that collaboration between government and the private sector through the creation of PPPs deepens individual and collective understanding of dark, opaque behaviour and as a result drives the development of effective mitigation strategies.

Blockchain technologies can improve information flow within PPPs as each node in the network can be related to a given IP address and an "event log" with transactions between actors being verified to ensure integrity as they become immutable after being submitted to the system (Hyvärinen, Risius & Friis, 2017) i.e. they are tamper resistant (Beck, Avital, Rossi, & Thatcher, 2017). The immutability of the logs of past transaction means that the system can be verified by multiple actors (Hyvärinen, Risius & Friis, 2017; Casado-Vara, Prieto & Corchado, 2018), even if they do not trust each other (Wang & Kogan, 2018; Bell et al. 2018). Beck et al. (2017, p.382) state that Blockchain could overcome information asymmetry by providing "a decentralised global information infrastructure in which no one is in full control, no one has absolute power, and no one can distort or lie about past or current events." Information sent to the blockchain can never be erased or changed. This is of particular value in maintaining PPPs, however, access to immutable information can only be achieved in a public or federated Blockchain as it is possible to manipulate private Blockchains if the central authority is corrupt, thus there is a "trade-off between information confidentiality [privacy] and transparency" (Wang & Kogan, 2018, p.2).

Information asymmetry is a key barrier to supply chain development, innovation and efficiency, and effective product recalls. Food supply chain governance PPPs provide an opportunity to improve transparency to ensure effective open regulation, an understanding of market standards and the opportunities for market access and a reduction in supply chain opacity. PPPs and a range of hybrid models can be operationalised suited to a given regulatory and market situation, especially a product recall. Further work needs to be undertaken to frame such approaches, including who the members of such PPPs should be and how the PPPs are operationalised in practice. In March 2021, The UK Food Standards Agency published a research report Food Data Trust: A Framework for Information Sharing and the report highlight that easier data sharing could “speed up information exchange along a chain in urgent situations such as food recalls and tracing incidents” (p.2). Good governance around data collection, sharing and storage is essential. The design and implementation of structures that can deliver good governance of food supply chains and including engagement with associated regulatory bodies, especially during a product recall is in in its infancy as we write this chapter. However, this is an exciting area of emergent research and policy and the outputs in terms of policy tools and governance structures should serve the industry and consumers in the future.

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