Technologies and audit systems for authenticating food trust

Our Land and Water National Science Challenge

June 2018

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6 June 2018

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Dear Paul

In accordance with our contract dated 2 May 2017, we present our final report *Technologies and audit systems for authenticating food trust*. We have appreciated working with you on this first stage of research and look forward to taking the ideas in this research further with you in the future. Please note that this document should be read in conjunction with the restrictions in the Disclaimer at the end of the report.

Yours sincerely

Bill Kaye-Blake
Director
Consulting

Table of contents

Introduction 1

Value chains and food trust 3

Digital media and smart technologies for assuring sustainability 13

Isotope testing and value chain authentication 31

Sustainability audit schemes and value chains 43

Future research 55

Conclusion 57

Bibliography 60

Disclaimer 69

Introduction

Background

Collaborative value chains that effectively communicate credence attributes will help enhance New Zealand's global reputation for sustainable and high quality primary products. This report describes technologies and systems that can assist New Zealand to capture greater value through the value chains for our food products.

A large share of New Zealand's food production is exported, and New Zealand has done well at growing the volume of food it produces. However, the environmental effects of agriculture are a long-standing concern both in New Zealand and increasingly for its key export markets. For New Zealand to prosper, it needs to grow the value it generates from food production while reducing the impact its production has on the environment. The use of credence attributes can allow New Zealand to capture greater value from its food products without requiring greater production volume.

Credence attributes are qualities a consumer believes about a product that cannot be observed or experienced before or after the point of purchase, such as animal welfare or the environmental impacts of production. Credence attributes appeal to consumers' preferences and values beyond the simple price, quality and quantity of the product. Because these attributes are not observable characteristics of products, consumers must believe or trust that products have them. Technologies and authentication systems support consumers' trust in the credence attributes that New Zealand can market with its products.

The Our Land and Water (OLW) National Science Challenge's mission is to "enhance primary sector production and productivity while maintaining and improving our land and water quality for future generations". The Greater Value in Global Markets theme of OLW contributes towards this goal by looking at how New Zealand can capture greater financial returns through its markets without needing to produce greater volumes. The use of credence attributes is a specific mechanism that can support OLW's mission, by increasing what consumers are willing to pay for a product and capturing a greater share of that value. Capturing this additional value requires a value chain that communicates information about those credence attributes from producers to consumers.

Prior research in the Greater Value theme developed a framework for understanding this complex issue. It included New Zealanders' values about methods of food production, consumer preferences in export markets for credence attributes and the level of collaboration in the value chain. These components were developed into five hypotheses:

1. It is possible to prepare and explain a list of physical and credence attributes related to sustainable land use choices and valued by domestic and international consumers of agri-food exports, made available to agribusinesses through a specialist web-based portal at the AERU.

2. It is possible to use original research in key international markets to determine credence attributes matched to New Zealand production systems that are valued by international consumers of all agri-food products sourced from New Zealand, especially from Māori enterprises.

3. It is possible to identify effective technologies and standardised audit systems that are trusted by international consumers that they are buying sustainable New Zealand primary products.

4. It is possible to identify specific governance features, data and measures that improve the performance of collaborative value chains in an agri-food context.

5. It is possible to create systems within collaborative agri-food value chains to reward providers for providing credence attributes valued by domestic and international consumers.

This report addresses the third hypothesis. The hypothesis has been explored by a research team across four organisations, with a particular emphasis on exploring the role of smart technologies in communication flows along global value chains. Each organisation contributed a chapter to this report, based on its area of specialisation.

Structure of the report

Following this introduction, the report comprises four chapters:

1. **Value chains and food trust** explores different types of value chains and the role of food trust in these value chains. Drawing upon its global programme of Food Supply and Integrity Services, PwC investigates how food trust can reassure everybody, from producers to consumers, that food is safe and comes from trusted producers and processors. The chapter extends that work to the topic of credence attributes.

2. **Digital media and smart technologies for assuring sustainability** outlines smart technologies used for understanding and communicating to international markets. The Lincoln University Agribusiness and Economics Research Unit (AERU) has developed a programme called *Maximising Export Returns* (MER), which has researched the types of smart technologies available to consumers for purchasing and researching food products.

3. **Isotope testing and value chain authentication** explores new tools being developed to prove product authenticity and support consumer confidence in agri-food products. These tools are being developed by the National Isotope Centre at GNS to identify attributes of food products from their chemical make-up. They can enable improved traceability of products throughout the value chains.

4. **Sustainability audit schemes and value chains** provides an overview of assurance and certification schemes for sustainability values, both in New Zealand and overseas. The *New Zealand Sustainability Dashboard* has participated in designing these schemes, and has researched how they can build trust in New Zealand's products.

The report concludes with a discussion chapter that describes potential subjects of future research and some conclusions.

Value chains and food trust

Contributor: PwC

Introduction

Credence attributes are qualities of a product that cannot be seen or directly experienced at the point of purchase, such as animal welfare or environmental impacts of production (Saunders, et al., 2015). Credence attributes are a mechanism through which New Zealand can capture a greater share of value from its food exports.

For credence attributes to be an effective mechanism, consumers must have trust in the authenticity of the attribute. It is not enough to simply make a claim about a product – consumers must actually believe a product has a credence attribute and value it before they will pay a premium for it. It is consumers' trust in products and claims that allows producers to capture greater value using credence attributes.

This chapter discusses:

1. how credence attributes link to different kinds of value
2. how New Zealand can build food trust among consumers
3. different approaches to food trust
4. the role of technology and authentication systems in communicating food trust through value chains.

The four types of value

To target the use of credence attributes and gain a greater share of value in value chains, it is helpful to consider the different sources of value. Dagevos & van Ophem (2013, cited in Saunders, et al., 2016, p. 8) describes four types of value that are generated through value chains:

- **Product value** – the inherent value of food products produced. It includes sensory properties of freshness, taste, texture and flavour as well as price.
- **Process value –** the value attributable to a product because of how it was produced. The value derives from the processes and practices used in its production. Land-use practices, value chain practices and animal welfare all contribute to process value. Some examples of process values include free range, organically farmed, sustainably produced or harvested, genetically modified organism-free and fair trade.
- **Location value** – the value of the location and setting where the product is purchased or consumed. A meal consumed at a restaurant will cost more than the same meal purchased at a supermarket to eat at home.
- **Emotive value** – the emotional response at the point of consumption and the value attributable to the 'story' associated with the product. This is a complex topic, with important contributions by Claude Lévi-Strauss, Mary Douglas, Pierre Bourdieu and Claude Fischler (Fischler, 1988). This symbolic or moral meaning can be significant. It encompasses more general values such as New Zealand's reputation as environmentally pure, and symbolic value associated with products such as pounamu through Māori culture.

These four types of value will either be able to be ascertained by the consumer before purchase, be experienced by the consumer directly after purchase, or be a credence attribute that they believe in without being able to directly confirm its presence (Table 1).

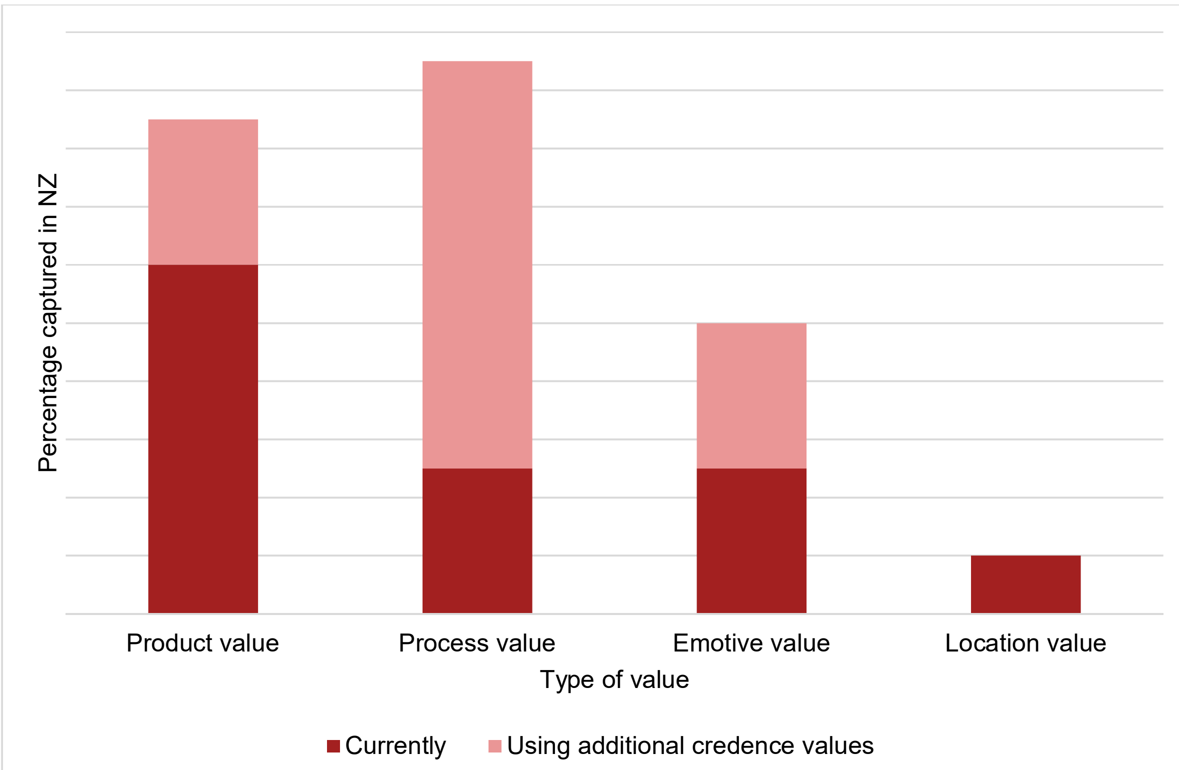
Table 1: Types of knowledge consumers can use to assure different types of value

Value type	Ascertained pre-purchase	Experienced directly	Credence attribute
Product	×	✓	✓ (some)
Process	✓	×	✓
Emotive	✓	✓	✓ (some)
Location	✓	✓	×

Credence values, as values that cannot be experienced directly, are predominantly process and emotive values. Location value is always experienced directly by the consumer where they consume the good so cannot provide value to New Zealand exporters. Some product values are not experienced directly, such as food products that claim to provide additional health benefits.

For types of value where there are potential credence attributes, it is possible for New Zealand producers to capture a greater share of that value, as we illustrate in Figure 1.

Figure 1: Illustrative proportions of total value captured in New Zealand by type of value with and without credence attributes



For credence attributes to help New Zealand capture more value, consumers must have trust that the claims made about New Zealand food products are true. How food trust works and how New Zealand producers build that trust is the subject of the rest of this chapter.

Food trust

Here we discuss how trust works in food value chains, how it connects to the four types of value, and the kinds of systems and technologies that will build trust.

Food trust shares many common features with trust in other areas. Contemporary society relies on trust to function properly (Fukuyama, 1995). We trust our family and friends to support us. We trust businesses and agencies to treat information collected about us with respect and responsibly. Kasperson, Golding and Tuler (1992) identify three attributes of trust:

- **Expectations about others and orientations toward the future** – Trust allows people to interact and cooperate without full knowledge about others and future uncertainties.
- **A notion of chance or risk taking** – Trust also implies that people have confidence that others will act voluntarily in a manner that is beneficial, even if they are certain.
- **Subjective perceptions about others and situations** – Trust includes perceptions of the intentions and attributes of others, their motivations, qualities of the situation, risks and uncertainties.

In the economic sphere, contracts can be used to specify rights and require performance of certain obligations. However, contracts cannot completely account for all possible states of the world and contingencies. In addition, as supply chains expand in length and complexity, the visibility that one participant has over how food is sourced and handled along the supply chain decreases. Trust fills the gaps in our ability to enforce standards through contracts.

In the food sector, several issues combine to make trust an especially important concern for three reasons:

- The potential impacts on human health from adulterated or contaminated food mean the impacts of food fraud are potentially more significant and more personal for consumers than fraud in other value chains.
- Long, opaque supply chains make it more difficult to trace the provenance of food products and mean consumers cannot easily verify attributes of food themselves. They need to rely on others.
- As a necessity, food has a demand that is relatively inelastic. As a result, consumers are potentially more fearful of issues with food fraud than in other products.

In food supply chains, customers generally rely on the knowledge they have about the trustworthiness of particular brands. They cannot fully evaluate all the possible risks and mitigations, so they make judgments about where to place their trust. Producers that support food trust by demonstrating integrity and a commitment to supply chain excellence, and managing risk appropriately can grow the trust that consumers have in their brand and use that to support the long-term growth of their business.

Food trust and the four types of value

Demonstrating the integrity of each of the values builds food trust. How trust is demonstrated to the consumer will vary across different types of value. For example, trust in the quality of a food product (product value) is built up over time through experience. Trust in the sustainability of a product's production (process value) cannot be directly experienced by the consumer and will need to be demonstrated differently using labels and narrative.

One source of this trust is through regulations and institutions. Where food products are subject a stringent regulatory regime, consumers may build trust in the wider regime and trust in the safety and claims made by food products subject to the regime. Trust in the regime is then denoted by an identifying feature such as 'Made in New Zealand'.

Regulatory institutions and firms need to build trust in their products and processes. Wansbrough (2005) describes three aspects that are necessary to build trust. First, producers cannot ask for trust from consumers and it must be earned. As the internet has made information more easily accessible, consumers are more aware of issues of food fraud and reliability than they have been in the past. Therefore, trust can be built only by showing how risks are managed and demonstrating the integrity consistently over time.

Second, trust is also based on behaviour, not just communication. The content and method of communication between firms and their customers is necessary but insufficient. Trust is built on how integrity is demonstrated in practice – how producers act, particularly in the face of a crisis. In a crisis consumers should be given the tools and information to manage their risks themselves. This requires transparency, acknowledging responsibility for an issue, addressing consumer fears and being transparent as to how decisions were made.

Thirdly, building trust takes time. It's the consistent demonstration of appropriate risk management, performance and communication over a long period that builds a reputation for trust.

Trust is an economic good

Traditional economic theory categorises goods into four categories:

- Private goods
- Common pool goods
- Club goods
- Public goods.

The types of goods in the four goods framework are distinguished by two independent characteristics:

- Excludable – the person with the good can prevent others from benefiting from it
- Rival – one person's use reduces the availability of the good for others.

Figure 2 shows how these two factors interact to identify different kinds of goods.

Figure 2. The four goods framework

Rival \ Excludable	Y	N
Y	**Private** Person A purchases a good. This prevents Person B from being able to use this same good.	**Common Pool** Person A and Person B do not need to purchase this good. Person A's use of the good prevents Person B from using this same good.
N	**Club** Person A purchases a good. Person B is still able to use this same good, as long as they purchase it too.	**Public** Person A and Person B do not need to purchase this good. Person A's use of the good does not prevent Person B's use of this same good.

Food trust is non-rival. The consumption of a food product does not necessarily diminish the availability of food trust embedded in that product and available for other consumers. Further, trust placed in a producer's food product does not diminish the capacity for consumers to place trust in a different producer or food product.

It follows that trust can be a club good or a public good depending on the extent to which trust in a food product is associated with New Zealand, and how much trust is associated with a particular firm.

Non-excludability – Trust as a public good

Because public goods are non-excludable and non-rival they lend themselves commonly to problems with over-use and under-investment. The 'tragedy of the commons' is the common description given to this economic phenomena. A resource is commonly owned and is used by a large community. Each individual's incentive is to use as much of this resource as possible. As no-one has exclusive rights to it, no-one is incentivised to invest in or develop the resource and soon the resource is depleted and overused.

For these reasons, public goods often lead to issues of which central or local government have to address as they require a collective rather than individual response. Because public goods are non-excludable, private businesses do not arise to provide them naturally, and it usually falls to government agencies to supply them.

Food trust is also mostly excludable. To the extent that consumers identify particular brands, trust in one firm's brand is exclusive and doesn't provide its benefit to other brands.

Excludability – Trust as a club good

Goods that are excludable but are not rival are considered "club goods", because of the similarity to the provision of collective services by clubs. The service can be provided to multiple users at once without detriment and the club serves to ring-fence the cost of providing the service. A golf club or a swimming pool are both canonical examples of club goods.

However, food trust is not entirely excludable because some trust in food products spills over to other food product attributes that are common across many types of foods. For example, trust in one New Zealand producer may benefit other producers as it builds trust the wider New Zealand brand. This can also be a significant risk – when trust is lost through a scandal with one brand, consumer trust in other brands from the same country may also be affected.

In food trust, certification schemes operate similarly to clubs, managing the costs of provision of trust while providing a level of trust in an excludable way to the firms that are willing to pay for it.

When does food trust become a club good?

Firms that rely upon the New Zealand country-of-origin (CoO) are using trust as a public good – a common resource that has low or no costs to use. However, there are risks to relying on brand New Zealand. If one large New Zealand food company has a scandal or issue with food safety, it can affect the food trust of all firms using the New Zealand brand. This risk is a negative externality – an external cost borne by all New Zealand food producers.

Certification and labelling schemes, and other authentication tools beyond CoO move the trust in food towards a club good. There are private costs associated with joining the scheme, but those costs mitigate the risk exposure to other producers' problems. Through joining a certification scheme, producers confine the likelihood of food-trust problems arising to a more limited group. Further, the labelling and marketing associated with the scheme allows them to distinguish their product in the mind of the consumer. Therefore, even if there is an issue affecting the trust in New Zealand produce as a CoO, producers can still point to their certified label to tell consumers that their product is trustworthy.

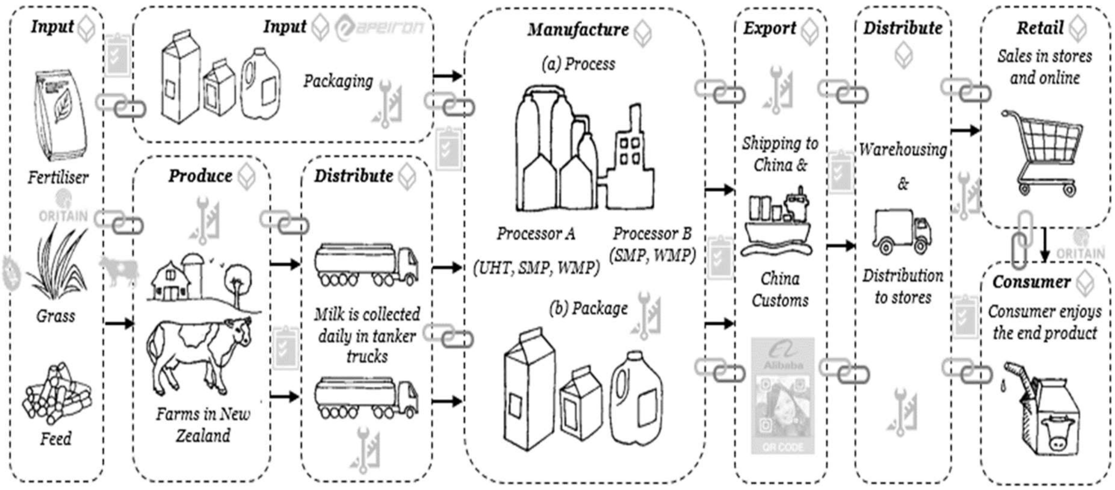
Firms' choice of using CoO or a group's certification will ultimately be a business decision for each firm. This will depend on the strength of New Zealand as a CoO brand in different markets, the risk of reputation being lost by another New Zealand producer and the associated costs and benefits associated with certification. How much New Zealand producers rely on the public good aspects of trust through country-of-origin and how much they rely on club good aspects of trust through certification schemes is an interesting question for further study.

Models of food trust inside value chains

Of the four kinds of value described earlier, consumers need reassurance about the trustworthiness of three of the types of value: product value, process value and emotive value. Here we consider how food trust relates to authenticating the integrity of the three relevant types of value. How different firms manage, demonstrate and communicate food trust will depend on their role in the value chain.

A typical value chain will have a wider variety of participants who add value at each step of the production of a final food product: input suppliers, producers, distributors, manufacturers, exporters, retailers and finally consumers. We illustrate an example of the stages of value chains using New Zealand milk being sold in China in Figure 3 below. Here, we examine how four main players fit with food trust.

Figure 3. Example value chain for milk exports from New Zealand to China



Producer

For the producer, demonstrating product value and process value is key. They have to demonstrate the quality of their product (product value). Where once product value alone was sufficient, process values such as environmental sustainability and animal welfare are now also being demanded by many consumers. Industry bodies and processors are often developing their own authentication systems for producers to demonstrate that they are meeting the expected standards of food safety, sustainability and animal welfare amongst other values.

Manufacturer

Manufacturers are expected to demonstrate food safety most of all. As the point in the value chain where ingredients are aggregated and combined, the risk of compromise to food safety is high. Accordingly, demonstrating how food safety risks are managed is most important for manufacturers. Robust processes and third-party assurance can provide the confidence to other value chain participants that manufacturer risks are being effectively managed.

Exporter

Exporters trade on process values and emotive values in addition to product value. This link is where New Zealand's brand as a clean, green country can provide value. In some countries, judgments about environmental factors in production have contributed to perceptions about food safety. This works in New Zealand's favour given the country's reputation as clean and green. However, process values and emotive values such sustainability and country-of-origin need to be backed up and verified as accurate or they can lose their power.

Retailer

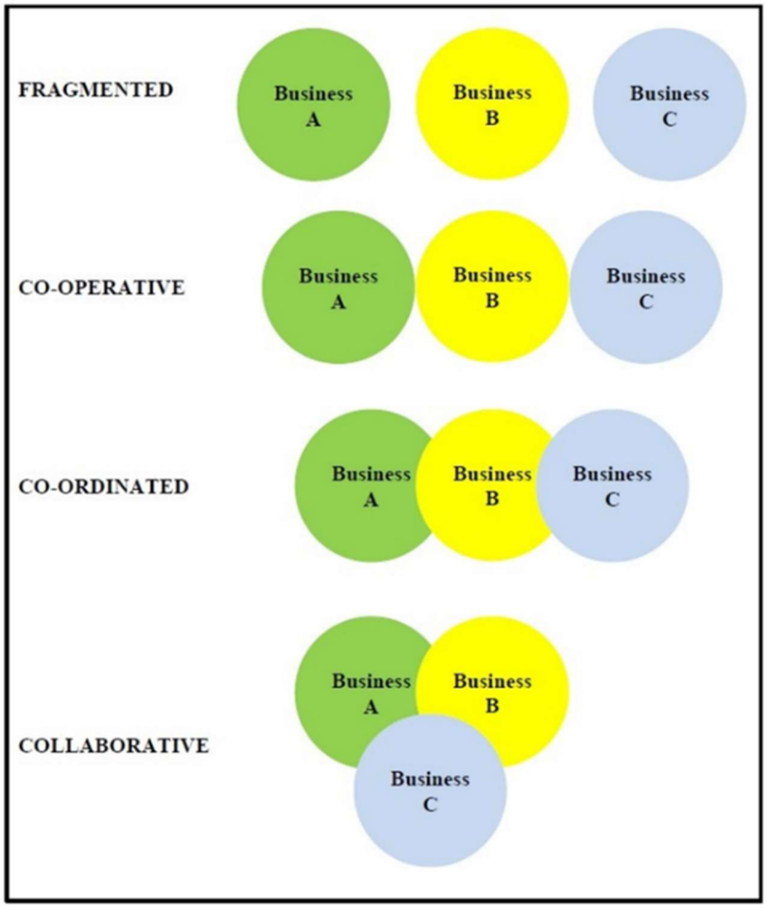
Retailers play a key role in value chains in receiving information from final customers about what they value and in transmitting information from the rest of the value chain. This information about the individual values and types of value customers most require is essential for other actors in the value chain. How and whether this information is communicated back through distributors, exporters and manufacturers to producers will determine how responsive a value chain can be to consumer preferences.

For credence attributes to be useful they must be communicated to the consumer. As the final actor in the value chain, retailers also play a vital role in communicating with consumers about a product's properties including its credence attributes.

Types of value chains

How food trust operates will also depend on the type of value chains a particular business operates in. The Value Chain Management Centre (2012, cited in Saunders et al., 2016, p. 10) describes a typology of value chains categorised into four types as illustrated in Figure 4.

Figure 4. Different types of value chains



Source: Adapted from Value Chain Management Centre (2012, p. 9) by Saunders et al. (2016, p. 10).

Fragmented

In a fragmented value chain, companies typically compete on a traditional footing. Relationships are principally contractual based on price, volume and quality. There is the bare minimum of information sharing between operators and no operational interdependency. Information sharing is minimised as companies fear insights about their operations will be used against them. Food trust is principally managed through contractual standards but visibility of processes will often be low.

Cooperative

In a cooperative value chain, operators share some information about themselves and their forward planning to better align their activities. However relationships are still principally contractual and there is the minimum interdependency between companies. Similar to fragmented value chains food trust is principally managed through contractual standards, however there may be scope to demonstrate the robustness of a company's process to assure food trust.

Coordinated

In a coordinated value chain, businesses are beginning to share information and work together for mutual gain over the short- to medium-term. This sharing goes beyond mere operational information to a common strategy. Businesses develop relationships beyond those as counterparties to contracts and have trusted relationships with long-term suppliers and buyers. These relationships allow opportunities for wider information sharing and some common use of resources and allows interdependencies to develop. In addition to managing food trust through contractual standards, shared processes can be developed and communicated to reassure other participants in the value chain that food trust risks are being properly managed.

Collaborative

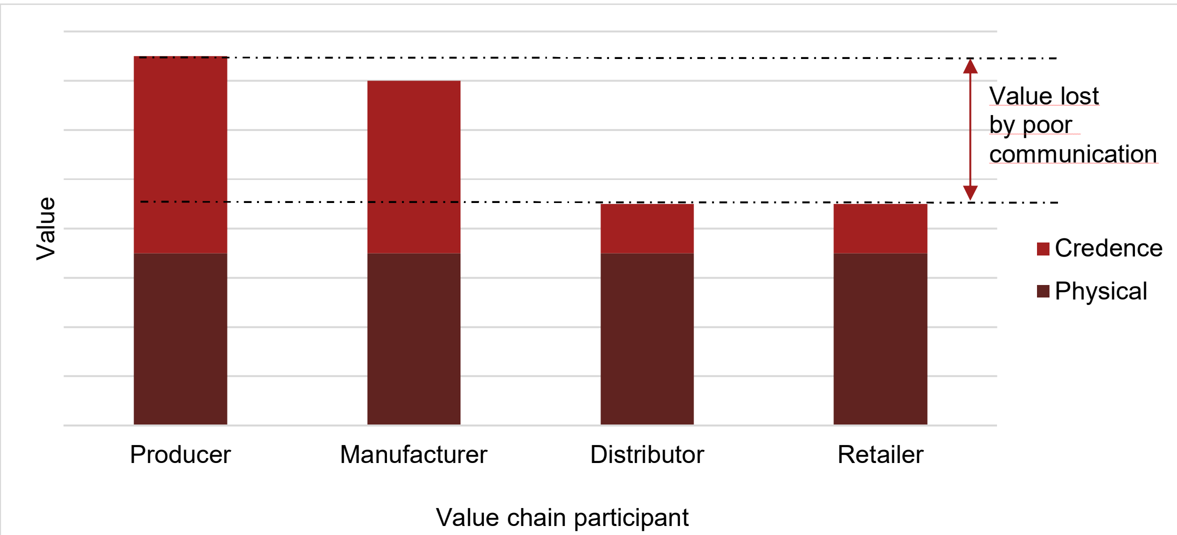
In collaborative value chains, businesses work together for their common benefit. There is significant sharing and interdependency of resources and information. These operations tend to span the whole value chain, bringing together producers, manufacturers, wholesalers and sometimes retailers. The sharing of information and collaborative control allows a whole-of-system approach to managing food trust risks. Over and above systems in place, collaborative value chains reduce food trust risk as each participant in the value chain shares the risks and rewards of the whole value chain, so are properly incentivised to minimise shared risks. The shared risks and rewards promotes investment in trust as a club good.

Communication through value chains

Credence attributes can support New Zealand primary producers to capture greater value. However, this value can be lost where credence attributes are not communicated to the consumer in a valid, verifiable and consumer-friendly way. Where credence attributes are not adequately communicated to the final consumer, their value is lost and the value returned to producers drops back to the minimum that is communicated. Figure 5 below illustrates this lost value. It shows the value, from both credence attributes and physical properties, that is maintained through different stages of a value chain moving from left to right. Through poor communication much of the value of credence attributes is lost between the manufacturer and distributor stage. An example of this in practice would be if free range eggs were mixed with battery farmed eggs.

To capture the maximum value, producers will need to communicate about the credence attributes in their products and target consumers who will pay a premium for those attributes. Part of that communication will be focused on the food trust associated with New Zealand's credence attributes, underpinned by new technologies. This communication can be either direct from producer and manufacturer to the consumer, circumventing other parts of the value chain, or it can be passed through all the links of the chain.

Figure 5: Illustration of value lost through the value chain



Communicating food trust

Producers, manufacturers and other value chain participants will communicate food trust differently depending on whether they see it as a club good or a public good. Firms that view food trust as a club good are more likely to invest in authentication systems to help them stand out from the field and reap the benefits of credence attributes and to avoid any fallout from issues that arise with firms that rely on country-of-origin branding. Firms that view food trust as a public good will rely on collective credence attributes such as CoO. These firms rely more on the public resource of New Zealand's reputation. Common resources such as trust can be overused and depleted if not managed carefully. Firms that rely on CoO branding that suffer from food safety issues or issues with fraudulent labelling tarnish the New Zealand brand for all firms that use it.

The club good approach using authentication systems and labels involves a greater upfront cost and investment, but offers a form of reputational insurance against other firms tarnishing the New Zealand brand. The authentication mark allows firms to distinguish their product as in a different category to other New Zealand produce.

Users of either approach need to communicate the credence attributes they are using, whether they be common pool attributes (eg CoO) or club good attributes (eg organically certified). There are a set of technologies that support communicating these credence attributes to consumers and building trust with consumers. These technologies are divided into primary technologies and secondary technologies:

- **Primary technologies** provide assurance that robust information has been generated at the producer stage and verify that it is accurate throughout the value chain. Primary technologies include audit systems, and communication and traceability technologies.
- **Secondary technologies** exist as a fall-back mechanism where information chains are broken and a response is needed to determine the origins or credence attributes of a product retrospectively. Secondary technologies require investment in order protect the New Zealand's reputation as a CoO (this idea is discussed in more detail in chapter 3, *Isotope testing and value authentication*).

Below we present blockchain as an example of a primary technology that can be used to support the transmission of robust information throughout value chains. Chapters 2 and 4 consider primary technologies and authentication system in further detail.

Blockchain

Blockchain is one example of a new technology that can provide assurance and demonstrate food trust. Blockchain is a cryptographic technology for building and sharing a secured ledger of transactions. It has the potential to change the way traceability and food trust is managed. Several large food companies are beginning to use blockchain to manage information about their food inputs and processes.

The strength of blockchain as a secure record lies in two key features, including that the:

- inherent difficulty in tampering with or falsifying transactions ensures the ledger's accuracy
- distributed nature of the ledger means it is difficult to bring down or corrupt.

Blockchain does not require a central authoritative record or a trusted third party. Rather, it uses an agreed set of rules that all by which system users must abide. New blocks of transactions submitted to the network must be validated and agreed by the whole network. This is computationally simple and many distributed agents independently check the validity of new records, making it very difficult for an agent to create a false ledger. Each agent on the network has a complete record of the whole chain, so to disseminate a false set of records would require falsifying records of many different independent agents.

Additionally, blockchain is very secure and it is very difficult to make a false record appear valid. Blockchain uses cryptographic techniques to digitally sign sets of transactions (in blocks) and links them together using their unique digital signature. Blocks of transactions are laid down in the sequence in which they are validated, and each new block includes the signature of the previous block. The strength of the system lies in the difficulty of changing the record retroactively. The 'hash' (the digital signature) for a block will be very different if any of the data used in the block is changed, and this includes the hash for the previous block. So to alter a record of transactions earlier in the chain would require new hashes for all subsequent blocks to be calculated. The rest of the network will be able to immediately see that all these values have been changed and can reject the change. To back-calculate valid transaction data that would result in the same digital fingerprints as the existing record becomes exponentially more difficult as more blocks are added.[1]

Figure 6 illustrates how this works using Bitcoin as an example. Bitcoin transactions are taken together as a new block and someone on the network validates that they are allowed. They add their own fee (prescribed in Bitcoin's rules) with the hash from the previous block (hashes represented here as fingerprints). This is used to create a new unique hash for the new block and the block is added to the chain and broadcast to the rest of the network. The rest of the network can see that the new block complies with the rules and update their record of the ledger accordingly. The signature of the new block will go on to become part of the next block. In this way a chain is formed that is very difficult to corrupt or falsify.

[1] Hashing algorithms are designed to be very easy to calculate in one direction but nearly impossible to calculate in reverse.

Figure 6. Illustration of blockchain process using Bitcoin

Source: Bits on blocks (Lewis, 2015)

Blockchain has been used predominantly in cryptocurrencies like Bitcoin, but its applications go much wider than that. Its potential to be used to enhance traceability in value chains is seeing it used by many large food companies such as Nestlé, Unilever and Walmart to enable them to trace contaminated products.

With this system in place, if an issue of contamination is traced to a batch of shellfish, investigators could scan the packaging and quickly learn where it came from and where the rest of that batch went. Affected retailers can quickly remove contaminated products, containing the spread of illness while having confidence they are removing only the contaminated product. In this way blockchain has the potential to revolutionise food trust by providing a much greater depth of traceability in complex and interlinked food manufacturing systems.

Blockchain can help producers to shift the trust in their products to that of a club good by excluding others. The blockchain assures the integrity of the value chain of only their product, so even if scandals affect other New Zealand producers, consumers have reason to trust in their particular value chain. By providing visibility of the entire value chain, producers are able to support consumers' trust in credence attributes associated with their products and capture a greater share of total consumer value. The traceability blockchain assists with trust in process and product values, and the link back to primary producers supports the narratives underpinning emotive values.

By supporting the use of credence values, blockchain can help New Zealand producers capture greater value from value chains.

Conclusion

Food trust is an essential element of modern agricultural value chains. As consumers, regulators and businesses have access to ever greater amounts of information, they are demanding more reassurance that they can trust in the food products they are being provided. Credence attributes – the aspects of food products that consumers buy based on trust – are particularly affected by these changes.

New Zealand food products have a high potential value from credence attributes. By enhancing the value New Zealand producers capture from credence attributes, OLW can support its mission to improve economic returns from agriculture while reducing impacts on the environment. To capture those returns, credence attributes will need to be communicated to the consumer in a valid, verifiable and consumer-friendly way.

There are new technologies emerging – like blockchain and others described later in this report – that support all participants in value chains to communicate and verify the value associated with their products to the end consumer. Technologies exist as well to detect food fraud and fill information gaps when issues arise and New Zealand's reputation is threatened.

Digital media and smart technologies for assuring sustainability

Contributor: Timothy Driver, AERU, Lincoln University

Introduction

In recent years there has been increasing use of digital media and smart technology by consumers and those in the value chain for accessing information and purchasing goods.[2] This has been facilitated by greater international access to consumer technology, such as home computers and internet access (OECD, 2015). There has been a significant rise in the use of mobile devices (eg smartphones) internationally, thereby creating a commercial environment in which most consumers have near-continuous access to the Internet. This enables the ability to acquire product information and make purchases without the restriction of a physical wired Internet connection. Increased consumer use of mobile devices has enabled the development and use of marketing, finance and commercial activities specifically for mobile device application (Andrews, Goehring, Hui, Pancras, & Thornswood, 2016; Dahlberg, Guo, & Ondrus, 2015; Gao, Rohm, Sultan, & Pagani, 2013; Kaplan, 2012; Strom, Vendel, & Bredican, 2014). Reflecting this, many of the technologies examined later in this chapter require interaction with smartphones to function.

This signals an important new paradigm in consumer technology use that could be considered in order to achieve maximum value for products. These technologies have enabled consumers to engage in the market in novel ways to obtain information and purchase products, as they enable information flows up and down the value chain and assist in the distribution and sales of goods. In particular, these technologies can be used by consumers to authenticate claims regarding product attributes, including the credence attributes of products. Credence attributes are qualities of a product that cannot be seen or directly experienced at the point of purchase, such as animal welfare or environmental impacts of production (Saunders, et al., 2015). Previous work undertaken by the AERU has shown that international consumers prefer and are willing to pay for a range of credence attributes in food and beverage products, such as food safety and traceability (Guenther, Saunders, Dalziel, Rutherford, & Driver, 2015; Miller, Driver, Velasquez, & Saunders, 2014; Saunders, et al., 2015). These attribute claims can be either validated or enhanced by the implementation of technology in the value chain.

In addition, these technologies can communicate various types of value to the consumer, including product, process, location and emotive value (Saunders C. , et al., 2016). It is also important to consider the types of value chains that each form of digital media and smart technology is most suitable for, including fragmented, cooperative, coordinated and collaborative value chains (Value Chain Management Centre, 2012).

Due to increased consumer use of digital media and smart technologies, there is an increasing need for firms in the value chain to understand how consumers use novel and existing technologies. In response to this, the following review is primarily focused on consumer attitudes to, use of and trust in digital media and smart technology, with particular emphasis on the agri-food value chain. While the operational nature of these technologies is also highly important, the following review is largely concerned with consumer trends and the implications of these for firms in the value chain.

This chapter examines consumer and firm attitudes to, preferences for and use of digital media and smart technology in the value chain. This includes the use of social media, mobile apps, QR codes, RFID/NFC chips, Bluetooth Low Energy Beacons and blockchain. It also includes the results of a study conducted by the AERU examining international consumer use of digital media and smart technology in relation to food and beverage product information gathering and purchasing (Driver, Saunders, Guenther, Dalziel, &

[2] Digital media refers to any type of communication that is digitally encoded (e.g. text, audio, video), while smart technology refers to electronic communication devices typically used for accessing information. Examples of these include electronic commerce (e-commerce), social media and mobile devices (such as smartphones).

Rutherford, Maximising Export Returns (MER): The use of digital media and smart technology in shopping and information gathering for food and beverages in markets relevant to New Zealand, 2015).

E-commerce

One type of digital media with high relevance to agri-food value chains is electronic commerce (e-commerce). E-commerce has been defined as "an online forum for the exchange of value" (Urbaczewski et al., 2002, as cited in Siddiqui & Raza, 2015). E-commerce can be classified as one of several types (Peet, 2000):

- **business-to-business (B2B)** – businesses trading goods and services with each other
- **consumer-to-consumer (C2C)** – consumers trading goods and services with each other
- **business-to-consumer (B2C)** – businesses selling to consumers
- **consumer-to-business (C2B)** – consumers selling to businesses.

Examples of online C2C marketplaces include eBay or New Zealand's TradeMe (eBay, 2017; TradeMe, 2017). The most relevant type of e-commerce for value chains is B2C e-commerce, which became commercially viable in the 1990s following the development and improvement of the Internet. This review is primarily focused on B2C e-commerce.

Multiple types of B2C e-commerce retail channels are currently in operation internationally. Firms may choose to operate purely e-commerce-based retail channels, selling their products exclusively online. Alternatively, firms may take a multichannel approach whereby a brick-and-mortar (i.e. physical) retailer may also have an online store (Siddiqui & Raza, 2015). In addition, brick-and-mortar retailers may also provide a "brick-and-click" retail channel, whereby consumers can purchase products online for home delivery or collection in-store (Campo & Breugelmans, 2015). These retail channels can also often be accessed via mobile devices (known as mobile commerce or m-commerce) (Chong, Chan, & Ooi, 2010). The provision of dual channel or brick-and-click e-commerce services may increase value for brick-and-mortar retailers, as food and beverage consumers (particularly in the premium segment) may prefer the experiential attributes of physical retailers over online alternatives, such as inspecting food and beverage products personally prior to purchase (Canavan, Henchion, & O'Reilly, 2007).

Notable examples of popular international B2C e-commerce websites include Amazon and Alibaba. Amazon is an US-based international B2C e-commerce company with multiple subsidiaries, including several category-specific e-commerce websites (e.g. books) and premium subscription media streaming services (Amazon, 2017a). Amazon is also becoming an increasingly influential company in the food and beverage value chain, having acquired U.S. grocery retailer Whole Foods Market, reducing product prices on multiple food items in retail outlets (Thomas, 2017). In addition, Amazon operates its own food and beverage retail and distribution subsidiaries, including grocery e-commerce site AmazonFresh and restaurant food delivery service Amazon Restaurants (Amazon, 2017b; Amazon, 2017c). In particular, AmazonFresh offers home delivery of groceries purchased using the service, including AmazonFresh Pickup, whereby premium subscribers can order groceries online to be collected at a physical outlet at a predetermined time (Amazon, 2017d). As at December 31st 2016, Amazon's net revenue was valued at US$13.66 billion, with net sales valued at US$43.8 billion in Q4 of 2016 (Amazon, 2017e).

Similarly, Alibaba Group is a Chinese e-commerce company with multiple subsidiaries operating worldwide. These include C2C website Taobao, wholesale trade website Alibaba.com and B2C websites AliExpress and Tmall.com (Alibaba Group, 2017a). In particular, Tmall.com and its offshoot company Miao Fresh sell food and beverage products to Chinese consumers, including meat, fish, dairy, fruit and vegetable products, many of which are specifically listed as imported products (Miao Fresh, 2017; Tmall.com, 2017). As at August 17th 2017, Alibaba Group's net revenue was valued at US$7.4 billion in Q2 of 2017, with approximately 446 million active consumers using Alibaba Group's e-commerce services over the previous 12 month period (Alibaba Group, 2017b).

The antecedents of consumer uptake and continued use of e-commerce are diverse. In particular, this includes factors relating to the content and delivery of e-commerce services, and demographic factors. Studies have shown that the perceived ease of use and usefulness of e-commerce services are important antecedents of e-commerce uptake and use (Ashraf, Thongpapani, & Auh, 2014; Bodini & Zanoli, 2011). In particular, this includes website design and information provision (Bodini & Zanoli, 2011; Chen, Hsu, & Lin, 2010; Clemes, Gan, & Zhang, 2014; Khare, 2016; Wu, Chen, Chen, & Cheng, 2014), product availability and variety (Clemes, Gan, & Zhang, 2014; Nagar, 2016), product and service quality (Clemes, Gan, & Zhang, 2014; Gehrt, Rajan, Shainesh, Czerwinski, & O'Brien, 2012), convenience (Clemes et al., 2014; Jiang et al., 2013; Khare, 2016; Yeo et al., 2017) and price (Clemes et al., 2014; Yeo et al., 2017). Wu et al. (2014)

found that reducing the time cost of information searching on e-commerce platforms can positively influence consumer repurchase intention for these services.

One of the key barriers to higher consumer uptake and use of e-commerce (as identified by current international literature) is trust (Chen et al., 2015; Ha and Stoel, 2009; Mortimer et al., 2016) and aversion to the perceived risks of online shopping (Chaparro-Pelaez et al., 2016; Quevedo-Silva et al., 2016). This includes risk factors such as the potential for reduced product quality, increased price and items not being delivered (Ariff et al., 2014; Pi and Sangruang, 2011), as well as concerns regarding the privacy and security of personal and financial information (Clemes et al., 2014; Ha and Stoel, 2009; Pi and Sangruang, 2011). Demographic factors, such as age and gender, have also been shown to influence consumer trust in online shopping services (Lian and Yen, 2014; Wu et al., 2010). There are also differences in consumer attitudes to and preferences for e-commerce across countries, suggesting that cultural context is an important factor for firms considering e-commerce applications (Ashraf et al., 2014; Brashear et al., 2009; Sakarya and Soyer, 2013; Smith et al., 2013). Furthermore, Maity and Dass (2014) found that consumers may also prefer particular tools for using e-commerce (e.g. personal computer/laptop or mobile device), with consumers preferring to carry out more complex purchase decisions on personal computers and less complex purchase decisions on mobile devices.

However, trust in e-commerce may be more important in relation to initial uptake rather than continued use. Kim et al. (2012) found that perceived trust in an online shopping service had a stronger effect on consumers with little prior experience with online shopping than those who had previously used online shopping services. The authors suggest that online retailers should focus on increasing consumer trust in e-commerce services over price promotions. Similarly, Mortimer et al. (2016) found that the perceived risk of an online shopping service has a stronger mitigating effect on repurchase intentions for infrequent over frequent online shoppers.

It is therefore important to consider antecedents of consumer trust in e-commerce. The previous studies suggest that familiarity and more frequent use of e-commerce has a positive effect on consumer trust in e-commerce (Kim et al., 20120; Mortimer et al., 2016; Quevedo-Silva et al., 2016). In addition, Ha and Stoel (2009) found that positive consumer perceptions of the service quality of an e-commerce website may positively affect consumer trust in the service. Similarly, Tsao and Tseng (2011) found that e-commerce service quality has a positive effect on web brand equity, which in turn can reduce risk perception and increase consumer value and service adoption. Thakur and Srivastava (2014) found that higher levels of personal innovativeness are likely to have a positive effect on the mitigation of risk perception of, as well as a direct positive effect on, e-commerce adoption. Wu et al. (2010) found that consumers' adoption of e-commerce was based on more hedonistic values, with personal values relating to openness to change and self-enhancement likely to positively impact e-commerce adoption and use.

Siddiqui and Raza (2015) conducted a literature review examining research relevant to e-commerce supply chains published spanning the years 2000-2015. The authors found that, of 167 papers reviewed, most examined the technical elements of e-commerce supply chains (80), followed by organizational (65) and economic (12) research perspectives. In addition, the most frequently examined topics included electronic supply chain modelling/design/implementation (42), followed by innovation/adoption/barriers (30) and supply chain integration/collaboration (28). Only 1 paper directly examined agri-food supply chains, with most examining general supply chains (80), manufacturing (32) and retail & wholesale (18). Siddiqui and Raza (2015) thereby clearly outline a gap in the academic literature examining the implementation of e-commerce activities specific to agri-food supply chains.

Vaneslander et al. (2013) outline a cost analysis of commonly used supply chains for grocery e-commerce. As previously mentioned, e-commerce operations can be complex, comprising purely online, brick-and-click and multichannel retail. These operations often employ "last-mile" delivery – usually the final logistics stage in the supply chain wherein goods are received by the consumer. For purely online retailers, the most common last-mile delivery methods are van delivery and parcel delivery. Van delivery is carried out using retailer-owned vehicle fleets delivering products directly to consumers following the transfer of products from suppliers to dedicated distribution centres. Parcel delivery is the same as above, however a secondary delivery firm is used to transport products from the retailer's distribution centre to consumers. For brick-and-click retailers, the most common last-mile delivery method is van delivery, whereby products are delivered to retail distribution centres by suppliers before being stocked in retail stores, from which consumers can opt to have products delivered or collected in-store. The authors find that last-mile delivery often constitutes the highest cost of any logistical stage of the supply chain, representing as high as 50 per cent of total supply chain cost. This cost can be mitigated with increased delivery density (e.g. the total number of delivery locations in proximity to each other) (Vaneslander et al., 2013).

Social media

Social media is a collective term used to refer to online platforms which involve elements of community, content creation and sharing (Merriam-Webster, 2017). Examples of social media with widespread popularity (as of April 2017) include Facebook (1.97 billion total users), Twitter (319 million total users) and Instagram (600 million users) (Statista, 2017). All social media services have different modes of operation, thereby requiring specific approaches (de Vries et al., 2012). Kaplan and Haenlein (2010) outline four major types of social media:

- collaboration projects (such as Wikipedia)
- blogs or microblogs (such as Twitter)
- content communities (such as YouTube)
- social networking sites (such as Facebook).

Brands have increasing established a presence on a range of social media websites. This is to provide consumers with customer service, product information and promotional materials, as well as build relationships with wider communities. In addition, as each type of social media is different in its operation, it requires different approaches from firms operating brand pages. Generally speaking, consumers are able to subscribe to a brand's page (such as "liking" it on Facebook), allowing them to see public posts from that brand in a personalised feed combining all other pages that the consumer has subscribed to (Beukeboom et al., 2015). It is therefore important to consider consumers' attitudes to brands and their activities on social media.

In response to this, many studies have examined consumer attitudes to brands on social media, showing a range of determinants. Akar and Topcu (2011) examined consumer attitudes to social media marketing, finding that frequent users of social media show a negative attitude to social media marketing compared with infrequent users. They also found that higher levels of family income were associated with greater positive attitudes to these activities. Demographic factors affect consumer attitudes to firm interaction on social media. Several studies have indicated that differences in social media use exist between different countries, suggesting that a specific approach may be required when engaging in geographically specific social media marketing activities (Berthon et al., 2012; Minton, 2013; Pookulangara and Koesler, 2011). Furthermore, social media may act as a complimentary rather than alternative channel to traditional and online media, particularly for consumers with a higher inclination towards multichannel media use (Kuttschreuter et al., 2014).

Social media can be a useful tool in enhancing consumer trust in brands. Habibi et al. (2014) examined the effects of relationships within brand communities (e.g. groups of consumers with similar preferences for particular brands engaged in socialisation) using social media on brand trust. The study found that social media positively influences consumer relationships with brands, products and companies, thereby enhancing brand trust (Habibi et al., 2014). Another study found that brand pages on social media share the characteristics of real-world and other online brand communities (Rosenthal and Brito, 2017). Boerman and Kruikemeier (2016) examined consumer attitudes to promoted tweets (e.g. paid advertising on Twitter) from brands and political parties. The authors showed that, in general consumers rarely notice that a tweet has been promoted using paid advertising mechanisms, but where they recognise this they express different attitudes for brands and political parties. For political parties, consumers recognised this as advertising material, responding with lowered trust in and increased scepticism towards the party, as well as an intention to not share the post. For brands, however, consumers recognised this to be advertising material but did not experience a decrease in trust towards brands (Boerman and Kruikemeier, 2016).

Social media has set in motion a shift in power from the firm to the consumer, allowing the consumer to participate in, and sometimes determine, the discourse of brand communications. Several studies have highlighted that the ability of companies to directly engage their customers has led to the involvement of the consumer in the storytelling process of the company or product (Singh and Sonnenburg 2012, Kaplan and Haenlein 2010, Hanna et al. 2011). One factor that illustrates this shift and has the potential to alter consumer attitudes towards brands and/or firms is electronic word of mouth (eWOM). It has been noted that within many virtual communities, eWOM is a major means of communication between participating individuals (Gupta and Harris, 2010; Gruen et al., 2006).

Previous research has suggested that eWOM has a considerable influence on product perception and consumer choice (Gupta and Harris, 2010, Gruen et al, 2006), for example, amongst consumers who want to make an informed purchase decision (Park and Kim, 2008). Doh and Hwang (2009) examined consumer interpretation of eWOM messages, finding that while positive eWOM generally positively influenced consumer attitudes towards products, including purchase intention, the presence of solely positive eWOM messages decreased the perceived credibility of the information, suggesting that the inclusion of some negative eWOM may be beneficial in improving consumer trust in overall eWOM content.

Furthermore, some studies have examined the determinants of consumer eWOM generation. Chu and Kim (2011) found that the strength between, and trust in the information provided by, social media users had a direct positive effect on intention to engage in eWOM activities. Wang et al. (2016) also found tie strength to be a determinant of eWOM activity, while trust did not exert a significant influence on this behaviour. Chu and Sung (2015) found that Twitter users with higher relative social influence, positive attitudes towards brands, heavier use of Twitter and higher brand engagement are most likely to tweet (e.g. communicate directly with) brands using this service. Boerman et al. (2017) examined the effects of sponsored posts on consumers' desire to endorse pages on Facebook, finding that the use of sponsored posts by brand pages on Facebook can decrease consumers' intention to engage in eWOM about brand page posts (Boerman et al., 2017). Liu et al. (2017) investigated strategies used by Fortune 500 companies in order to encourage the generation of positive eWOM for their companies on Facebook. These companies published posts employing one or more of three main concepts to engage with consumers for this purpose: 1) vividness – the richness of sensory experience of published posts; 2) interactivity – the degree to which consumers could interact with posts, and; 3) emotional appeal – posts that infer an emotive or symbolic association with products/companies. The study found that posts with higher vividness and/or emotional appeal were more effective in generating consumer eWOM behaviour than the interactivity of the post, with vividness enhancing emotional appeal (Liu et al., 2017). There is also some evidence suggesting that eWOM indicators (such as star ratings and consumer reviews) can be used to determine future trends in firm profitability (Tang et al., 2016).

With regards to brand endorsement via eWOM, Bernritter et al. (2016) showed that consumers are more likely to endorse particular non-profit and for-profit brands on social media that have greater perceived "warmth" (based on a consumer tendency to anthropomorphise brands), with non-profit brands experiencing easier consumer endorsement than for-profit brands (Bernritter et al., 2016).

The brand-consumer dynamic that is facilitated by social media requires firms to adopt a two-way communicative strategy in order to better leverage value. The ability of firms to interact directly with consumers using social media, as well as the consumer's ability to create content relating to companies, brands and products, means that the consumer is able to generate marketing material, rather than simply observe it (Berthon et al., 2012; Gensler et al., 2013). In addition, the presence of a human conversational voice representing brands on Facebook has been shown to positively correlate with increased positive brand evaluations and purchase intention by consumers (Beukeboom et al., 2015), suggesting there is a need for brands to maintain two-way communication on social media.

The approach taken by firms regarding their relationship with consumers may also affect the ways in which they use social media. Ryden et al. (2015) found that firm managers with a traditional approach to the business-consumer relationship (e.g. selling *to* consumers) use social media purely as a tool to increase sales, while firms managers with a more communal orientation (e.g. selling *for* consumers) use social media as a strategic tool for collaboration, treating consumers as active participants in their business processes.

The two-way communicative nature of social media, if not carefully managed, can also lead to 'social media crises', wherein consumers publically express negative sentiment towards firms and brands on social media, thereby affecting wider public perceptions of the firm/brand (Gregoire et al., 2015). For example, Peng et al. (2015) examined the effects of micro-blog use on public opinions towards food safety incidents and its related products in China. Following a food scare involving yogurt products in 2012, influential users of micro-blog service We-Media disseminated opinions regarding this event, which were then forwarded across the service by other micro-blog users. This resulted in the large-scale public dissemination of information to the Chinese public, signalling that this form of information proliferation could ultimately negatively affect brand reputation and sales volumes. This indicates that social media can be used by consumers to influence wider public opinion regarding food products. Peng et al. therefore argue that it is important to outline strategies to mitigate negative response prior to the establishment of a company or brand social media presence (Peng et al., 2015).

The potential for social media to be used for food risk and benefit communication is significant. This is due to factors such as its speed, accessibility and interactive elements in communication information (Rutsaert et al., 2014). However, the use of social media for crisis communication requires careful management and higher investment in order to mitigate risk. These risks can include damages to reputation and brand image (Roshan et al., 2016), and can be caused by factors such as a propensity for the spread of misinformation, lack of trust and risk of information overload (Rutsaert et al., 2013; Rutsaert et al., 2014).

The use of social media to mitigate food crises can be seen in the British Food Standards Agency's (FSA) reaction to the "Horsegate" food safety incident of 2013. In order to mitigate negative response during the incident, the FSA used their social media outlets to communicate with concerned consumers regarding food safety and/or ethical issues. In particular, the most ubiquitous platforms were used by the FSA (Facebook and Twitter), in addition to other online communication channels (e.g. FSA website, email updates). In addition, the FSA developed mobile "apps" to assist in the dissemination of timely information. Through the use of these platforms, the FSA was able to successfully manage consumer expectations of government responsiveness and promote a positive behavioural outcome from the events, while simultaneously developing a sense of the public outcry and monitoring the situation from a social angle. In this sense, the use of social media channels was used effectively to mitigate some public concern regarding food safety issues within the UK food chain (Panagiotopoulos et al. 2013). Similarly, a study of by Gaspar et al. (2014) found that during a foodborne E. coli outbreak in 2011 in Europe, Spanish consumers used Twitter to seek and provide information regarding the outbreak (by finding information provided by involved agencies or communicating possible strategies to avoid illness), as well as to communicate their feelings regarding events associated with this. The findings of this study suggest that consumers may use social media during food crises as a means of coping with the current situation, as well as providing and receiving assistance in relation to these events (Gaspar et al. 2014).

As a secondary benefit to firms, the use of social media can also provide market intelligence to firms in the value chain. This is useful as marketers are able to directly track a significant amount of information regarding consumer response to brands in real-time using social media metrics and analytics, such as text mining (Carr et al., 2015; He et al., 2013; He et al., 2015; Hogg, 2010; Peters et al., 2013). This can be seen in the application of social media information for purposes such as product development (Bashir et al., 2017; Carr et al., 2015). However, while it has high potential as a source of market intelligence, information derived from social media is currently used as an informal source of intelligence, with large firms preferring to employ external research and development organizations to gather market information (Bashir et al., 2017). In addition, there may be barriers to information disclosure on social media, with consumer concerns regarding the privacy of information and intensity of social media use affecting this. However, increased trust in social media can effectively mitigate this concern (Lin and Liu, 2012).

There is some literature available examining the attitudes of firms to social media use. Alarcon-del-Amo et al. (2016) examined Spanish exporters' attitudes and behaviour in relation to social media, showing that firms' beliefs regarding the effectiveness of social media for managing foreign customers affects adoption rates of social media. In turn, a greater importance is placed on the use of social media the more a firm relies on exports for continued business (Alarcon-del-Amo et al., 2016).

It has also been proposed that the analysis of social media data can lead to improvements in supply chain management. Singh et al. (2017) examined the analysis of Twitter data for the purpose of improving Taiwanese beef supply chain management practices, employing text mining and sentiment analysis to determine broad consumer response to beef products internationally. The analysis identified a number of consumer satisfaction issues in the international beef supply chain, including bad flavour and unpleasant smell, traceability issues, extra fat, discolouration of beef products, hard texture and presence of a foreign body in beef products. The researchers were then able to identify at which stages of the supply chain it was likely that these issues could occur (Singh et al., 2017). However, it is currently unclear as to whether this type of analysis can be employed by individual firms or applied to specific products within the value chain.

Social media is a significant communication tool for firms in the value chain as it can transmit many types of value to the consumer. This could include product, process and location value. Firm use of social media can also transmit emotive value to consumers through the publication of materials that associate brands and products with emotive and symbolic meaning, such as using graphical/design devices or celebrity endorsements (Liu et al., 2017).

The use of social media may also be useful in the establishment and development of relationships between firms, including improving information sharing, collaboration and operational processes, leading to increased firm efficiency and innovativeness (Drummond et al., 2017; Lam et al., 2016). This suggests that social media may act as an enabler of greater value chain collaboration. Therefore, while it is possible for social media to be used by any type of firm in the value chain, its use is more suited to co-ordinated and/or collaborative value chains.

State of current technology

Technology can provide multiple benefits across all stages of the value chain. This includes technologies such as mobile applications (apps), quick response (QR) codes, radio-frequency identification (RFID) and Near Field Communication (NFC), Bluetooth Low Energy (BLE) beacons and blockchains. These technologies primarily assist in the provision of additional information regarding product provenance, physical characteristics and credence attributes, and can therefore be used by consumers to authenticate product claims.

Apps

The widespread use of smartphones has led to the development and dissemination of mobile applications (or "apps"). Mobile apps are defined as "end-user software applications that are designed for a cell phone operating system and which extend the phone's capabilities by enabling users to perform particular tasks" (Purcell et al., 2010, as cited in Kim et al. 2013). These tasks can include mobile banking, accessing maps and finding locations, searching for product information and purchasing products online (Kim et al., 2013). Mobile apps provide a number of benefits to consumers, including the provision of information, entertainment, social inclusion and credibility enhancement (Alnawas and Aburub, 2016). Mobile apps are also used to communicate the authenticity of products to consumers.

The popularity and versatility of this technology has led to firms developing their own branded mobile apps (Kim et al., 2013). Various studies have shown that consumer use of branded mobile apps can increase interest in brands and associated product categories (Bellman et al., 2011). In addition, several consumer benefits derived from the use of mobile apps (including information provision, social inclusion, personal connection and entertainment) can increase consumer satisfaction, ultimately leading to increased purchase intention (Alnawas and Aburub, 2016; Bellman et al., 2011; Kim et al., 2015). Furthermore, consumer purchase intentions also increase as their frequency of mobile app use increases (Kim et al., 2015; Wang et al., 2015).

There are several examples of mobile apps that present information obtained across the value chain regarding the provenance of and processes associated with agri-food products. Examples relating to wine products include Vivino and Wine-Searcher – apps which interact with wine product labels to provide users with more information regarding the products. Vivino is an app that allows the user to take a photo of a wine label, prompting information about that product to be displayed to the consumer. This includes product ratings and reviews, average prices, tasting notes and food pairings, information regarding its type and provenance, as well as the option to purchase the product and have it delivered to a home address. The app also tracks and saves a list of previously scanned or purchased wines, and is available for iOS and Android operating systems (Google Play, 2017a; iTunes, 2017a). Similarly, Wine-Searcher allows the user to take a photo of a wine label to display further information about the product, including its provenance, price and purchase locations (Google Play, 2017b).

Other examples of mobile apps which interact with products include the Vision module of Samsung's Bixby app, currently available for the Samsung Galaxy S8 smartphone. This app allows the user to take a photo of a product (including food products) to display further information (such as provenance and ratings/reviews) and purchasing options. Bixby Vision also allows the user to quickly scan QR codes (discussed later in this chapter) to access more information about products (Bohn, 2017; Samsung, 2017). In addition, the Pinterest Lens app (available for iOS and Android) integrates the above interactive abilities with the social media service Pinterest, allowing the user to identify real-world objects. Users take a photo of a real-world object (which can include food products), which is then identified with a series of keywords, which are then used to search for similar images on Pinterest. Users are then able to purchase related products found using the service (Newton, 2017; Pinterest, 2017).

As shown above, mobile apps are most useful in communicating process and location value to consumers. This is particularly important as these devices can be used to obtain more information about and purchase products. While mobile apps can be used by less connected value chains, they are more likely to be effective if employed within more connected value chains.

Quick Response codes (QR codes)

Another vehicle for product claim verification is the QR code. The appearance of the QR code is similar to the barcode, but differs in its square shape and "pixelated" appearance (comprising a series of smaller black squares within the centre of the larger boundary square). Like 1-dimensional barcodes, the QR code is "scanned" using a laser or camera (e.g. smartphone), which then automatically directs the internet browser of the smartphone to a specific web address wherein product information can be stored. QR codes have also been internationally standardised via the International Standards Organisation (ISO/IEC 18004). Other types of 2-dimensional codes (similar to QR) that are currently in use include Data Matrix, Aztec and EZ codes (Ebling 2010). The potential applications of 2-dimensional code technology are broad, with one potential application pertaining to a mobile tagging system for the identification and provision of information regarding genetically-modified food (Shiang-Yen et al. 2013).

Multiple studies have examined the feasibility of using QR codes in traceability systems for the dissemination of supply chain information to consumers. These have found QR codes to be cost-effective, efficient and valuable in communicating meaningful information to the consumer, as well as generally positively influencing purchase decisions (Appelhanz et al., 2016; Bradu et al., 2014;), provided that consumers find QR codes useful, entertaining and easy to use (Kim and Woo, 2016; Ryu and Murdock, 2013). In addition, the provision of product information via QR codes can also increase positive consumer perceptions relating to food product safety, quality and sustainability attributes (Dopico et al., 2016).

There are several examples of QR code-based systems currently in operation to communicate the authenticity of products to consumers. Authenticateit™ is an anti-counterfeit product identification app (available for iOS and Android) that allows users to scan a barcode, QR code or DataMatrix code of a product (including food products) to allow the user to verify if a product is genuine or not (Google Play, 2017c). As at September 2017, Authenticateit™ has partnered with 23 companies (including 17 food companies) (Authenticateit, 2017a), with preliminary evidence that the use of these systems has increased sales for participating companies (Authenticateit, 2017b). In addition, New Zealand government certification body AsureQuality has partnered with Authenticateit™ for their inSight™ programme, which requires participating agents to undergo audits to verify product credentials. Users then use their mobile device to scan inSight™-labelled products, thereby displaying information regarding the provenance, process and other credentials of the product (AsureQuality, 2017).

Consumer use of QR codes varies between markets. To determine common uses of QR codes internationally, Lerner et al. (2015) analysed logs of QR code scans, providing an overview of total QR code scans for 241 countries. Their analysis shows a diversity of geographical regions exhibiting the highest rates of QR code scanning, with Taipei exhibiting the most QR code scans over a 10 month period (approximately 1.46 million scans), followed by Hong Kong (approximately 757 thousand scans) and Moscow (approximately 436 thousand scans). Their analysis also showed high rates of QR code scanning occurring in a diverse range of cities in Asia, Europe and North America (Lerner et al., 2015).

Recent evidence has suggested that QR code use is particularly popular in China. This is driven by an increasing consumer use of cashless digital payment systems and virtual shopping (as discussed below), known as offline-to-online (O2O) commerce. “Offline” QR codes are presented to the consumer (visually displayed either in a retail setting or on advertising and promotional materials), which are scanned using a smartphone to provide an online link to an e-commerce platform. QR codes are also displayed on many Chinese e-commerce websites, as well as used in product authentication schemes to prevent counterfeiting (Loras, 2015).

As discussed above, QR codes can also be used by consumers to directly purchase products via O2O commerce applications. Such an example is UK retailer Tesco’s South Korean arm HomePlus’ use of “virtual shops” in 2011. HomePlus used a consumer-facing poster-based advertising campaign to promote online shopping via smartphone interaction. Placed in prominent public spaces, such as underground train stations, the poster campaign featured the display of a life-sized supermarket shelf, on which items faced towards the train platform, constituting a “virtual store”. Consumers used their smartphone to scan a QR code affixed to the picture of each product, adding items to a virtual shopping cart via the HomePlus smartphone app or mobile website. Following the submission of payment information and the completion of the online sale, deliveries of the selected items would be made to the consumers’ specified address, allowing for a less time-intensive grocery shopping experience. Through the use of this campaign, total sales increased by 130 per cent for HomePlus, and registered users of HomePlus online shopping increased by 76 per cent (Solon, 2011; The Telegraph, 2011).

Therefore, the use of QR codes for accessing verification systems and online shopping by consumers is effective in transmitting product and process value to the consumer. In addition, due to being highly effective in traceability systems, QR codes are most useful in transmitting location value to the consumer. As with mobile apps, QR codes can be used in less connected value chains, but are likely to work more effectively in more collaborative value chains.

Radio Frequency Identification (RFID)

The use of microchip-based identification systems can be beneficial in providing assurance information to the consumer. This includes radio-frequency identification (RFID) chips, as well as consumer technologies such as Near Field Communication (NFC). RFID is a small microchip containing information which is read using a scanner (i.e. an RFID “reader”), similar to that used for scanning barcodes (Abad et al., 2009). NFC chips are smaller than RFID and designed for two-way communication between electronic devices, with NFC readers commonly installed in many modern smartphones (Badia-Melis et al., 2015).

Several experiments have tested the effectiveness of RFID in providing traceability information along the supply chain, finding RFID to be highly effective in recording and transmitting actual whole chain traceability information (Abad et al., 2009; Alfian et al., 2017; Jakkhupan et al., 2015; Kelepouris et al., 2007; Musa et al., 2014; Parreno-Marchante et al., 2014; Sun et al., 2007). RFID can provide traceability to the paddock through the use of RFID animal tags, allowing for traceability to the individual animal level (Bai et al., 2017; Sun et al., 2007). This has also been tested successfully in a New Zealand supply chain context for beef, venison and velvet products (Clarke, 2015; Hartley, 2013; Hartley and Sundermann, 2010). RFID functionality can also be expanded with the inclusion of additional devices, such as environmental sensors (e.g. temperature and humidity) to assist in assuring food safety credentials of products along the supply chain (Abad et al., 2009). Experiments have signalled RFID to be a highly effective means of tracking environmental conditions (such as temperature and humidity) thereby ensuring food safety and freshness (Abad et al., 2009; Alfian et al., 2017; Bibi et al., 2017; Chen et al., 2014). This has been tested successfully in tracking food safety information along the entire supply chain, including the end consumer (Liu et al., 2016).

RFID technology has also been shown to improve supply chain management practices. In particular, this includes improvements in inventory management, cost reduction, increased data accuracy, improved information sharing and increased overall performance (Rundh, 2008; Sarac et al., 2010; Tajima, 2007; Vlachos, 2014). Chen et al. (2013) found that in the implementation of RFID systems in the supply chain could improve total operation time by 81 per cent, showing return on investment for RFID implementation. Similarly, Qian et al. (2012) found that while RFID implementation in wheat supply chains increased overall costs by 17.2 per cent, sales income associated with its use increased by 32.5 per cent. There is also evidence that the application of product-level RFID can assist retailers in reducing inventory inaccuracies, providing stocking information, higher labour productivity and assist in product pricing initiatives (Cui et al., 2017; Kim et al., 2008; Liu et al., 2007; Shin and Eksioglu, 2015).

While RFID can provide high levels of information, it has relatively higher implementation costs than other technologies such as QR codes – however, these costs are expected to decrease over time (Abad et al., 2009; Bottani and Rizzi, 2008; Qian et al., 2015; Rundh, 2008). There is also a potential for loss and/or corruption of data held in RFID chips, however this can also be mitigated through the use of data mining techniques (Alfian et al., 2017). In addition, compared with other established systems, RFID technology may not be as readily available to firms in the supply chain, thereby imposing a barrier in technology sourcing (Costa et al., 2013).

It is also useful to examine current firm attitudes to and determinants of RFID adoption in the value chain. Park et al. (2010) examined South Korean and U.S. firm attitudes to RFID technology, finding similarly positive attitudes, particularly for its use in distribution and supplier networks. Pedroso et al. (2009) examined the determinants of RFID adoption by 57 large-scale Brazilian companies, with the major motivations of adoption including increasing efficiency and reducing costs (84.2 per cent), improving client service (54.4 per cent), integrating suppliers and clients (35.1 per cent), implementing new processes or business models (35.1 per cent) and an opportunity to try out the technology (22.8 per cent). By comparison, major reasons for not having an RFID initiative in place included a lack of financial resources (54 per cent), the immaturity of the technology (46 per cent), lack of adequate RFID applications (26 per cent) and a lack of knowledge regarding RFID (11 per cent) (Pedroso et al., 2009).

For consumers, RFID/NFC technology provides a multitude of benefits. The use of RFID technology along the supply chain and NFC technology at the point of sale allows consumers to use their smartphones to potentially view logistics and other information pertaining to products from producer to retailer, thus providing whole chain traceability (Badia-Melis et al., 2015). This can be achieved with the inclusion of RFID in product packaging, which could communicate information such as product expiry dates (Grunow and Piramuthu, 2013). One method by which this can be achieved is through the implementation of RFID/NFC in product packaging, such as intelligent packaging, which in combination with additional sensors can detect the incidence of freshness and/or food safety credentials in packaged food products (Ghaani et al., 2016; Vanderroost et al., 2014). However, consumer trust and acceptance of RFID/NFC should also be considered before implementation. For example, Chrysochou et al. (2009) identified several barriers to consumer RFID/NFC use, including trust and privacy concerns (such as personal data breaches), health concerns and the perception of additional cost (Chrysochou et al., 2009).

Sari (2010) found that the adoption of RFID technology in a supply chain may encourage greater degrees of collaboration between firms, with the benefits of RFID use intensifying in line with collaboration intensity. In addition, Fosso Wamba et al., (2008) found that in order to gain benefits from RFID implementation in the value chain, broad strategic management is required – particularly, a greater degree of collaboration between firms in the value chain. This suggests that not only can RFID facilitate value chain integration, its benefits may be shared and strengthened given greater collaboration between participating firms.

Bluetooth Low Energy (BLE)

BLE Beacons are a relatively new technology which has seen some application in the value chain in recent years. BLE Beacons are devices comprising a small computer and Bluetooth radio transmitter which can communicate with smartphones via Bluetooth. Applications of this technology include proximity-based communication (e.g. connecting with user at a particular location) and indoor location services (e.g. assisting the user to find a particular location). Variations of this technology include the iBeacon – Apple's own distribution of the technology (Newman, 2014).

Due to the location-based nature of this technology, BLE Beacons have been mostly integrated with retail environments thus far. This technology allows retailers to communicate with customers via their smartphones within a physical retailer, transmitting personalised promotional materials, loyalty programmes, optimising the in-store experience, as well as allowing the customer to purchase products directly via their smartphone (Dudhane and Pitambare, 2015). However, it should be noted that consumers may have concerns regarding the privacy of their personal information when using BLE Beacons (Newman, 2014). In addition to consumer-facing applications of this technology, some feasibility studies have shown that BLE beacons can be applied by retailers to assist in inventory management and performance assessment systems (Dudhane and Pitambare, 2015; Ramakrishnan et al., 2016).

As previously mentioned, BLE Beacons specifically transmit location value to the consumer, but may also be useful in providing additional product and process information. In addition, due to their localised application, they are most suited to be used by retailers.

Blockchain

Blockchain is a data transaction system whereby modifications of data are combined to create a "block" of information (see pages 11-12 of this report). This is then encrypted (securely encoded) to ensure that no further modifications of information can take place within the block. This information forms a "chain", allowing participants to view all changes of information dating back to the first transaction. This system was originally designed for use with digital cryptocurrency (e.g. bitcoin) to allow for more secure transactions between actors. However, it has recently been considered for applications beyond this. The use of blockchain systems in the value chain allows for the integrity of information to be retained along the chain without the need for intermediaries to verify claims. This can enhance trust between the points of the value chain regarding product provenance and history, providing a more complete and reliable traceability record (Pisa and Juden, 2017).

There are several examples of value chain-focused blockchain verification systems currently in operation. BlockVerify is an anti-counterfeit programme aimed at providing verification of product authenticity for a number of product types, including pharmaceuticals, luxury items, diamonds and electronics. Products are labelled with a BlockVerify tag, which uses blockchain technology to provide an encrypted permanent history of the provenance of the products. Retailers and consumers are able to verify the authenticity of participating products through the use of mobile devices (e.g. smartphones) (BlockVerify, 2017). Similarly, Provenance is an authentication scheme which verifies the origin of a range of products using blockchain technology. Producers and businesses sign up to the programme online, uploading assurance and other supply chain-related information for their products. Each product is then given a unique identifier code which can be searched for by consumers using the Provenance website. This can include the addition of a QR code and/or RFID/NFC tag in product packaging. As of September 2017, over 200 food and beverage producers and retailers are using this service to securely verify product claims (Provenance, 2017). Other examples of blockchain verification systems currently in operation include SKU Chain (aimed at facilitating transactions between firms in the value chain) and Hijro (a verification system designed to improve the efficiency of supply chain operations (Hijro, 2017; SKU Chain, 2017).

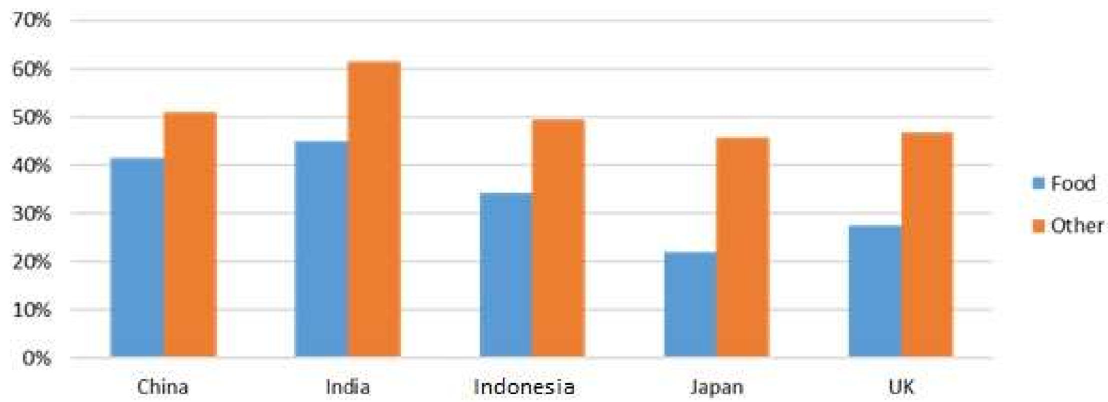
Due to the security of information transfer in blockchain verification systems, it can be trusted as a technology enabling reliable authentication of product claims. In addition, blockchain is capable of retaining and disseminating significant volumes of information, thereby potentially transmitting product, process and location value to the consumer. Furthermore, due to the nature of secure information transfer in blockchain verification systems, this technology can be used by any type of value chain, provided that firms are cooperative in their provision of information. However, it should be noted that consideration of the application of blockchain technology in the value chain is a relatively recent development, and there is comparatively little known regarding consumer attitudes to its use.

Consumer preferences for and use of digital media and smart technology in the value chain

In order to determine consumer use of technology with regards to food and beverage shopping, the Agribusiness and Economics Research Unit (AERU) conducted a study of five international markets important to New Zealand known as Maximising Export Returns (MER). The study examined consumer uptake and use of digital media and smart technology in relation to food and beverage shopping, surveying approximately 1,000 consumers in each of the following countries – China, India, Indonesia, Japan and the United Kingdom. In particular, the study examined the use of electronic commerce (e-commerce), social media, mobile devices and apps, barcodes/QR codes and microchip reading technology (such as RFID/NFC) (Driver et al., 2015).

The AERU's MER Programme examined international consumer use of e-commerce, particularly in relation to food and beverage purchasing. The study asked international consumers to indicate which percentage of their regular shopping for food and beverage products and other products was carried out online. Overall, participants indicated that they used online shopping for a much higher percentage of products other than food and beverages, with consumers in developing countries (China, India, Indonesia) using online shopping for a higher percentage of their regular shopping than their developed country counterparts (Japan and the United Kingdom). These results are shown in Figure 7.

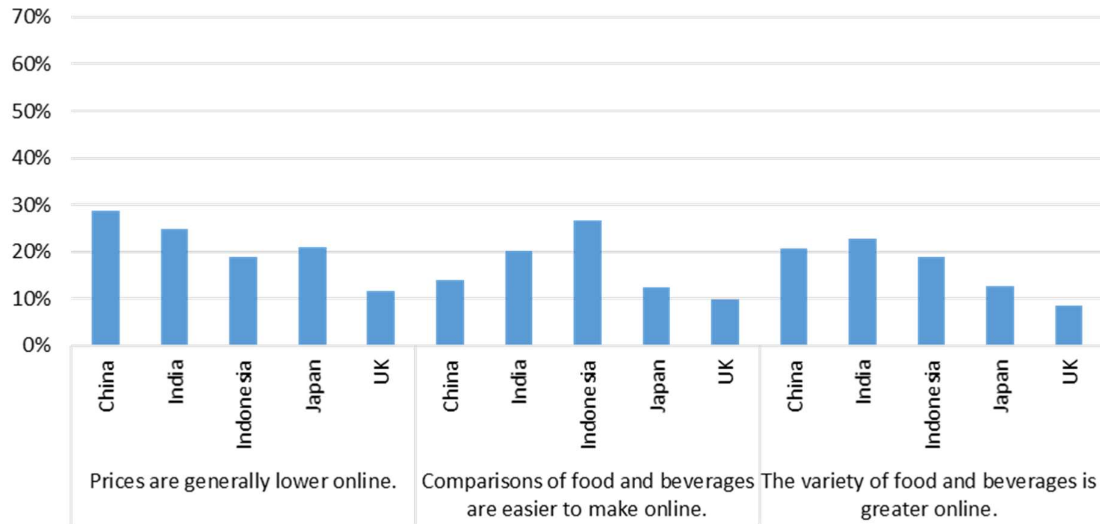
Figure 7. Percentage of shopping done online, by type



Source: Driver et al, 2015.

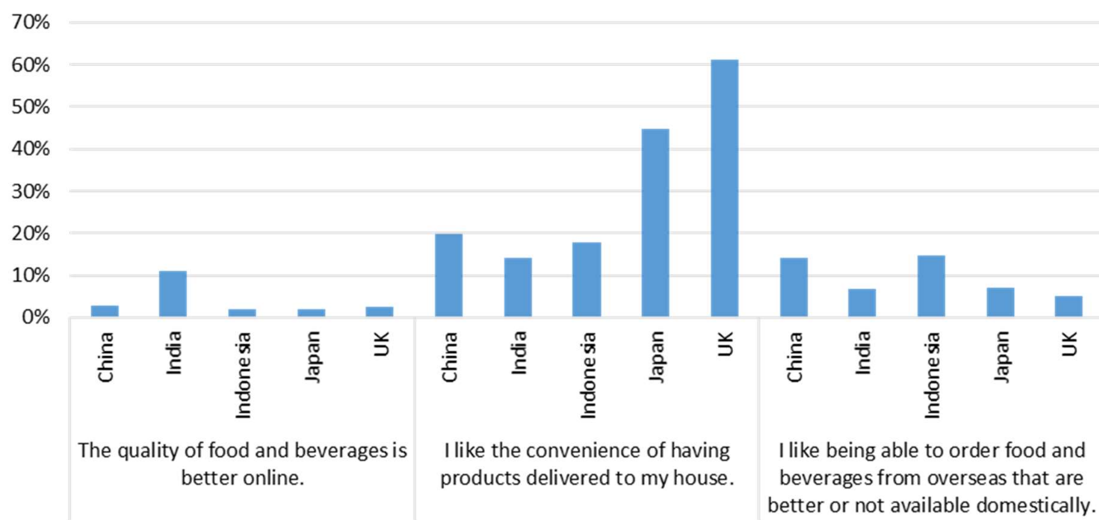
In addition, participants were asked to indicate their main reasons for shopping online from the following options: that prices are generally lower online; comparisons of food and beverages are easier to make online; the quality of food and beverages is better online; the variety of food and beverages is greater online; the convenience of having products delivered to their house; and the ability to order food and beverages from overseas that are better or not available domestically. The results presented in Figure 8 and 6. Reasons for using online shopping services varied between countries. Cross-country comparison showed that, for Chinese and Indian participants, generally lower prices online was the top reason for using online shopping. This was followed by a greater variety of food and beverage products and the convenience of having products delivered. Conversely, the ability to make easier comparisons between products online was the top reason for using online shopping as stated by Indonesian participants, followed by generally lower prices and a greater variety of products available. In contrast, participants from the developed countries of Japan and the UK indicated that the convenience of having products delivered was the top reason for shopping online, followed by generally lower prices and a greater variety of products available online.

Figure 8. Reasons for shopping online (1)



Source: Driver et al, 2015.

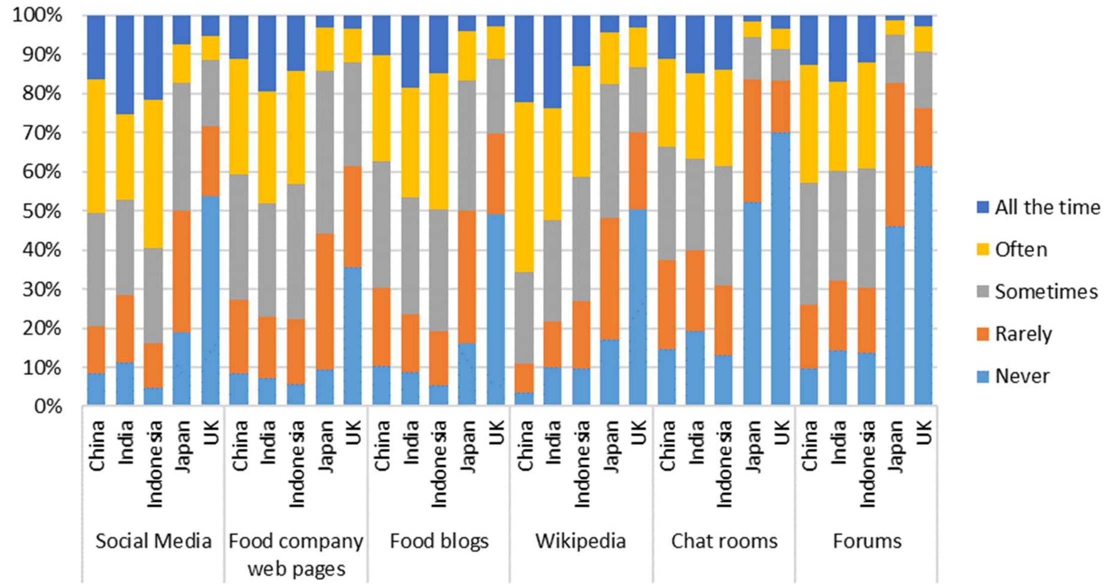
Figure 9. Reasons for online shopping (2)



Source: Driver et al, 2015.

The AERU's MER Programme examined consumer use of social media in relation to information gathering for food and beverage products. Participants were asked to indicate the frequency at which they used specific types of websites (including social media, food company web pages, food blogs, Wikipedia, chat rooms and forums) to search for information on food and beverages. These results are shown in Figure 10 below. The highest usage in terms of searching for information on food and beverages that was claimed by participants in all countries was social media. In particular, Indonesian participants indicated the highest use of social media sites for this purpose (22 per cent all the time, 38 per cent often), followed by Chinese (16 per cent all the time, 34 per cent often) and Indian participants (25 per cent all the time, 22 per cent often).

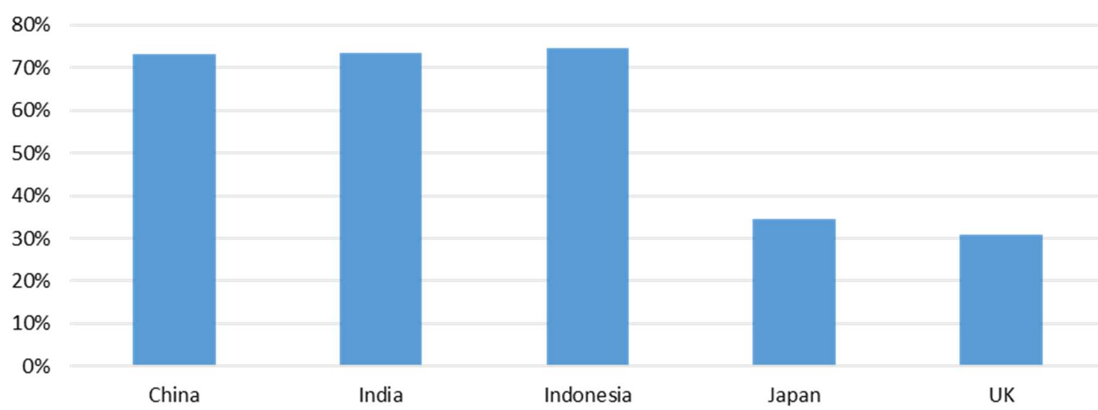
Figure 10. Website types used to search for information regarding food and beverages



Source: Driver et al, 2015.

The MER Programme also examined consumer use of smart technology (e.g. smartphones) in food and beverage information gathering and purchasing behaviour. In particular, when participants were asked to state if they had ever used a mobile app to find out more about food and beverages, results showed a clear distinction between the developing countries and the developed countries (see Figure 11). While more than 70 per cent of respondents in each of China, India and Indonesia stated that they have used a mobile app for obtaining more information on food and beverages, only a third of UK and Japanese respondents claimed to have ever used an app for this purpose.

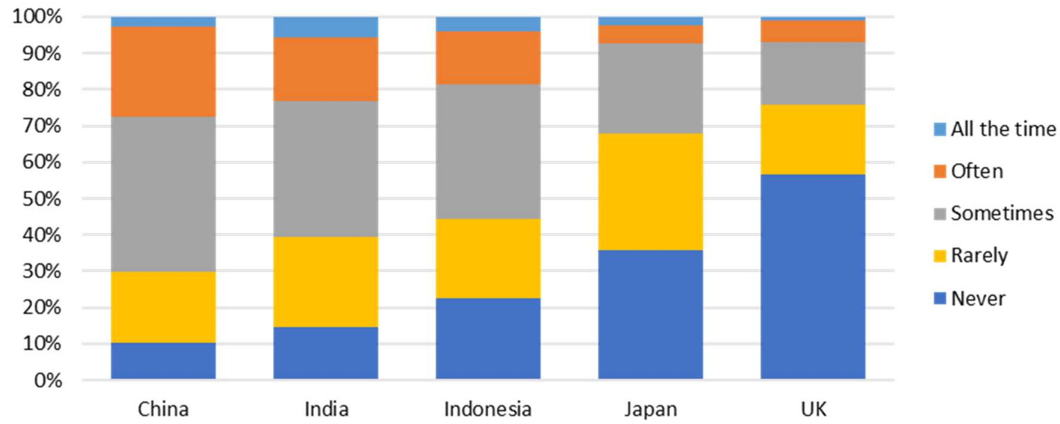
Figure 11. Mobile apps used for obtaining information on food and beverages (per cent responding yes)



Source: Driver et al, 2015.

The next question asked participants to indicate (on a five-point Likert scale ranging from *all the time* to *never*) the frequency of their mobile device usage to purchase food and beverages. As shown in Figure 12, participants from China, India and Indonesia indicated an overall higher frequency of use than those from the UK and Japan. The usage of a mobile device for online purchases was particularly frequent in China (25 per cent *often*), followed by India (17 per cent *often*) and Indonesia (15 per cent *often*). Participants from the UK indicated the lowest frequency of use of mobile devices to purchase food and beverage products (57 per cent *never*).

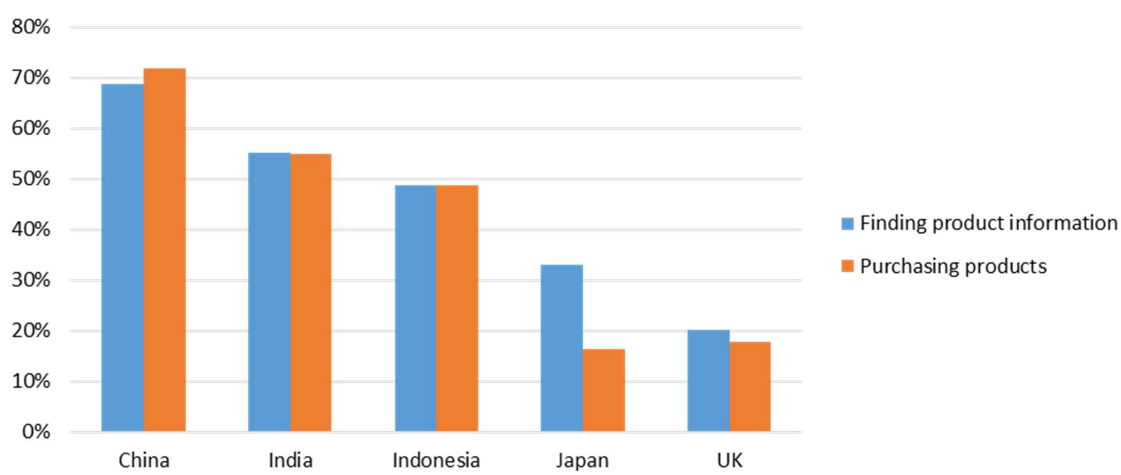
Figure 12. Use of mobile devices for purchasing food and beverages online



Source: Driver et al, 2015.

Then participants were asked if they used their mobile device(s) in conjunction with barcodes and/or QR codes for finding more information about and/or purchasing food and beverage products. For information gathering, this was most frequently undertaken by Chinese (69 per cent) and Indian participants (45 per cent), as shown in Figure 13. In contrast, the majority of respondents from the UK and Japan stated they had never used their mobile device in conjunction with barcodes and/or QR codes for the purpose of finding more information about food and beverages. For purchasing food and beverage products, the majority of Chinese and Indian participants stated that they have used these for purchasing food and beverages while the majority of Indonesian, UK and Japanese respondents indicated they have not used their mobile devices in conjunction with barcodes and/or QR codes for food and beverage purchasing.

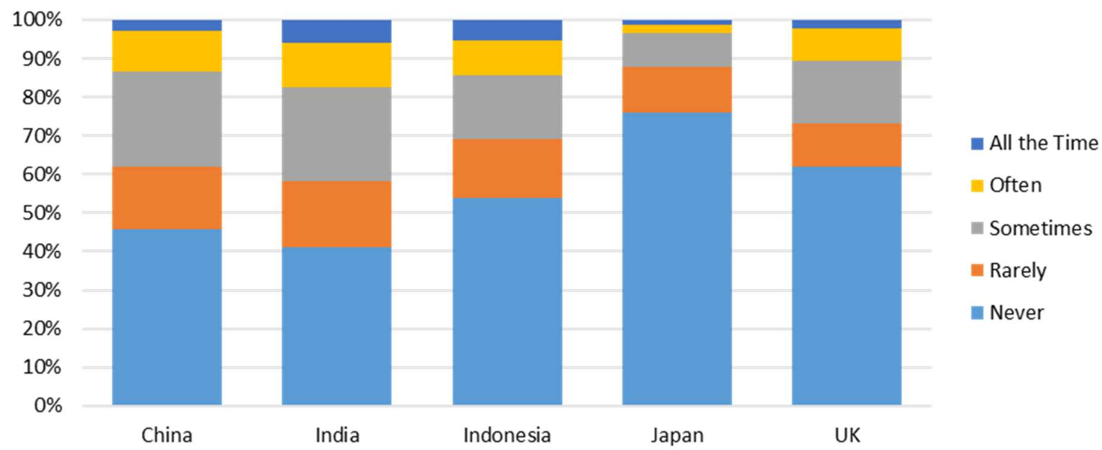
Figure 13. Mobile use in conjunction with barcodes and/or QR codes for searching for information about and purchasing food and beverage products



Source: Driver et al, 2015.

The AERU's MER Programme examined international consumer use of microchip reading technology (e.g. RFID/NFC) in relation to food and beverages. With regards to the frequency of use of microchip reading technology, Figure 14 shows that respondents from China, India and Indonesia have used this more frequently than participants from the UK and Japan. Indian participants indicated the highest rates of use (6 per cent *all the time*, 12 per cent *often*), followed by Indonesian (5 per cent *all the time*, 9 per cent *often*) and Chinese participants (3 per cent *all the time*, 11 per cent *often*).

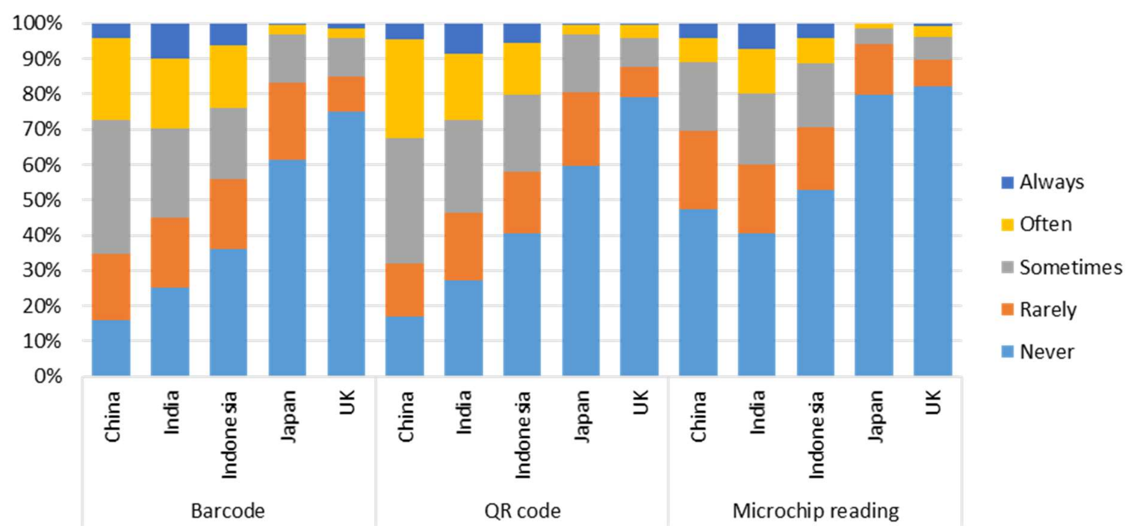
Figure 14. Use of microchip-reading technology



Source: Driver et al, 2015.

Importantly, this study asked participants to consider the frequency at which they used different types of smart technology (e.g. barcodes, QR codes and microchip reading technology) to verify the credentials of food and beverage products using a five-point Likert scale ranging from *always* to *never*. As shown in Figure 15, the greatest use of barcodes was shown by Indian participants (10 per cent *always* and 20 per cent *often*). In contrast, the use of QR codes for verifying food and beverages' credentials was more popular among Chinese respondents (4 per cent *always* and 28 per cent *often*). The majority of UK and Japanese respondents claimed to have never used a barcode (75 per cent *never* and 61 per cent *never* respectively) or QR code (79 per cent *never* and 60 per cent *never* respectively) to verify product credentials. The use of microchip reading for the credential verification had a lower uptake compared to QR codes and barcodes. Indian participants indicated the highest frequency of use of this technology (7 per cent *always*, 12 per cent *often*), followed by Indonesian participants (4 per cent *always*, 7 per cent *often*).

Figure 15. Verification of food and beverage product credentials via technology, by type

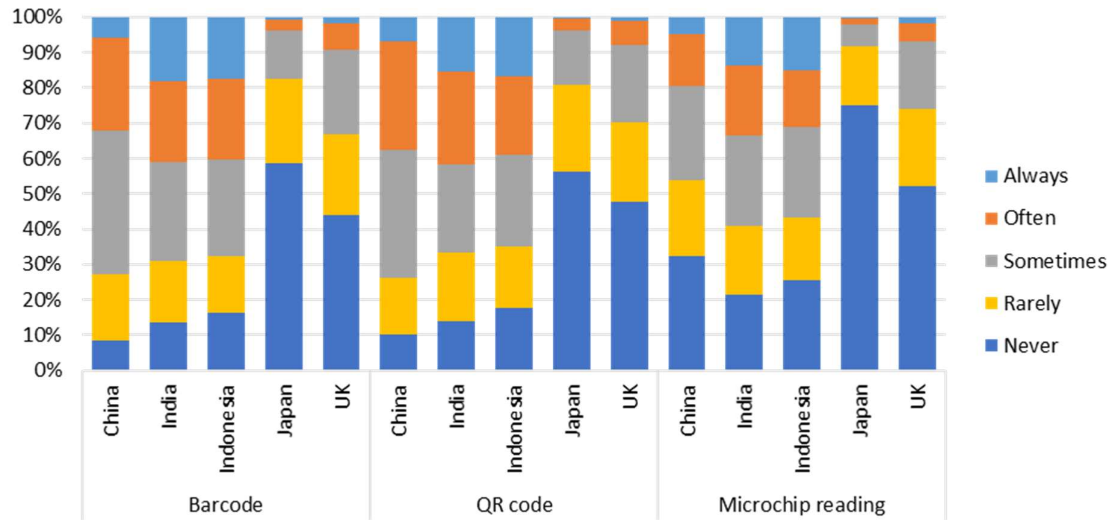


Source: Driver et al, 2015.

In addition, the study asked participants to indicate the frequency at which they would use the same technology for product verification if it was available. As shown in Figure 16, the intention to use these technologies if available is positive across all countries, with a more frequent intention indicated by participants from Indonesia, India and China than from the UK and Japan. In particular, the intended use of barcodes and QR codes was high in India and Indonesia with more than 15 per cent of participants indicating that they would use either of them always for verification of credentials of food and beverages if available. Results on respondents' intentions to use microchip reading technology if available showed a lower intended uptake by participants across all countries, with the highest intention to use signalled by

Indian (14 per cent *always*, 20 per cent *often*) and Indonesian participants (15 per cent *always*, 16 per cent *often*). The majority of Japanese and UK respondents indicated that they had no intention to use microchip reading technology for the verification of credentials of food and beverages if available.

Figure 16. Intended verification of food and beverage product credentials via technology, by type



Source: Driver et al, 2015.

Overall, the results of this study demonstrate that international consumers are engaging with technology in relation to food and beverage information finding and purchasing, and that these technologies are being used in this way more frequently and intensely by consumers in the developing countries. In particular, while current technology use for the verification of product credentials is low, intended use of these technologies is shown to be positive across all countries examined. This suggests that consumers are interested in using smart technologies to verify food and beverage product claims (Driver et al., 2015).

Conclusion

The widespread use of digital media and smart technology (such as social media and mobile devices) has led to an increase in its use in the value chain. Digital media and smart technology enable information flows and improve distribution in the value chain. Digital media and smart technologies have enabled consumers to engage in the market in novel ways to attain information and purchase products. This is important as effective two-way communication is key to the success of a market-oriented value chain.

As previously stated, the final consumers' willingness to pay for a product or service is the source of all value in the value chain. As consumers have exhibited preferences and increased willingness-to-pay for a range of credence attributes in food and beverage products, digital media and smart technology can be used to assure consumers of the validity of product claims.

International consumer use of e-commerce (primarily B2C) has led to multiple changes in traditional value chains. Online retailers are increasingly entering into grocery and food & beverage categories, such as US online retailer Amazon's acquisition of Whole Foods Market and establishment of its own-brand grocery delivery service AmazonFresh. In response to the increasing entry of online retailers into these categories, physical retailers have adopted new strategies, including online ordering, brick-and-click and multichannel approaches in order to retain market share. The antecedents of consumer uptake and use of e-commerce are diverse, with benefits including its perceived ease of use and usefulness, and barriers including trust and a lack of knowledge. Furthermore, while some research has identified key structures and elements of e-commerce supply chains, there is scope for further investigation.

Social media (such as Facebook, Twitter and Instagram) are used to communicate food product authenticity, with brands exhibiting an increased presence on a range of social media websites. While a range of factors influence consumer uptake and use of social media, such as demographic and preference factors, it is a useful tool for enhancing consumer trust.

Social media has set in motion to a shift in power from the firm to the consumer, allowing the consumer to participate in, and sometimes determine, the discourse of brand communications. The ability of companies to directly engage their customers has led to the involvement of the consumer in the storytelling process of the company or product, such as through the use of electronic word-of-mouth (eWOM). By allowing the consumer to create content relating to companies, brands and products, the consumer is effectively able to generate marketing material, rather than simply observe it. Considering this, this brand-consumer dynamic requires firms to adopt a two-way communicative strategy in order for firms to leverage value. If not carefully managed, this can also lead to 'social media crises', wherein consumers publically express negative sentiment towards firms and brands on social media, thereby affecting wider public perceptions of the firm/brand.

As a secondary benefit to firms, the use of social media can also provide significant volumes of market intelligence along the value chain, allowing firms to directly track consumer response to brands in real-time using social media metrics and analytics, such as text mining. The use of these intelligence gathering techniques has led to the ability of firms to detect consumer issues regarding food products and at which point in the value chain these issues are likely to first occur.

Social media use by firms in the value chain has also been shown to improve supply chain management practice and enhance the establishment and development of relationships between firms. This suggests that social media may act as an enabler of value chain collaboration.

Other types of technology, such as mobile apps, QR codes, RFID/NFC and blockchain, can assist in the provision of product provenance, physical characteristics and credence attributes information to the consumers, thereby authenticating product claims.

Mobile apps such as Vivino and Wine-Searcher allow the user to view product information regarding provenance and physical characteristics, as well as purchase products, while apps such as Bixby and Pinterest Lens interact with real-world objects, providing direct purchasing options for the consumer.

QR codes have been shown to be useful and effective in communicating product provenance and credence attributes information to consumers, particularly traceability information. Other schemes have allowed consumers to engage in "virtual shopping", wherein consumers can use their smartphone to interact with a virtual store-front and have products delivered to their homes.

The use of microchip-based identification systems (such as RFID/NFC) can be beneficial in providing provenance and other product information to the consumer, and can be implemented in the value chain to monitor food safety and environmental conditions (such as temperature and humidity). In addition, the employment of RFID systems in the value chain has been shown to encourage greater degrees of collaboration between firms, with the benefits of RFID use intensifying in line with collaboration intensity. This suggests that the benefits of RFID may be shared and strengthened given greater collaboration between participating firms.

Blockchain is a relatively recent technology to be applied to the value chain, providing a secure and traceable chain of information. The use of blockchain systems in the value chain allows for the integrity of information to be retained along the chain without the need for intermediaries to verify claims, thereby enhancing trust between firms. There are several examples of value chain-focused blockchain verification systems currently in operation, such as BlockVerify and Provenance, which provide authenticity assurance to consumers. These systems have also integrated QR codes and RFID/NFC.

The Agribusiness and Economics Research Unit (AERU) conducted a study of five international markets of relevance to New Zealand exporters (China, India, Indonesia, Japan and the United Kingdom) to determine consumer preferences for and use of the above digital media and smart technologies. This included the use of social media, mobile apps, barcodes/QR codes and microchip reading technology (RFID/NFC) for gathering information about and/or purchasing food and beverage products. In general, these technologies were used by participants in all markets, with higher use shown by those in developing countries than their developed country counterparts.

In particular, participants were asked to indicate to what extend they used barcodes, QR codes and microchip reading technology to verify the claims of food and beverage products. This showed mixed responses, with developing country participants generally indicating higher use. In addition, the use of microchip reading for product credential verification had a generally lower uptake compared to QR codes and barcodes. When asked to indicate to what extent they would use these technologies for verification purposes if it was available to them, intended use was comparatively positive across all countries.

As shown in this chapter, digital media and smart technologies provide an opportunity to leverage value in value chains, as well as a powerful medium for communicating with consumers. However, issues still remain, such as consumer trust in relation to the adoption of these technologies. This signals a possible future avenue for research in examining methods by which consumer trust in technology, as well as the information it provides, can be enhanced. In addition, while tools such as the blockchain show significant promise for application within the value chain as a means of enhancing consumer trust, there is relatively little current research examining this. This warrants further examination, particularly with regards to consumer understanding of and trust in blockchain technology. Furthermore, while consumer studies are plentiful in relation to technology use in the value chain, there is comparatively little regarding firms and their interactions via these technologies. A deeper examination of firm and inter-firm use of the above technologies in the value chain would therefore be useful.

Isotope testing and value chain authentication

Contributors: Karyne Rogers and Troy Baisden, GNS Science

Introduction

The technologies described in other chapters of this report convey trust across supply chains, but they can potentially be breached in most or all cases when packaging, tags or paperwork become separated from the product or when they are fraudulently modified. A number of technologies exist to measure properties of the food itself, as a direct means of assurance that food can be trusted as being authentic. These forms of technological assurance apply to *appellation or process value*, such as organically-grown produce, or *location value*, including New Zealand's products within Country-of-Origin Labelling (CoOL).

The scientific authentication and traceability tools that provide assurance of process and locational value are diverse and demand a high level of technical expertise. In some, but not all instances, they may require large infrastructure investment in instrumentation and development of mapping or information systems, and in validation of the techniques through scientific publications and peer review. For these reasons, we assume that the evolving methods to track and verify food along a supply chain, ranging from paper trails to QR codes and blockchain, can be considered as primary assurance technologies. We consider that authentication and traceability tools will be sought-after as secondary assurance technologies, and we introduce a framework to evaluate how and when to develop these tools to fill critical gaps in assurance.

Case studies provide scattered yet diverse examples capable of guiding the development of a framework for evaluating the potential gains from secondary assurance technologies, thereby providing direct assessment of authentication and traceability. We use four key examples:

- **Mānuka honey** provides an example of where the industry has achieved a remarkable level of product value despite significant market access issues around authentication and problems with an internationally accepted testing method in 2011.
- **Milk powder** is one of our biggest export products, yet has attracted negative attention over the years, particularly in China in 2008, due to adulteration and contamination of infant formula by melamine addition to improve the protein (nitrogen) content.
- **The common egg** can sell for up to three times more if it is labelled as organic or free-range. Recent fraud issues have been reported where higher value free-range eggs were substituted with cheaper barn or caged varieties both in New Zealand and overseas.
- **New Zealand's thriving wine industry** is currently in a high growth phase yet there is risk for wine to be mislabelled and blended with cheaper wines to improve yield and profit. This could cause uncertainty and distrust for consumers and disrupt overseas exports into China and other key markets.

At its heart, the framework we propose encourages growing industries and associated regulators to proactively consider the potential risks of value loss due to trust or assurance issues. As part of a process of understanding the components of value chains reaching into distant markets, our framework encourages appropriate investments in scientific authentication and traceability tools before a serious incident occurs, especially where the risk and value of loss exceeds a supplier's ability to assume the loss. The formula for this simple value assessment used to calculate market value loss is obtained from the product of the total expected market value, the risk of loss, and the fraction of value lost.

In this chapter we describe stable isotope technologies and their use as a scientific authentication and traceability tool that provides assurance of process and locational value in the context of the other chapters in this report. We propose a technological framework for its prioritisation and use to reliably verify and assure high-value primary production. While we focus on stable isotopes, other technologies capable of addressing issues of product authentication currently include; DNA, trace elements, mass spectroscopy, palynology, radiogenic isotopes such as lead or strontium, Nuclear Magnetic Resonance (NMR), and Near Infrared spectroscopy (NIR). Together, they provide an insight into the molecular structure, origin and history of the elements and biological markers contained in products, forensically linking them back to a place or process.

Food fraud activities

Food fraud threatens food safety and security in many overseas markets, as mislabelled foods laden with harmful pesticides or toxic metals can fraudulently enter the food chain affecting human health, particularly vulnerable citizens such as infants and the elderly. In New Zealand, food fraud and mislabelling is not yet considered a significant threat or risk to consumer health, although in mislabelled foods the non-declaration of ingredients or substitution with ingredients containing allergens could be life threatening for some consumers.

Globalisation and competitive markets provide incentives and opportunities for fraud, where the consumer is usually the disadvantaged entity, paying more for a purposely mislabelled, inferior product which does not meet its claims. Three of the main categories of food fraud in value chains are:

- **Counterfeiting** – where inferior products are specifically made for the purpose to on sell as high-quality products
- **Substitution** – where an inferior product is substituted as a high-quality product
- **Adulteration** – where a high-quality product is diluted or extended with an inferior product.

Although the producer's intentions cannot always be identified, the use of stable isotopes is a growing technology employed to understand how and where the product was made or grown, and whether tampering has occurred.

Stable isotopes

Stable carbon, nitrogen, sulphur, oxygen and hydrogen isotopes are determined in food and beverages using isotope ratio mass spectrometry (IRMS). They determine inconsistencies in labelling or packaging information with the food's origin, source, production methods and manufacturing history (Table 2).

Table 2. Stable isotopes and their application for origin and authenticity

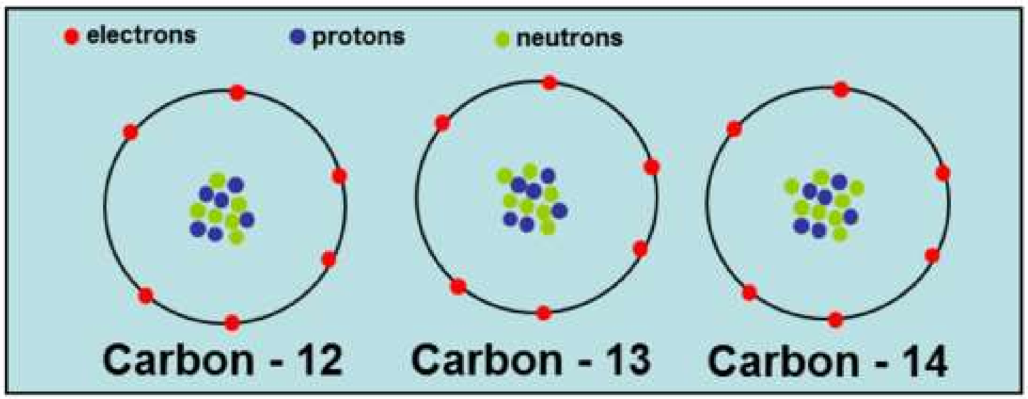
Stable Isotope	Environmental effect	Food fraud	Product suitability
Carbon ($^{13/12}C$)	Photosynthesis (C4, C3 and CAM pathways), diet/feeding	Adulteration e.g. cane sugar addition, petro-chemical substitutes, environmental effects	Honey, juice, wine, oils, vanilla, fish, health products, cereals
Nitrogen ($^{15/14}N$)	Diet/feeding, agriculture practice, fertiliser type and anthropogenic pollution	Substitution (synthetic versus organic fertilisers); Mis-labelling (organic, free range products)	Fruit, vegetables, meat, eggs, organic products, tea, coffee
Sulphur ($^{34/32}S$)	Soil type, geolocation (coastal or inland) and geological inputs including fertilisers	Counterfeiting, substitution, geographical origin	Meat, vegetables, wine, health products, honey
Oxygen ($^{18/16}O$)	Geolocation and climate through regional rainfall	Mislabelling and substitution (origin), adulteration (dilution)	Meat, vegetables, wine, water, fish, health products, honey, oils
Hydrogen (D/H)	Geolocation and climate through regional rainfall	Mislabelling and substitution (origin), Adulteration (dilution)	Meat, vegetables, wine, water, oils, eggs, health products, honey, milk products, coffee, cereals, tea

Standardised reference materials are run for each element in every batch analysis to ensure that stable isotope measurements are normalised and reproducible, with international commercial and research isotope laboratories regularly undergoing inter-laboratory ring tests and proficiency tests to ensure global analytical consistency. Typically, less than a few milligrams of material is required for analysis, so for food analysis, the biggest challenge is homogeneity to ensure a representative sample of the product is taken. A single sample may not be representative of the entire batch, product or site and may require further sampling to test whether the characteristics are representative across the product or location.

Definition

Stable isotopes are atoms of the same element that have different numbers of neutrons, and hence a different mass, so their isotopes behave differently in nature (Figure 17). Stable isotopes do not decay into other elements such as radioactive isotopes like radiocarbon (^{14}C). The five light isotopes (hydrogen, carbon, nitrogen, oxygen and sulphur) are building blocks of biological production, recording nutrient usage and water uptake in environmental systems. Used individually or, more commonly, as a multi-isotope fingerprint, they provide an enduring record to check provenance and authenticity of many food products.

Figure 17. Stable isotopes of carbon-12 and carbon-13, and the radioactive isotope carbon-14

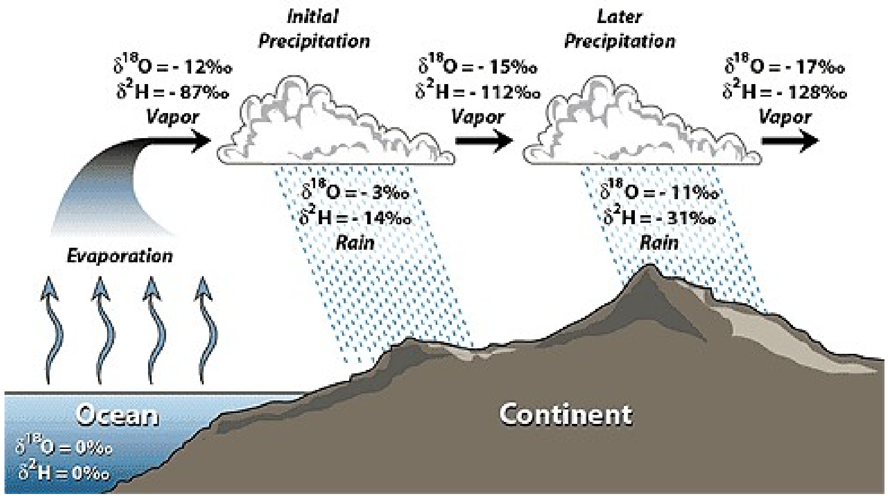


Note: A carbon atom has six electrons and protons, with the different isotopes containing six, seven or eight neutrons.

Regional factors – water (Hydrogen and Oxygen isotopes)

Worldwide water sources are distinguishable by their individual isotope composition (Dansgaard, 1964). Throughout the water cycle (evaporation and rain), water follows the movement of global air masses and changes its isotope composition continuously (Figure 18). This means that specific hydrogen and oxygen isotope ratios occur in different regions. These ratios can be detected in the region's precipitation, plants and any water containing product. The benefit of these differences is that products containing water can be matched to their geographic region of origin. These products include water and water-based food products, such as protein foods (e.g. meats, seeds), carbohydrate foods (e.g. honey, flour), and lipid-based foods (e.g. oils, waxes) as water is the basis of all life on earth.

Figure 18. Isotopic changes in hydrological water masses are affected by latitude (temperature), altitude and distance from evaporative water bodies such as oceans



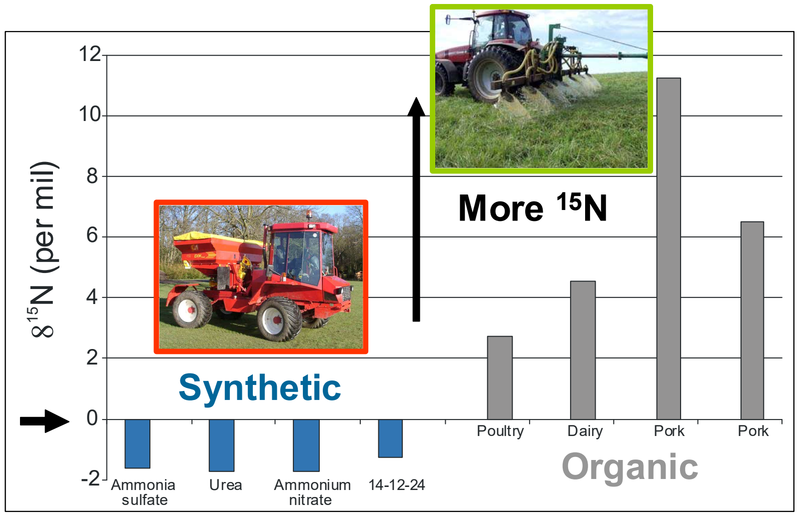
Local factors – Carbon, Nitrogen and Sulphur isotopes

Every plant contains carbon (C) and uses nitrogen (N) and sulphur (S) from the soil it grows in, giving unique local characteristics that can be detected using stable isotopes. The relationship is also affected by elemental supply from the water (dissolved constituents), additives to soil (e.g. fertilisers, bacteria and organic matter) and air (including air pollution).

Carbon isotopes determine the plant types used in animal diets and feeding methods, and show distinctive isotopic differences based on the type of metabolism of plants (either C3 or C4). C3 plants include most farm crops and wild plants (e.g. grains, cereals, sugar beet, and grass), while C4 plants consist of corn and sugarcane.

Nitrogen and sulphur isotopes differ between fertiliser types, for example organic fertilisers have a higher level of ^{15}N compared to synthetic fertilisers (Figure 19) providing indicative signatures about farming methods of produce. The isotopic fingerprint of plants used for animal feeds are reflected in an animal's corresponding biomass, or their products (e.g. eggs or meat) retaining a traceable pathway to identify added-value. When animals ingest organic diets or are corn-fed, they will display different isotope values than conventionally fed animals (Rogers, 2008).

Figure 19. Effects of nitrogenous fertilisers (synthetic and organic manures) on nitrogen isotopes of crops



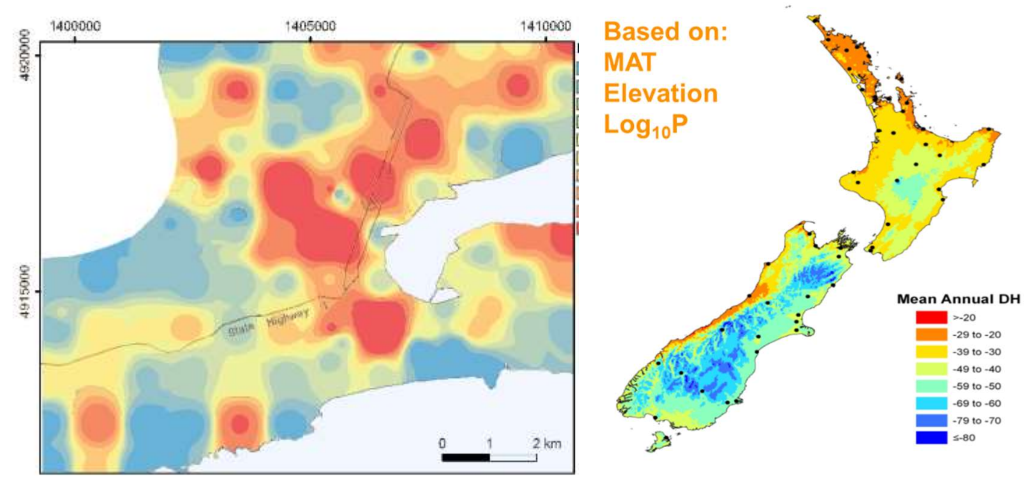
Sulphur isotopes vary according to geography and soil type. For example, geological (volcanic) sulphur has different isotope values than coastal or non-volcanic soils. New Zealand has diverse geological terrain with significant coastal regions providing comparatively unique signatures regionally as well as internationally (Rogers et al. 2017).

Connectivity between a sample and its origin – a top-down or bottom-up approach?

Geographical differences are oriented to climatic and soil specific factors, while authentication usually refers to the integrity of the product. Two main approaches exist when building an authentication database for food products. The unique and naturally occurring isotopic fingerprints of unknown samples can be used comparatively (to known authentic products) or predictively (to predetermined isotope maps that generate a statistical likelihood of authentication). It is not possible to study every single sample from every single site, and to study only one or two samples is usually insufficient. Batches may vary, and products may change according to seasons (temperature and rainfall), and external influences such as fertilisers, feed or processing. Generally composites (a mixture containing up to 20 individual samples that are homogenised and then resampled), batches or representative populations are collected for analysis. It is necessary to understand the natural variation of the product from the specific locality based against the total variation across all available samples to determine whether the product has a point of difference. Precision and accuracy of both instruments and natural variability will determine the size of the database and strength of evidence that can be determined from the results.

In instances where it is impractical to sample rigorously across populations, a bottom up approach is taken where samples are collected and comparative interpretation is made on spatial or temporal patterns between sites or across batches (Figure 20). Where more time is available and databases of authentic samples can be made, a top down approach can be used where construction of spatial or temporal isotope maps enables comparative matches with an unknown to establish a probability or likelihood of origin or authenticity (Figure 20).

Figure 20. Isotope map plotting spatially discrete samples that are used for comparative purposes only with known samples in a database and isotope maps plotting isotope ratios in a spatially predictable model



Case study 1 – Mānuka Honey

Mānuka honey provides a nearly ideal example where recognition of a product's attributes has allowed it to develop from a curiosity to a $300 million per annum export industry over 20 years. Uniform data available from 2004–2017 (SOPI, 2017) shows that the industry grew consistently along an exponential curve from 2004 through 2016 (23% year-on-year increases), with a single exception during 2011. During 2011, increased border scrutiny by importing countries (e.g. China, USA, Canada etc) resulted in enhanced international use of an isotope authentication test that was known to fail many batches of mānuka honey. They appeared to be "adulterated" with cane sugar or corn syrup based on the test, but these results were shown to be dominated by 'false positives' (Rogers et al. 2014, 2014a; Chesson et al. 2017). Scientific efforts to explain and ultimately fully understand the chemical mechanisms for the failures were successful and the industry resumed its growth trajectory in 2012. Only in 2017 has the growth trajectory apparently levelled out, due to low harvest of mānuka honey in the 2016/17 season due to poor weather.

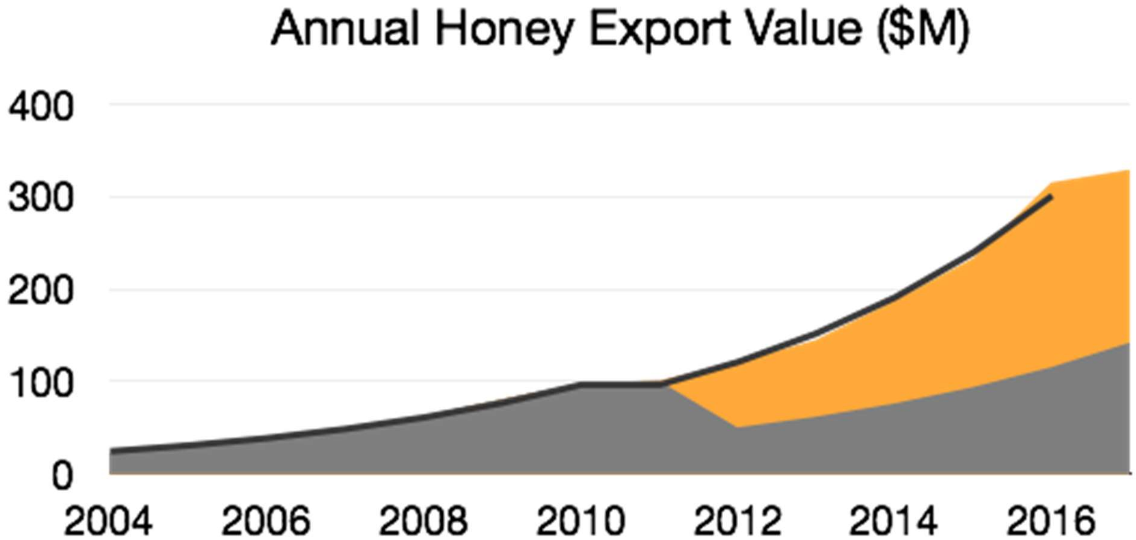
The intervention in 2011 was an illustrative example because it included a number of elements of technology and science investment that often fail to co-occur in New Zealand due to the limited size and scale of its industries and science system. A lesson from the example is the potential for better targeting timely science to respond to the requirements of global consumers and regulators, ensuring New Zealand growth industries are able and ready to respond to foreseeable risks to trust, providing credible explanations and robust science to support findings.

The mānuka honey example provides a simple basis for calculating the benefits of the scientific response to assurance problems circa 2011. Based on the simple assumption that value was knocked back 50% in 2012 and then resumed 23% growth, $600 million in exports were saved over five years (Figure 21, orange region). Had growth not resumed, $900 million or more could have been lost over the same period.

In this example, it is possible to evaluate realistic scenarios representing a large loss versus ongoing growth, with precision made possible by five years of hindsight. The ability of national and international science and regulatory frameworks to support the ongoing growth of the mānuka honey industry through authentication and geographical assurance has relevance to a wide array of fast growing primary industries containing the following characteristics:

- industry starts in isolated regions, serving the New Zealand internal and tourist market
- it grows rapidly to international scale
- overseas regulatory demands are more rigorous than domestic regulations.

Figure 21. Annual honey export value



Note: The dark line shows the fit Log(Export Value) = 3.21 + 0.227 Year ($R2$ = 0.992). Year was calculated as 2004 = 0, with 2011 excluded. Grey shows the actuals to 2011 with reduced value from 2012 onwards. Orange shows the actual values from 2012 to 2017.

Recently Ministry for Primary Industries (MPI) has recognised the unique attribute of mānuka honey and the international issues around fraud and mislabelling. There is now more rigorous testing and acceptance criteria around mānuka honey that must be met before export occurs. It is anticipated these new regulations will enforce compliance and consistency in markets, avoiding mānuka scandals and assuring process and location value.

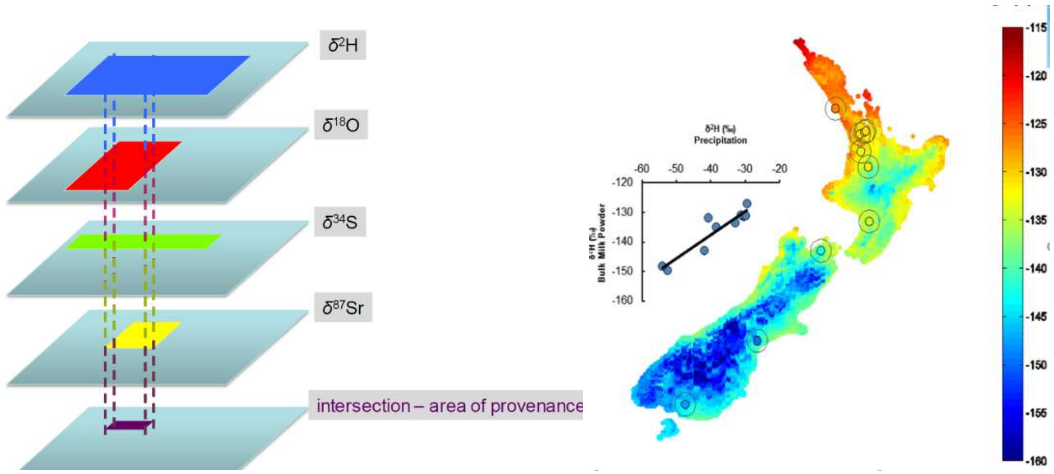
Case study 2 – Milk Powder

Tainted milk powder scandals in international markets sent alarming ripples through the New Zealand dairy industry back in 2008 with melamine contaminated milk powder in China. At the time, regulatory frameworks in international markets were insufficient to identify if contaminated batches originated from New Zealand or from local Chinese markets throwing New Zealand's solid reputation for high quality dairy products into peril.

From this incidence, a PhD study was undertaken by Ehtesham (2013) that showed that milk powder is highly correlated to regions of origin based on rainfall through the hydrogen isotope (Figure 22) and was used to define the concept of isoscapes or isotope predictive mapping to understand the origin of milk powder (Ehtesham et al. 2012).

More recently in 2013, tracing the origin of commercial farming chemical Dicyandiamide (DCD) became hugely important after traces were found in New Zealand-based dairy products. DCD is used in the farming process to prevent the fertilizer by-product nitrate entering waterways, and is also used as a means of "promoting pasture growth". Products were recalled from seven international countries and milk powder isotope tested to determine the processing plant origin from New Zealand to understand which farms may have supplied tainted milk. In 2014, a criminal blackmail threat was made to poison New Zealand infant formula with pest control agent 1080. Product was pulled from supermarket shelves across New Zealand while stable isotopes identified and matched baby formula held by the offender with contaminated products sent to Ministry for Primary Industries, providing vital evidence required to link the offender with the crime.

Figure 22. Multi isotope fingerprinting refines origin by increasing statistical probability



Note: Milk hydrogen isotopes correlate to hydrogen isotopes in precipitation, δH(milk) = -106 + 0.79 δH(rain) with R2 = 0.86.

While smart technologies including QR codes and mobile apps can easily link a product directly back to the farm, when the link to these supply chains is broken or fraudulently altered or removed, then secondary technologies are the only route to forensic identification.

Case study 3 – Eggs

Eggs are one of the most popular commodities sold in New Zealand supermarkets and are worth upwards of $226 M per year. Egg prices are defined by a wide selection of production and welfare methods advertised on the cartons (eg barn, free-range, organic etc) with the free-range and organic eggs costing up to three times more than caged or barn eggs. Frequently eggs are purchased from primary suppliers by distributing companies before being repackaged and on sold to supermarkets. This practice blurs the egg's origin, giving rise to opportunities for mislabelling and fraud for economic gain. Large scale fraud was discovered in New Zealand in 2017 and 2018 where tens of thousands of caged eggs were repackaged and sold as free-range into local supermarkets (Newshub 2018, 2018a). This type of fraud is not new, as large-scale egg mislabelling scandals have hit UK and Europe in the past decade. Even more concerning are recent food safety egg scandals where up to 40 countries received eggs contaminated with harmful insecticides used to kill ticks and fleas on poultry.

The technique for differentiating caged, barn, free-range and organic eggs was first developed in 2008 at GNS Science using stable carbon and nitrogen isotopes due to the hen's dietary and environmental access differences (Rogers 2009, Rogers et al. 2015). Until isotope methods were developed, egg fraud could only be identified using careful detective work on shoddy accounts or paperwork which eventually disclosed a dubious origin, or by observing cage marks on the shells of 'free-range' eggs, or from fluorescing particles from indoor lights which settled on the eggs.

Initially the egg industry was reluctant to admit there was an issue. They did not trust that stable isotopes could demonstrate anomalies in feeding habits of caged or barn hens versus free-range and organic hens. The technique has since become widely accepted as a robust authentication tool to identify differences in poultry feed and living environment.

While most packers have careful traceability methods around egg origin (e.g. cage/barn/free-range/organic) New Zealand methods are not yet as robust as those employed in international markets where every egg is stamped at the farm and rechecked at packing centres.

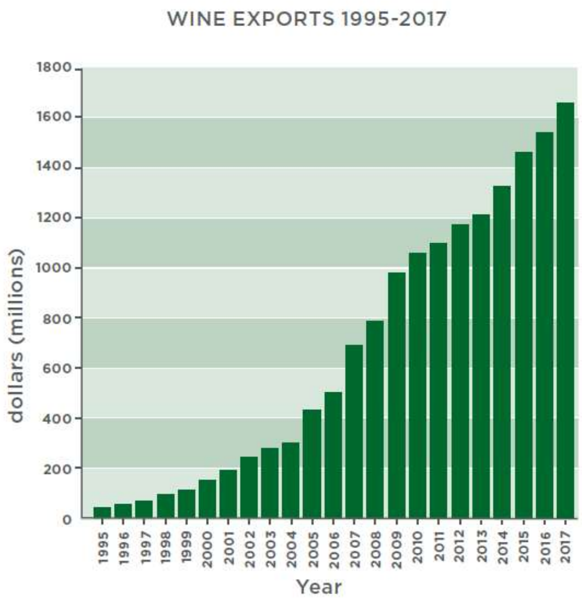
Nonetheless, it is the responsibility of supermarkets to sell correctly labelled eggs, and the use of isotope testing provides a further layer of assurance at point of sale or along the distribution chain. In overseas countries where eggs are exported, Country-of-Origin also becomes a problem, particularly around assuring egg quality and food safety. Further work has been undertaken using hydrogen isotopes to provide assistance for the geographical location of eggs. This is particularly useful in Europe where high value local eggs can be substituted with cheaper imported eggs from countries with less stringent regulations around chemical contaminants in poultry feeds and veterinary products such as antibiotics.

Case study 4 – Wine

Wine fraud comes in many forms, particularly overseas, where wines are watered, substituted with cheaper imported products or cheaper wines are relabelled as a more expensive brand. In some extreme cases, synthetic ethanol can be added to grape juice.

In Europe, an EU wine databank was established in 1991 to maintain the reputation of EU wine and minimise fraudulent practices such as sugaring and dilution of wine with water, playing a fundamental role to perform authenticity services using isotopes and protect valuable markets. Participating wine producers submit wine samples annually to the databank, allowing stable isotopes to authenticate claims of geographical origin of wine to a high level of accuracy.

Figure 23. Growth in New Zealand wine exports from 1995 to 2017



New Zealand can be defined by the isotopic composition of the groundwater. Due to the shape of the country being longitudinally diverse, most wine growing regions have distinctive ^{18}O values. Consequently, grapes grown in the regional groundwater will ‘take up’ the oxygen isotope signature of the region they were grown in. By analysing the wine water, it is possible to determine the geographical origin of wine by determining the oxygen isotopes ratios. Further work using hydrogen isotopes and other components of wine can further refine the origin or traceability of wine, while the carbon isotopes can be used to check if sugar has been added to boost fermentation and the alcohol content. Establishing regional fingerprints will allow scientific identification of any wine falling outside these areas. This technology is also applicable to other beverages, particularly the juice industry, where freshly squeezed New Zealand juices can be substituted with concentrates or imported juices, or have sugar added to improve the taste.

New Zealand’s wine industry has grown dramatically in the last 10 years, founded on a reputation for high quality wines with a target of $2 billon of exports by 2020 (Figure 23). Currently authentication testing is not mandatory in New Zealand. While many vineyards and bottling plants hold retention samples of the previous year’s vintage, there is no requisite to submit samples for testing to a databank as in Europe. Although compliance is usually well ingrained into every company, records can still be tampered or bypassed. For companies which process multiple wine varieties or wines from different vineyards, and/or import overseas wines, it is possible that undeclared blending or substitution may occur or an unintended error is made during bottling (Stuff, 2017). Both New Zealand Winegrowers Association and MPI are working hard to protect the New Zealand wine industry and in 2017 prosecuted a New Zealand wine company for fraud, dating back to 2011 to 2013, who sold tens of thousands of bottles overseas with false information regarding vintage, variety and origin (Stuff, 2017a). Secondary assurance methods such as stable isotopes would be a fast, low-cost and efficient regulatory tool to detect vintage changes and authenticate the New Zealand origin of wine, reducing the potential harm to high value export markets.

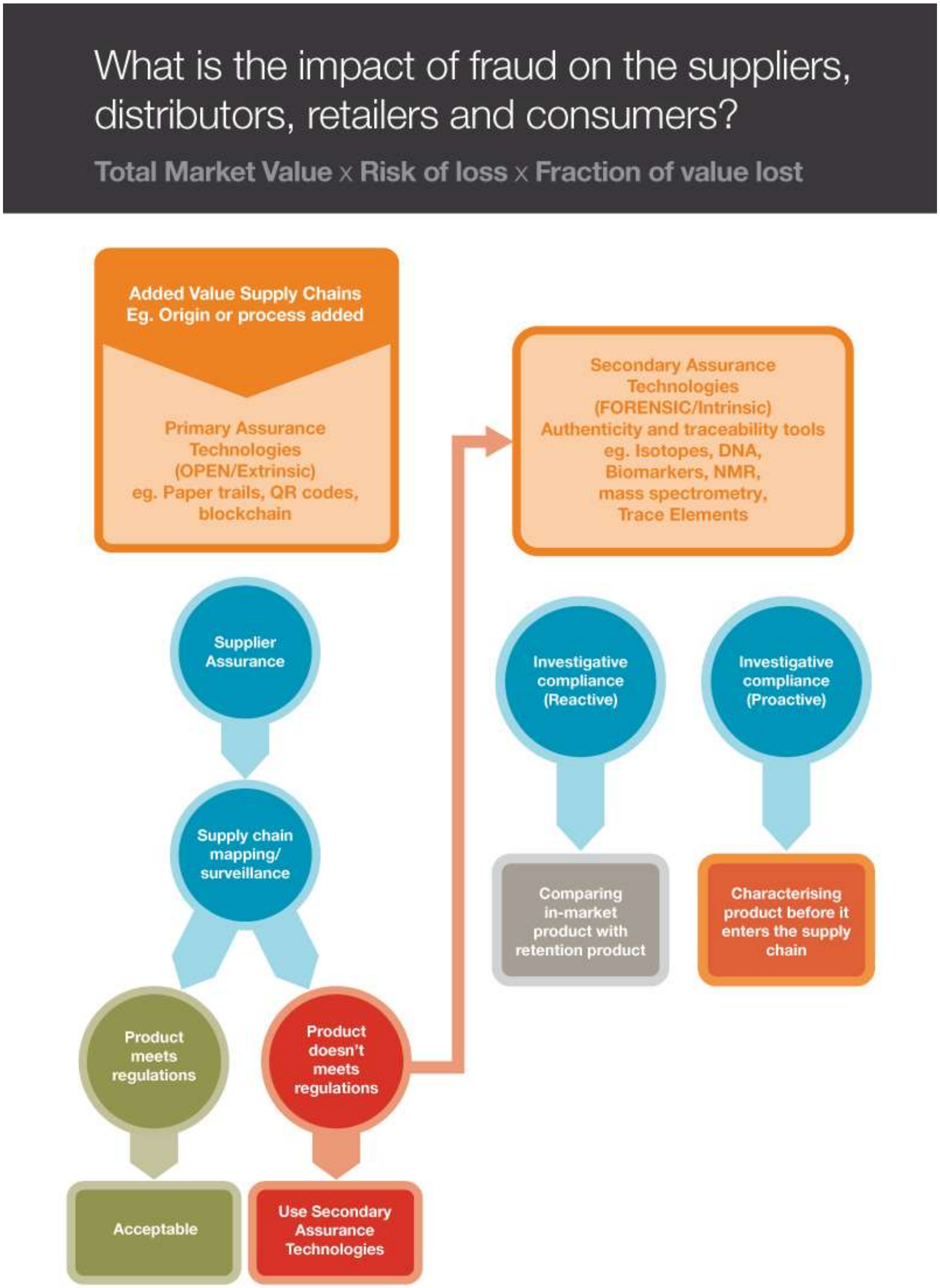
Impact of Value Chain Authentication

A value chain needs to be continuous to be efficient and robust, eliminating opportunities for fraud and disruption. Integrated value chains along the entire supply chain to the consumer ideally have all the necessary primary assurance technologies and have been assessed to identify risk and any weak points in the value chain. Where risk or weak points are identified, it is imperative that secondary assurance technologies are employed to verify origin or authentication of products, protecting the value chain. This could be a temporary measure until an alternative primary assurance technology can be implemented or it may become a mandatory testing requirement implemented by industry to regulate and monitor product from its origin to the supermarket shelf.

The initial expense and outlay to develop secondary assurance technologies can be minimal (when it is simply comparative) or considerable (where significant database acquisition is required to determine all possible scenarios). In instances where a product recall requires confirmation of origin or authentication using retention samples, then isotopes or other molecular technologies can quickly and readily confirm the origin and source. Where the unknown product does not conform to known samples, then forensic investigation frequently requires further sampling until a match is found. This was the case in 2011 where cucumbers contaminated with *E. coli* killed more than 16 people across Europe and the origin of the cucumbers were unknown. Similarly, a serious incidence of food fraud occurred in Europe in 2013, where horsemeat was substituted into ready meals and frozen beef burgers. These two high profile cases highlighted the vulnerability of supply chains, and the fact that when the scandal hit, no one was quite sure who was responsible for dealing with it, nor were there adequate procedures and technologies linked to authentication and origin in place.

Overall, we suggest that New Zealand value chains have a strong bias toward under-investment in assurance technologies, and in particular poor consideration of secondary assurance technologies. Figure 8 provides a framework for guiding collaborative or integrated value chains to target investment in assurance technologies. A business case can be developed by comparing the cost of technological development to the potential impact of fraud (quantified as the product of three quantities: the total market value; the risk of loss; and fraction of value lost in a fraudulent event).

Figure 24. Stepwise flow chart to determine assurance actions for integrated value chains



Summary

There are growing accounts of sophisticated counterfeit techniques that bypass primary assurance technologies and supply chain trust. We propose a value chain authentication framework that provides suppliers and consumers with a two-stage process consisting of regulatory procedures (Primary Assurance) and authentication technologies (Secondary Assurance).

Traditional supply chain assurances (eg. Passive systems such as barcodes, tags, packaging and paperwork) and smart technologies (e.g. Active systems such as Radio Frequency Identification or RFI's) provide tangible or visible evidence passed along from the producer to the supplier and the consumer. However, our framework proposes additional security measures (both pro-active and reactive) to authenticate and validate product prior to it entering the market or in-market to add a secondary level of product compliance, especially for high-value or high-risk commodities such as key exports (dairy, wine, meat, fruit, honey etc). Forensic (intrinsic) testing at a molecular level can either provide a comparison of in-market produce with genuine products retained by the manufacture (comparative) or from an unknown product back to its origin (investigative). These secondary assurance technologies are growing in popularity and compliment primary assurance tools, acting as a deterrent and strengthening weak points in value chains, especially where declaration of origin or authenticity does not meet the forensic test outcomes.

Despite the recent advances in isotope authentication, a key barrier to secondary assurance technology usage is the low numbers of experts and laboratories undertaking this work globally, and the initial outlay to set up large databanks. Key international testing laboratory entities such as Eurofins, and various national food testing agencies are well equipped to deal with some product types, while other databases are still under development or non-existent. Outside Europe and North America, especially in under-developed markets such as Asia and South America, testing methods are only beginning to be developed, however this technology is expected to consolidate within the next five years.

Sustainability audit schemes and value chains

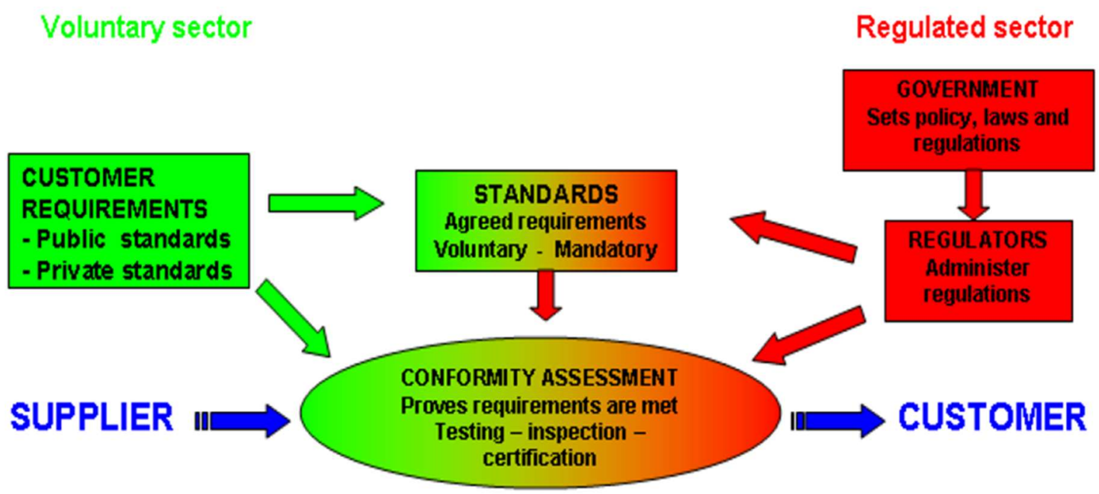
Contributor: Jon Manhire, the AgriBusiness Group

Introduction

The provision of assurance on the quality or the attributes of a product or production system from which it was produced has evolved rapidly over the last 20 years with the increased demand from discerning consumers who want assurance regarding the intrinsic and extrinsic attributes of what they consume. However, the historical origins of quality assurance can be traced back to China and other regions, such as the assurances provided by Guilds in medieval Europe.

Figure 25 provides an overview of how assurance is provided in the voluntary sector (ie industry) and the regulated sector (ie government) and the process used for conformity assessment/assurance for customers.

Figure 25. Relationship between voluntary and regulated sectors and standards



In relation to the voluntary sector, requirements are often set by the customer, but there is no legal requirement to comply with any standards and requirements cannot be challenged through World Trade Organisation (WTO) rules-based processes. However, failure to meet customer specifications will probably result in the loss of the sale. In contrast, regulatory requirements are legally enforceable.

Both the regulated and voluntary sectors rely on standards or agreed specifications and on internationally accepted conformity assessment procedures:

- **Conformity Assessment Bodies** (CABs) are organisations who provide certification and/ or inspection services.
- **Accreditation** is an endorsement of a CAB's competence, credibility, independence and integrity in carrying out its conformity assessment activities.
- **Certification** determines whether products, processes, systems or persons meet requirements.
- **Standards** are documents, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.

There are three main methods of assessing conformance:

- **First-party** – self-declaration of conformity to a particular standard. This may be acceptable for low-risk products and may need to be supported by a technical file containing justification for the declaration.
- **Second-party** – assessment by a customer or other interested party to ensure that the product or process meets their requirements.
- **Third-party** – an objective assessment by a technical expert or organisation that is independent of the producer and the customer.

Third-party assessment is the most credible, and most common, method of confirming that a product, system or process complies with a standard. It provides both the supplier and the customer with the added assurance that compliance has been independently verified.

Third-party conformity assessment is carried out by independent inspection bodies and certification bodies. Accreditation is the process of ensuring that these inspection bodies and certification bodies are themselves competent to conduct specific assessments. It is the checking of the checkers. Accreditation bodies must be independent of the bodies they are assessing (third-party) and must also apply recognised standards to assess competence.

Assurance of sustainability attributes

Agricultural sustainability

There are multiple definitions of what constitutes agricultural sustainability. However, at its core agricultural sustainability addresses multifactorial environmental, social and economic outcomes, resilience (the ability of a system to buffer shocks) and persistence (the ability of a system to continue over the long term) (Pretty et al., 2008). Agriculture in New Zealand is the largest trade sector, accounting for 72 per cent of all New Zealand merchandise exports in 2014 (Stats NZ, 2016). In addition, New Zealand also has the lowest level of producer support for agriculture in the developed world making a unique and highly relevant site of focus for sustainability research (OECD, 2008b).

Drivers for sustainability assurance

There is a growing consumer expectation for corporate responsibility and reporting around issues of food safety and environmental impacts (KPMG, 2011a). New Zealand farmers operating in local and global markets are increasingly required to monitor, measure, and report on their management practices in response to not only consumer expectations, but also changing regulatory and certification requirements. There is also a growing awareness in the agricultural sector, much the same as in the corporate environment, that paying close attention to all of a business's interactions with the environment and society can lead to opportunities for business improvement. The three key drivers of sustainability as recognised by the New Zealand Sustainability Dashboard (NZSD) and described by Hunt et al. (2014) are:

- **Overseas markets**: Key influences on the marketing of New Zealand's primary products (Saunders et al., 2013) include:
    - the development of agri-environmental policies in the EU and the US
    - the move towards sustainability in markets driven by the private sector and retailers (eg Global Good Agricultural Practice (GlobalGAP) and the Red Tractor Scheme)
    - the change in consumer attitudes and behaviours towards accountability for environmental and social impacts of the products consumers are purchasing and the promotion of sustainable practices
    - climate change (carbon footprinting)
    - water quality and quantity (water footprinting)
    - protection of biodiversity and wildlife
    - animal welfare
    - the emphasis on local food.

- **Regulatory requirements**: Many frameworks have been developed by regulatory bodies (The Agribusiness Group, 2013). These are designed to protect the environment and fit well under the dimension of sustainability which concentrates on "agro-environmental integrity". In addition, there are many regulations such as those to do with human rights, employment, animal welfare, company reporting and food quality and safety that cross the economic, social and environmental sustainability dimensions.
- **Business Improvement**: A review (Hunt, 2014) considers the development of the definitions given to sustainability, in particular business sustainability and how this has been measured in the development of different business improvement models and generic frameworks which include some aspect of business

The first two of these drivers (overseas markets and regulatory requirements) are external pressures on a business, whereas the third driver (business improvement) arises from a need or opportunity within a business.

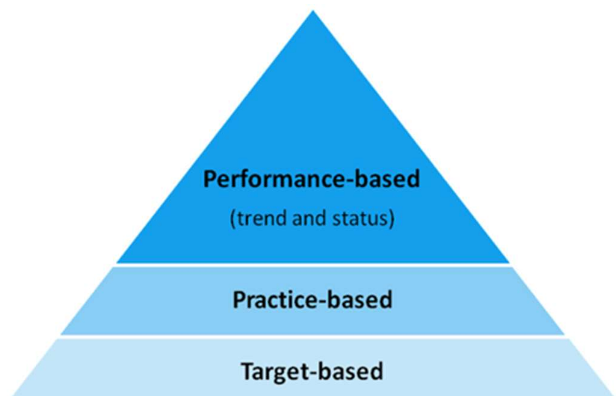
Methodologies for sustainability assurance

There are a number of methods for undertaking the assessment, reporting and providing assurance of the sustainability of a product or a business:

- **Product based models** – the lifecycle assessment approach is the main system for providing product-based assurance. This involves an analysis of the inputs, outputs and potential environmental impacts of a product system throughout its lifecycle.
- **Business sustainability models** – these typically include an assessment of all aspects of the business management and operation in relation to sustainability.

All these approaches use indicators to assess whether a product/supply chain or a business are meeting sustainability objectives that are included in the scope of their sustainability programme or standard.

Figure 26. Sustainability assessment indicators



Source: Food and Agriculture Organization of the United Nations' (FAO) Sustainability Assessment of Food and Agriculture systems (SAFA) Guidelines.

Figure 26 illustrates the main type of indicators with those types higher up the pyramid being of higher value because of their accuracy:

- **Performance-based indicators** (also called results-oriented or outcome indicators) are focused on the results of compliance with an objective and can measure the performance of an operation, identify trends and communicate results.
- **Practice-based indicators** (also called prescriptive or process indicators) are focused on the prescribing the necessary tools and systems required to achieve best practices. These indicators are process rather than outcome-oriented. These indicators assume that, for example, having water or health and safety management systems in place leads to better management of environmental or health and safety issues. However, the cause-effect between a given practice and a result is never precise.
- **Target-based indicators** are focused on whether the operation has plans, policies or monitoring, with targets and ratings based on steps towards implementing them.

Regulatory based sustainability assurance

Sustainability issues have traditionally been outside the scope of international or national trade rules or regulations, however there are some indications that this will change. Various governments as well as international organisations see an increasing need to address the current confusion regarding sustainability/green product claims by developing regulatory controls regarding sustainability labelling. These developments could create barriers to market access for New Zealand companies if they do not meet the regulatory sustainability labelling requirements as well as potentially increasing the associated compliance costs. Examples of international, regional and national regulatory initiatives are provided below.

International

The WTO set rules to ensure that regulations are not used as unnecessary barriers to trade. The Agreement on Technical Barriers to Trade (TBT Agreement) covers regulations applying to both agricultural and non-agricultural products. Member governments of the WTO may challenge other member governments over regulations that cannot be technically justified. At the heart of the WTO system are two key principles:

1. **National Treatment principle** (NTP) provides that countries should give the same treatment to foreign goods and traders as they do to domestic goods and traders.
2. **Most Favoured Nation principle** (MFN) provides that countries should not discriminate between the goods and traders from different countries.

New Zealand has agreed to extend MFN status to all members of the WTO. The TBT Agreement does not prevent countries from adopting the standards they consider appropriate for things like product safety, labelling or environmental impact but, for the benefit of consumers and producers alike, it encourages countries to use international standards wherever appropriate. If the circumstances that led a country to adopt a regulation change, or a new less trade-restrictive measure becomes available, then the TBT Agreement says the regulation must be removed. The TBT Agreement requires the procedures used by Governments to decide whether a product conforms to national standards to be fair and equitable.

In relation to eco-labels the WTO make the following comment (World Trade Organisation, 2010):

> "*Eco-labels may be used to manage the un-priced negative effects of economic activity on the environment. The Agreement on Technical Barriers to Trade defines technical regulations as documents that lay down product characteristics or their related processes and production methods. Similar language is used in the definition of voluntary standards. The second sentence of both definitions refers to labelling requirements "as they apply to a product, process or production method"*

Sustainability labelling schemes there have been the following disputes:

- Protection of trademarks and geographical indications for agricultural products and foodstuffs (World Trade Organisation, 2005)
- Tuna-dolphin case, where the US label indicating 'dolphin-friendly' tuna was found to be acceptable as it did not lead to unfair discrimination between domestic and imported products.

The other main agency establishing international rules for the trade in agricultural products is the Food and Agriculture Organisation of the United Nations (FAO) (Food and Agriculture Organisation of the United Nations, 2017a) through Codex Alimentarius (Food and Agricultre Organisation of the United Nations, 2017b). Codex facilitate the development and host international food standards, guidelines and codes of practice. Codex texts are considered by the WTO as the international reference for food safety and nutrition standards. In 1999 Codex released the *Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods* (World Trade Organisation, 1999), however Codex does not appear to be active in the development of any additional sustainability standards or guidelines.

Regional and National

European Union

The European Union (EU) is possibly the most advanced in establishing policies and strategies to address sustainability claims and includes the following initiatives:

- **Europe 2020 strategy**. '*A Resource-Efficient Europe*' (European Commission, 2017a). This strategy was developed in 2011 and includes a number of strategies to increase resource productivity and to decouple economic growth from both resource use and environmental impacts. One of its objectives is to establish a common methodological approach to enable member states and the private sector to assess, display and benchmark the environmental performance of products, services and companies based on a comprehensive assessment of environmental impacts over its lifecycle (environmental footprint). These are currently being developed by the Product and Organisation Environmental Footprint project which will develop harmonized methodologies.

- **Single market for green products** – this initiative aims to address the issues relating to the confusing range of choices of methods and initiatives for establishing a product's green credentials (European Commission, 2017b). Some specific parts of this initiative are the development of two methods to measure environmental performance throughout a lifecycle:
    - Product Environmental Footprint (PEF)
    - Organisation Environmental Footprint.

From 2013 to 2016 a pilot phase was undertaken involving 26 pilots to develop specific Product Environmental Footprint Category Rules (PEFCRs) and draft Organisation Environmental Footprint Sector Rules (OEFSRs) for the specific products or sectors. It is planned that the approval for PEFCR and OEFSR will be finalised by the end of 2017 (European Commission, 2017c). Pilots relevant to New Zealand exports include dairy products, beef/lamb meat and wine. The compliance process to be used for these programmes is currently unclear though background research provides some insights (European Commission - DG Environment, 2014). It is possible that compliance with these protocols will become mandatory for any products (included those imported into the EU) if any product sustainability label claims are going to be made.

China

In China there have been some recent changes in relation to regulations covering food safety in response to increased consumer concerns resulting from a number of food safety incidents. A new Food Safety Law was adopted in 2015 and it introduced stricter controls on the monitoring and supervision of food standards and safety standards.

There has also been government initiatives to promote the production of `Green Food' led by the government agency the `*China Green Food Development Centre'* (Green Food, 2017). This agency develops green food standards, oversees their certification and related labelling laws. Green Food covers organic food as well as other levels of food with sustainability credentials. In 2017 it was reported (XinhuaNet, 2017) that there were over 10,000 accredited green food companies producing more than 26,000 types of products.

There is however ongoing concerns regarding corruption in food supply chains and environmental pollution issues as well as the treatment of workers (Maplecroft Global Risk Perspective, 2014). There are signals that the government of China is placing a higher priority on the management of these as reflected in its current 5 year plan (China Daily Asia, 2016).

United States

The United States has been at the forefront for the development of markets for products with sustainable production attributes as reflected in the 2016 US$47 billion market for organic food (FIBL & IFOAM, 2017). It has also developed a range of mostly voluntary policy instruments for protecting environmental quality including facilitating the labelling of sustainable products and providing financial incentives. The US Department of Agriculture (USDA) is a leading agency for the establishment and implementation of these. In relation to labelling standards – initiatives to assist with the certification, production and labelling of food with sustainability attributes they include:

The National Organic Program (NOP) – a regulatory program responsible for developing and administering national standards for organically-produced agricultural products (United States Department of Agriculture - Agricultural Marketing Service, 2017).

Process Verified Program – this is a verification service that offers applicants to identify, verify and market their products to cover one or more agricultural processes or portions of processes. Some attributes that have been verified through this programme include – diet eg grassfeed, age, breed, source management eg non hormone treatment (United States Department of Agriculture - Agricultural Marketing Service, 2018).

There are some compulsory compliance mechanisms where producers have to meet standards for environmental performance before they can access subsidies such as for the protection of erodible land or for the management of environmental issues such pesticide and effluent pollution. There has also been the establishment of some voluntary mechanisms such as environmental credit trading – an approach for reducing pollutant discharges that uses market forces to allocate pollution control costs effectively among different pollution sources such as for nitrogen contaminants.

Voluntary sustainability assurance and audit requirements

International sustainability initiatives

In recent years there have been a number of international initiatives to develop sustainability standards, rules for their use as well as for making any claims in relation to sustainability attributes. A key driver for the development of many of these is to assist consumers and other stakeholders have a better understanding of the relative merits of sustainability/green assurance programmes.

International Social and Environmental Accreditation and Labelling (ISEAL)

The ISEAL Alliance is the global association for sustainability standards. It works with established and emerging voluntary standard systems and provides guidance to help strengthen the effectiveness and impact of these standards (ISEAL Aliance, 2017a). It also works with companies, non-profit organisations and governments to support their referencing and use of voluntary standards. ISEAL has developed codes to promote best practice for the development and use of voluntary standards which include:

- **Assurance Code** – sets out minimum criteria for implementation of the assurance process while recognising that different models can be effective for different purposes (ISEAL Aliance, 2017a). It outlines the principles of assurance:
  - consistency
  - rigour
  - competence
  - impartiality
  - transparency
  - accessibility
  - detailed requirements to meet these.
- **Impacts Code** – offers a framework for building a monitoring and evaluation system capable of examining both short-term and long-term outcomes from the adoption of Standards (ISEAL Aliance, 2017a).

The Global Reporting Initiative (GRI)

GRI supports the standardisation of reporting on economic, environmental and social performance values (Global Reporting Initiative, 2017a). It has developed a Sustainability Reporting Framework which includes Sustainability Reporting Guidelines. Its latest version of standards was released in 2016 with the consolidated set including 36 sustainability reporting standards (Global Reporting Initiative, 2017b). GRI also has a sustainability disclosure database that allows for the comparison and benchmarking of a company or organisation's sustainability report against GRI Guidelines (Global Reporting Initiative, 2017c). There are currently 11,012 organisations and 42,634 reports in the database.

International Organization for Standardisation (ISO)

This is the main international standard-setting body composed of representatives from various national standards organizations (International Organisation for Standardisation, 2017). ISO have developed a number of standards that are referenced in sustainability programmes including ISO 9000 Quality Management, ISO 14000 Environmental Management and ISO 2600 Social Responsibility. They have also developed standards that define certification and external audit practices. Some of these standards are:

- **ISO/IEC Guide 65** – general requirements for bodies operating product certification systems
- **ISO 17011: 2004 Conformity assessment** – general requirements for accreditation bodies accrediting conformity assessment bodies
- **ISO 17021: 2011 Conformity assessment** – requirements for bodies providing audit and certification of management systems

- **ISO FDIS 17065 Conformity assessment** – requirements for bodies certifying products, processes and services.

UN FAO SAFA Guidelines

The SAFA Guidelines have been developed by FAO to provide an agreed approach to the assessment of requirements which underpin sustainable production, manufacturing and retailing of food and agriculture products (Food and Agriculture Organisation of the United Nations, 2017a).

Retailers

Retailers have been a key driver for establishing the demand for sustainability programmes. Some retailers have established their own sustainability programmes to enhance their brand and require suppliers to comply with these. Examples include the Tesco (Natures Choice) and Carrefour (AGIR) programmes. Other retailers are using GlobalGAP, Sustainable Agriculture Initiative (SAI) or other sustainability schemes as a requirement for supply. Some processors have also created a demand for sustainable raw materials. As an example, Unilever has committed to sourcing 100 per cent of its agricultural raw materials sustainably by 2020.

Non-Government groups and other influencers

Non-Government Organisations (NGOs) are becoming more important in relation to their role in reviewing the integrity of sustainability and 'green' product claims and providing directions to consumers on their use. They also have an influence on retailers and their purchasing decisions. Some influential organisations are outlined below and where available their positions on sustainability standards, certification and audit processes.

UN International Trade Centre

United Nations International Trade Centre (UNITC) have established the Standards Map initiative that provides users with information enabling them to analyse and compare information on 120 voluntary standards operating in over 200 countries, and certifying products and services in more than 80 economic sectors (International Trade Centre, 2017).

Sustainability Consortium

The Sustainability Consortium (TSC) is a global non-profit organisation working to transform the consumer goods industry by partnering with leading companies to define, develop, and deliver more sustainable products (The Sustainability Consortium, 2017). It has a focus on the development and implementation of science-based sustainability metrics. In 2017 it outlined its goal to create a consumer-goods ecosystem that is sustainable using a common approach to measuring and tracking the product sustainability of US$1 trillion of retailer sales over the next five years.

EcoLabel Index

This site claims to be the largest global directory of ecolabels and currently lists 465 labels in 199 countries (Ecolabel Index, 2017).

The Sustainability Standards Comparison Tool

This is part of a larger project of the German government's Quality Check: Sustainability Standards that aims to increase the transparency and comparability of standards in order to drive increased uptake (Sustainability Standards Comparison Tool, 2017). This comparison tool enables the assessment and comparison of sustainability standards using, in part, the information from the ITC Standards Map.

New Zealand – sustainability assurance

Regulatory – sustainability assurance

New Zealand has established a wide range of regulations to protect the environment and to encourage the sustainable management of resources. In relation to exports the Ministry for Primary Industries (MPI) is the main government agency for facilitating the provision of assurance for the primary sector. It works with independent verification agencies to ensure that certification and official assurances of export products meet New Zealand standards and, where needed, certify that the products comply with the requirements for export to trading partners overseas. The MPI Official Organic Assurance Programme (OOAPP) (Ministry for Primary Industries, 2017)is an example of a programme that covers sustainability claims. It covers exports of organic products to the European Union, Switzerland, USA, Japan and Taiwan. MPI recognises AsureQuality and BioGro New Zealand Limited as third party agents that audit organic operators to ensure compliance with the appropriate international rules and standards.

The Government has also established other voluntary programmes for the promotion of New Zealand and its exports through an association with sustainability values. These are linked with the Government Business Growth Agenda that aims to lift exports to 40 percent of GDP by 2025 (Ministry of Business, Innovation and Employment, 2017). One of the Agenda objectives is to *Develop and grow New Zealand's international marketing brand* (Ministry of Business, Innovation and Employment, 2017). A key initiative for this is the New Zealand Story, the development of which was led by Tourism New Zealand, New Zealand Trade & Enterprise and Education New Zealand with extensive input from other stakeholders. The New Zealand Story has established the FernMark Licence Programme to help promote and protect New Zealand products on a global scale. The programme gives licensees the right to carry the FernMark if they are: GST registered in New Zealand, are compliant with all New Zealand laws and relevant regulations, of good character and repute, have a substantial level of New Zealand ownership, governance and full time employees and have been exporting for a minimum of 12 months. Though these criteria do not include any assurance of sustainability integrity it does provide a platform to which these could be included. In 2017 there were over 70 Fernmark licence holders (Fernmark, 2017).

Voluntary sustainability programmes

There are a large number of voluntary assurance programmes established in New Zealand that include some components of sustainability assessment and reporting. The Sustainable Agriculture Management Systems Network (SAMSN) reviewed twenty-one programmes in use in New Zealand in 2003. The programmes covered a wide scope and were grouped by broad programme type and included Sustainable Management Systems (SMS), Environmental Management Systems (EMS), Quality Assurance (QA), and integrated pest management (IPM) programmes. Programmes grouped as SMS incorporated environmental, economic and social characteristics within the programme. EMS generally had a greater focus on environmental considerations. IPM programmes, had a main focus on pest management. QA programmes, where the objectives are focused predominately on food safety and quality issues, were included because such programmes had some linkage to environmental issues in that the use of agrichemicals is a key factor for consideration. Many of the sector programmes commenced as IPM or QA programmes but had been modified to incorporate additional components. Also included in the review were four codes of practice or standards that are tools to assist implementation of EMS/QA-type programmes. Across this range of programmes some common components were identified such as the level of registration and auditing required, and mechanisms used in the delivery of the programmes, such as checklists and use of external documents. It was also identified that the scope of some programmes was being extended to have a wider coverage, reflecting the demand for environmental and social accountability.

A Lincoln University AERU 2017 report *Private Standards in New Zealand Primary Industry Sectors and a Comparison to International Best Practice* (Whitehead & Driver, 2017) provided an update on the status of the various primary industry programmes that incorporated some aspect of sustainability assessment New Zealand.

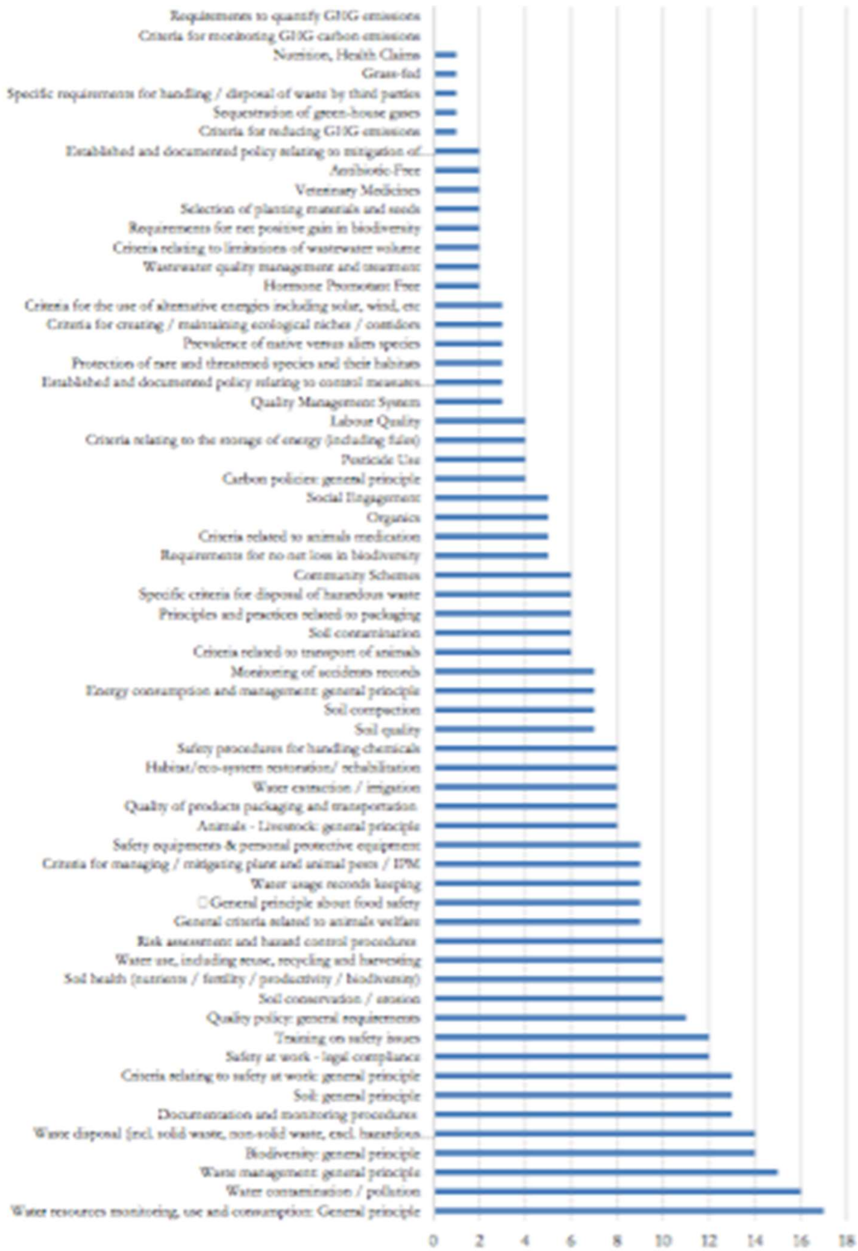
Figure 27. New Zealand primary sector standards and their coverage

Industry Sector	Standard	Industry Coverage
Dairy	BioGro	0.3% (PB)
	Fertiliser Association	Unknown (No industry information)
	Fonterra Supplier's Handbook	84% (TP)
	Synlait Lead With Pride	2.9% (TP)
	Water Accord	96% (TP)
	AsureQuality Organic Standard	0.6% (PB)
Sheep and Beef	Quality Mark	100% processing (PB) 85% Retail (PB)
Wool	WNZ	5% (PB)
Forestry	FSC	70% (TP)
	NZFOA	Unknown (No industry information)
Deer	QA	Unknown (No industry information)
Aquaculture	A+	82% Registered(PB)
Wild Caught Seafood	MSC	75% Deepwater Fisheries (TP)
Wine	SWNZ	94% (TP)
Kiwifruit	ZespriGAP	95% (TP)
Horticulture	NZGAP	33% (PB) (85% of industry has some form of GAP certification though)
Processed Foods	Conscious Consumers	60 businesses (PB) (very little information available)
	Fairtrade	0.5% (TP) (supermarket and grocery sales)

Source: Industry coverage statistics. *Private Standards in New Zealand Primary Industry Sectors and a Comparison to International Best Practice.*
Note: PB refers to percentage of production base (producing units covered / total producing units). TP refers to percentage of total production (production covered / total production).

The report also provided an analysis of the scope of the 18 standards that were reviewed.

Figure 28. The number of standards addressing sustainability attributes



Source: *Private Standards in New Zealand Primary Industry Sectors and a Comparison to International Best Practice.*

Sustainability Assessment – issues and opportunities for New Zealand companies

There is market demand for assurance of the sustainability of production systems as well as mechanisms in place, such as standards and assurance programmes, to support this. These provide opportunities for many New Zealand companies, as well as some issues that are discussed below.

Opportunities

Positive sustainability impacts

The core rationale for sustainability assurance programmes is to enhance the sustainability of the participating operators and minimise negative environmental, social and economic impacts.

Market access and price premiums

As outlined, a number of food processors and retailers are now requiring that products they sell have an assurance of the quality and sustainability of the production system and value chain. These demands reflect the buyer's interest in servicing the needs of customers as well as a strategy to protect their companies' reputation from association with any negative news. Typically, access to these markets provides a price premium.

Resource use efficiencies

Sustainability assurance programmes typically encourage the efficient use of resources such as water, energy and production inputs. This can result in productivity and profitability gains.

Reputational gains

The establishment of sustainability programmes and the reporting of an organisation assessment results can contribute to increased consumer and societal trust in the organisation. The sustainability assessment process can also identify risks and areas of concern that the organisation can then target. Initiatives such as those facilitated through the Sustainability Consortium have a key driver for participation and management of any reputational risks from often long supply chains to ensure that a company's brand value is not compromised.

Attracting investment

Increasingly, some investors are looking for responsible investment opportunities. In 2016 the Global Sustainable Investment Alliance (GSIA) (Global Sustainable Investment, 2016) estimated that the market for these types of investments was over US$22.89 trillion of assets being professionally managed under responsible investment strategies, an increase of 25 per cent since 2014. For Australia and New Zealand, the 2016 GSIA report outlined that assets managed by asset managers, asset owners, banks and advisors grew substantially, both at retail levels and institutional levels, across all responsible investment strategies. In both countries combined, responsible investment assets had grown to reach US$515.7 billion (NZ US$53.5 billion) in 2016.

Internalisation of environmental and social costs

Sustainability assurance programmes encourage the adoption of many practices that decrease or manage social and environmental risks such as the pollution of rivers and the reduction in the production of greenhouse gases.

Issues

Though there are advantages for the adoption of sustainability assurance programmes, there are some issues. There are generally few detailed analyses of the costs and benefits associated with joining sustainability assurance programmes, however the following suggest that this would be useful.

Transaction costs

There are costs associated with establishing and managing a sustainability assurance programme. These include the direct costs such as the costs for audits, as well as indirect costs that an organisation may have to confront to meet the sustainability audit requirements. For many food companies it may establish additional demands for their suppliers to meet so that the required standards can be met. For some suppliers this may be an additional burden that they don't want and they may move to another processor/exporter that does not have these requirements. This can often be the case for small producers who may not have the resources to be able to comply with the requirements of sustainability assurance programmes.

Selection of best option

As outlined, there are a large number of sustainability assurance options. The selection of the most appropriate option is not simply taking into account differing regulatory and market demands and the diverse scope of programmes. Once an assurance programme has been selected there is always a risk that the standards or the compliance processes may evolve to create higher barriers to entry or a requirement for more expensive production technologies or possibly decreases in productivity to meet the sustainability programme demands.

Implementation Challengers

Once a sustainability programme has been chosen it needs to be implemented. This requires:

- the establishment and management of information and traceability systems to enable the tracing of products and their attributes through a value chain
- gaining participation of those in value chains such as farmer suppliers
- developing more favourable relationships and returns such as market premiums to fund the additional costs associated with implementing the programme.

If these cannot be achieved then the long-term future of the programme may be at risk.

Disruptive Technologies

Though there are many technologies that will assist with the sustainable production systems and sustainability assessment systems there are others that may not be as positive. As an example synthetic milk, according to one producer, could cut greenhouse gas emissions by 84 per cent and water use by 98 per cent, while also requiring 90 per cent less land than dairy (Stuff, 2017).

Future research

Credence attributes can produce greater value for New Zealand producers and manufacturers. To get the most value from their products, producers need to be able to communicate the credence attributes associated with New Zealand products in a consumer-friendly way. Technology can be used to support communicating values and attributes through complex value chains. Technologies are also needed to verify credence attributes and claims after the fact when questions are raised about a product's provenance or the authenticity of its claims.

This report has identified both primary technologies and systems to support communicating credence values, and secondary technologies to fill information gaps about food products. To get the most value from these technologies and audit systems, we have identified several areas of potential further research. We have grouped future research questions into four categories:

- Market and consumer value
- Producers' understanding of the market
- Uptake of new technologies
- Consumer understanding of new technology.

Market and consumer value

Research into the market for primary products worldwide can shed more light on how technologies are being used and how value is being communicated. Some questions include:

- How much value is associated with credence attributes compared to product value?
- Are specific types of value linked to specific techniques for traceability and communication?
- How are New Zealand food producers relying on country-of-origin branding versus third-party certification of credence attributes?
- Is New Zealand being left behind by other country-of-origin branding, for example Origin Green from Ireland?
- How much value can be generated through better use of authentication technologies?
- How much are different technologies used and trusted?

Producers' understanding of the market

To help primary producers in New Zealand gain greater value from value chains, further research on producers' current understanding of consumer demands and use of technologies would be useful. Some research questions that could be answered include:

- How well can the New Zealand primary sector respond to changing and more varied consumer demands?
- How much do producers know or understand about the growing body of sustainability standards?
- What support do they need to be responsive?

Uptake of new technologies

Further research into the benefits of various technologies and their uptake will help New Zealand producers understand how to use them to demonstrate and communicate value. Some questions for further research include:

- How can technologies be integrated to give a bigger picture of the whole value chain?
- What are the real-world constraints, such as cost or acceptance, on greater use of new technologies?

Consumer understanding of new technology

Research into New Zealand's key export markets can help value chain participants understand how to use these technologies to build trust among consumers. Some topics to research include:

- Which technologies/verification mechanisms do consumers trust?
- What would lead consumers to use technology further?

A greater understanding in these areas can help to ensure value chains are working collaboratively to share value, from consumer to producer. Collaborative value chains that effectively communicate credence attributes will help enhance New Zealand's global reputation for sustainable and high-quality primary products.

Conclusion

The OLW National Science Challenge seeks to increase or maintain the economic returns from agriculture while reducing the impact of its production on the environment. This report supports the Challenge's mission by describing how credence attributes can be used to capture more value from New Zealand primary products without requiring greater production volume. The report describes the current state of knowledge about the technologies and standardised audit systems that are in place to ensure international consumers have trust in sustainable New Zealand primary products.

New Zealand's global reputation for producing trusted and sustainable primary products is crucial to getting the most value out of our products. These products need a value chain that builds and supports that trust. Internationally, consumers expect greater quality and value from their food than ever before. At the same time, the value chains that produce that food are becoming more complex and less transparent, making it more difficult to provide trust in credence attributes associated with food products.

Trust in food protects the values associated with it

Producers are increasingly seeing the need to encourage trust in their products through establishing and communicating information to consumers. The following types of value are particularly important for New Zealand primary food products:

- **product value** – attributes such as the taste, quality and cleanliness of a product
- **process value** – attributes such as sustainability and animal welfare in production
- **emotive value** – attributes such as being produced on a family farm.

Traditionally, there has not been an accurate way for consumers to verify that claims made about products are genuine and the food they consume supports their values. Credence attributes associated with process value and emotive value have been particularly difficult to verify. Instead they have relied on brand and reputation for trustworthiness. Features such as branding and reputation support credence attributes that make up a significant proportion of the value of food products.

Sustainability is becoming more important

The sustainability of food products is becoming increasingly important to consumers, governments and other organisations. Sustainability falls into the category of 'process value' – consumer values attached to the process of production. New regulations are being developed and enacted to ensure that food products adhere to standards of sustainable production and processing. As this importance grows, sustainability may become a condition of entry to some key export markets for our food products. There are a wide range of sustainability standards and certification systems that purport to verify the sustainability credentials of food products, many of them in use in New Zealand already. The proliferation of sustainability audit systems is a natural response to the wide nature of the term 'sustainability'. Different systems will focus on different aspects of sustainability, and will be more or less relevant in specific industries and sectors. Care needs to be taken however, that certification schemes are sufficiently robust and provide genuine backing for the sustainability of the products they certify.

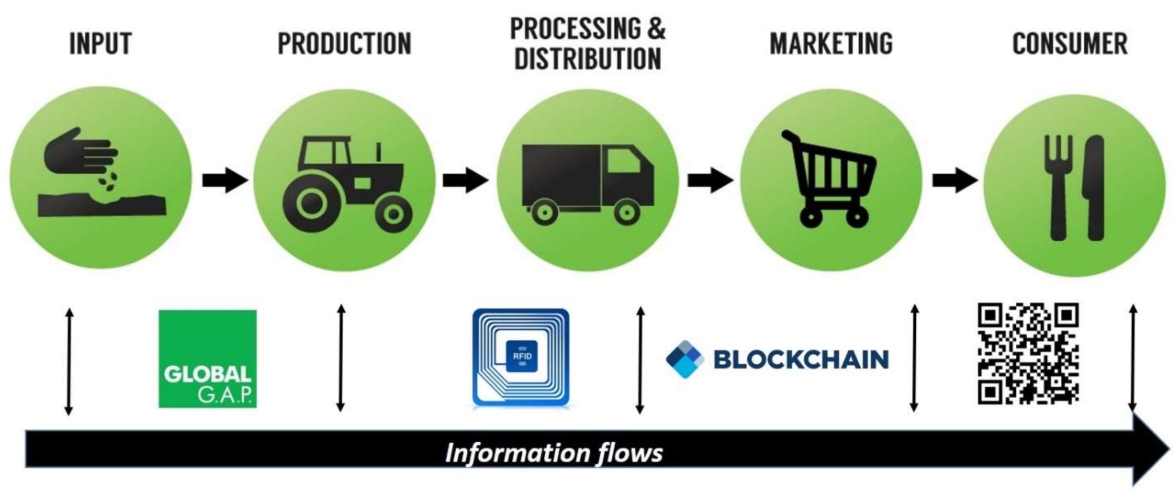
Smart technologies can be used to communicate through the value chain

Establishing value starts at the beginning of the supply chain, with farmers and growers. New technologies can trace food right from the farm to the fridge. It is important that these technologies are used throughout the entire value chain to maintain the flow of information.

One type of smart technology, which we call primary technologies, communicates information along the value chain in an unbroken way. As shown in Figure 29, for primary technologies, audit schemes provide assurance that robust information about practices and processes has been generated at the producer stage. Primary technologies help to capture more value by providing traceability and communicating that information throughout the value chain. A number of these technologies are currently in use, and gaining popularity in our key export markets, including QR codes and RFID. QR codes are one of the most popular technologies, with Asian markets such as Taiwan and Hong Kong reporting wide use of QR codes. QR codes are used for traceability, and are a cost-effective way to communicate meaningful information about products. RFID is used similarly, to provide traceability through the whole value chain from the farm all the way to consumers. It has been shown to improve supply chain management practices, but because a physical transponder is necessary for it to function, it is more expensive than other communication technologies.

Blockchain is another technology that provides traceability and is increasingly being used by food producers. The advantage of blockchain is that data is encrypted, meaning it cannot be modified and keeps a secure record of all transactions in the value chain for participants to view. While it is still a new technology, there is large potential for its use in food value chains.

Figure 29: Primary technologies supporting information flows through value chains

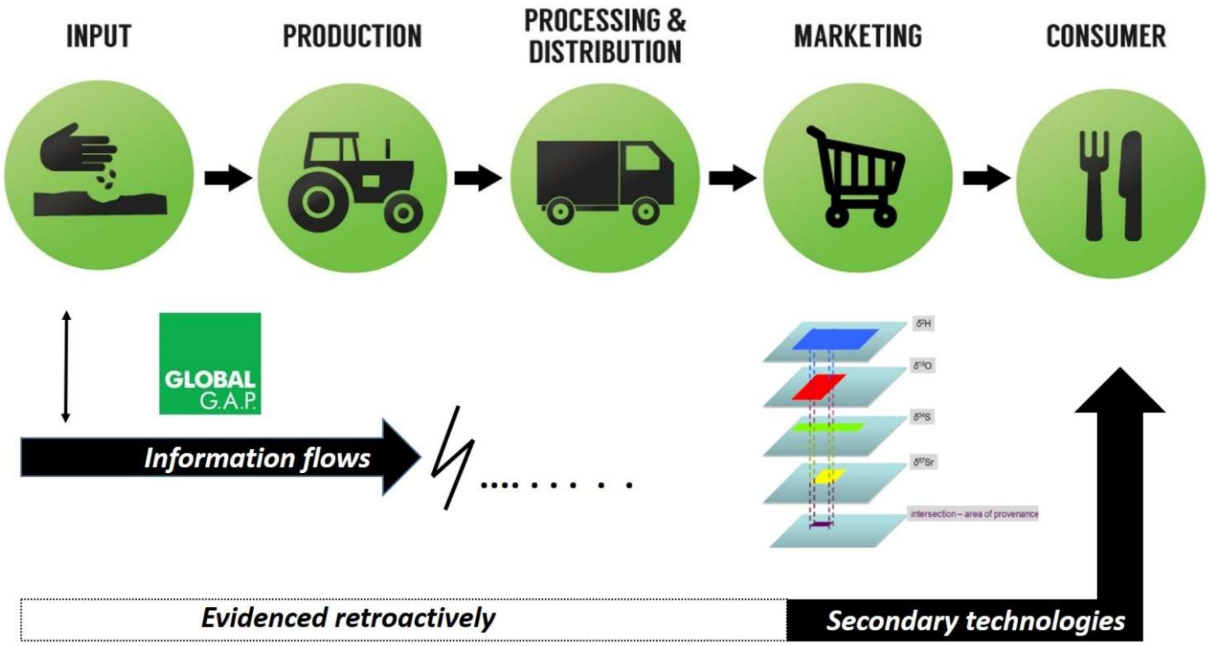


We have technologies for 'cure' as well as 'prevention'

A second set of technologies, which we call secondary technologies, can be used when there are breaks in the chain of communication about the provenance of a product or the authenticity of its claims. These technologies exist to quickly provide information when questions and issues arise after a break in the information chain (Figure 30). Isotope testing, along with other forms of scientific authentication, has been developed as a way to support product, process and emotive value in food products. Isotope testing is a useful secondary technology for verifying the provenance and attributes of food products when questions arise. It can be used to confirm or rebut questions on the authenticity of products claiming to be New Zealand product and help to protect the legitimacy of New Zealand credence attributes.

When there is potential food fraud, New Zealand needs to be able to address it quickly and decisively to protect the trust consumers have in New Zealand products and to protect the value of brand New Zealand. Technologies such as stable isotopes, DNA testing and biomarkers can be used to verify or refute claims made about the authenticity or provenance of food and beverage products.

Figure 30: Secondary technologies filling information gaps in value chains



Government has a role in maintaining food trust

Food trust exhibits aspects of a club good and aspects of a public good. To the extent that trust in food relies on New Zealand as a Country-of-Origin (CoO) label, firms are using the common pool of trust in New Zealand. This can create externalities (costs created by one firm but borne by other firms) where that trust is broken. A food scandal with one New Zealand firm whose product is labelled "made in New Zealand" will affect the reputations of other firms using New Zealand as a CoO.

The nature of trust in New Zealand-made food as a public good suggests that government involvement may be warranted. Typical problems faced in the management of common pool resources are over-use and under-investment. These issues suggest there are possibly roles for government in investing in the development of CoO branding, or in mitigating the externalities for firms using it.

The government is already involved in mitigating and reducing the effects of food scandals on 'brand New Zealand'. Primarily it is involved through regulating the food sector – through food safety and animal welfare regulations. In addition, the government will sometimes assist with managing the reputational effects of a food scandal if it threatens to have a significant enough effect. The government already acts to mitigate the externalities; however, there may be greater role for the government to invest in getting the full benefit from New Zealand's reputation, similar to the Origin Green campaign seen in Ireland. Whether this is necessary is a question for further study.

Value depends on informing consumers

Getting the most value from products relies on information about the value and attributes getting to consumers. This is of particular importance for credence attributes. The increasing use of digital media and smart technology by consumers means that it is a key avenue for making information accessible.

These technologies are important for ensuring that accurate information about a product is maintained and communicated to all participants in the value chain. Consumers are increasingly making use of these technologies for both accessing information and purchasing products. As these technologies become more trusted, so too do the producers that use them.

We have identified a range of technologies and audit systems that are currently in use to build trust in New Zealand's primary products, as well as others that are being developed, supporting Hypothesis 3 of this project. New Zealand producers need to be aware of these technologies and how they can use technologies and audit systems to maximise the value in their products.

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