

Evolving Risks in Global Food Supply

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Moore is a global accountancy and consultancy network with its headquarters in London.

Since its foundation a century ago, Moore Global has grown to be one of the largest international accounting and consulting groups worldwide. Today the network comprises 614 offices in 112 countries throughout the world, incorporating 30,168 people and with fees of more than US\$2,908.6 million.

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Executive summary

The farming of crops and livestock is more than 12,000 years old, but it is only over the past 200 years that the food supply chain has evolved into the form we see today. Accounting for more than \$8 trillion of global GDP and a critical element of all countries' infrastructure, the collective importance of food supply chains around the world is unrivalled.

Across the globe, there are four phases of food supply chain development: from local producers using local markets and direct selling through to the sophisticated mix of online sales and traditional retail in most developed economies today. Given the complexity, inter-dependency and competition, it is now widely recognised that the food supply chain is not so much a chain, as a complex network of producers, processors and retailers. This complexity is amplified by the pre-processing of raw ingredients, which are used for second stage processing.

Within this complex and evolving network, there are many opportunities for the insurance industry to provide insurance products that support this globally connected infrastructure.

Sources of new business

The food supply sector is consolidating due to stiff retail competition and the growing power of retailers, both ultimately driven by consumer demand. Consolidation means that contamination, business continuity and contract frustration costs can be much higher for processors in the supply chain, which is increasing demand for comprehensive insurance policies. It can also mean better control of standards and oversight makes consolidated businesses more attractive propositions for insurers.

Food supply chains, from field to fork are also feeling the effects of digitalisation.

Smart farming has been identified as one of the changes needed to increase the productivity of food production. Wherever data is generated and used, issues of ownership, liability and cyber risk also arise.

Changes in the way society functions means consumers are more aware of the provenance surrounding the food they consume. Supply chains need to be 'consumer aware' and any failures in livestock care, labelling, contamination and environmental impacts will threaten the economic survival of those businesses in it.

New insurance product development

Cyber: with the digitisation of the agricultural and livestock supply chains, cyber resilience and cyber-crime protection is becoming increasingly sought after. In a study cited in this report, agricultural and food systems are identified as particularly vulnerable to this sort of risk. Fast recovery from cyber-attack is critical if companies want to reduce business interruption and the loss of stock – and therefore the costs of recovery.

Reputation management: With growing social consciousness on how the farming industry treats livestock and consumers' increasing interest in the food they eat, provenance is becoming more and more important. This change is increasing demand for reputation-related insurance products, mainly for retailers and product brand leaders. Product recall insurance is also needed to match societal demands for assured quality.

Devaluation of stock: food producers are capitalising on the trend to spend discretionary disposable income on luxury foods. From ice cream to organic produce, there are premium ranges of most items on supermarket shelves today.

Food producers must buy stock to meet retailer product test quotas and product launch plans. Insurers could offer products that re-capitalise food producers for the loss or write down of stock in the event of a failed launch.

Conclusions

From brand management and product recall to cyber insurance and stock management, the modern food supply chain – and other non-food supply chains - offer substantial opportunities for the insurance industry.

Furthermore, inevitable evolution of the food supply chain will give rise to new risks, new demands and new opportunities for innovative insurance companies.

Using the information in this report, insurance companies will also be able to foresee the needs of less developed food supply chains and adapt existing products to serve new markets. Insurance companies will also be able to apply some of the insight from this complex sector to similarly evolving non-food chains.

Objective and content of report

This report has been prepared to provide thought leadership on contemporary and near future risk in food supply chains and to serve as the basis for further discussion. The focus of this report is on the dynamics of the supply chain and primarily the dynamics between producers, processors and retailers. Logistics, the commercial activity of transporting goods to customers, is recognised as part of the supply chain process, but also as a subject that justifies a separate report. Within this report, the role of logistics is acknowledged, but the detail of risks from logistics operations are excluded from the scope of this report.

The objective of the report is to:

- Generate a better understanding of food supply-chain risks and their implications for the insurance market, including gaps in cover and other opportunities to improve services for supply chain organisations.
- Provide the Lloyd's market with an overview of current and future risks arising from food supply chains.
- Assess what the future might hold for the food supply chain industry and how those changes might affect the insured risks.

Insuring the supply chain

The modern food supply chain is more accurately understood as a highly complex and dynamic food supply system or network. It is the flow of foodstuffs from multiple producers to multiple consumers, via a network of processors and retailers. The food supply chain is also recognised as one of the essential global systems for human survival and civilization. At present, according to the World Bank, the food system; production, transport, manufacturing and distribution accounts for 10% of world gross domestic product (GDP)

Unsurprisingly, with immense value and complexity, the food supply chain is subject to many complex and dynamic risks. These risks can broadly be categorised as economic, operational, geographic, moral and regulatory. As examples: Retailers can be left with costly recalls due to contamination of their products, farmers may have land quarantined and livestock destroyed due to disease. Extreme weather may result in catastrophic losses in all parts of the supply chain. Overproduction can result in below-cost pricing. Food shipments may be stalled by a cyber-attack and other physical interruptions. And, in many of these events, processors may be left with empty idle factories, incurring contingent business interruption losses.

For each step in the supply chain, insurance offers a range of products and services to help companies protect themselves against losses. As companies within the supply chain consolidate, adapting to changes in production, regulation, technologies, markets and market standards; the risks also change. This creates fresh opportunities for insurers to expand their current coverage and create new types of policies and services.

There is also opportunity for insurers to partner, as some already have, with other entities in the food supply chain or technology sector, to reduce risk, improve risk pricing, incentivise compliance and increase resilience.

A recent report listed the top five risks in food systems that insurance products could address: Non-damage business interruption; fraud and adulteration, political risk, contamination of stock and extreme weather.

Typical offerings

Most of what is presently offered by the insurance industry to this sector is similar to forms of insurance available to any business, including property, business interruption, product recall, liability and reputational damage. Cyber insurance is considered a growth opportunity for the insurance industry. Sasha Romanosky of RAND Corporation estimates that the market for cyber insurance will grow to \$10-15Bn in the next decade, noting agriculture and food systems are generally considered very vulnerable to attack (Jahn, 2019).

Food retailers primarily look for insurance to cover their physical infrastructure, business interruption, liability, and product recall events. Due to the large number of suppliers that retailers use, the retailers' high brand profile, and consumer-facing business, risk profiles for retailers are considerably different than for more upstream interests in the food supply chain.

Food distributors and logistics companies move foodstuffs and ingredients from the producer to the processor, and from the processor to retail outlets. Insurance opportunities in this sector will focus on infrastructure, liability, catastrophic events and security breaches. Changes in weather patterns may have especially important effects on transport whether by road, rail, air or sea. Furthermore, the integration of smart devices and surveillance throughout supply chains opens up new vulnerabilities and risks from cyber threats.

Processors look to minimise the effect of risks that interrupt their business or damage relationships with clients and suppliers. Processors also work to reduce their exposure to major swings in the price of their inputs, and to reduce product recalls due to contamination events within their facilities.

Agricultural producers look for insurance that is a hybrid between commercial and personal cover that protects their home and business premises. In some instances, producers may also extend cover to include business interruption and liability.

Insurers provide several forms of insurance to cater to these needs including; business interruption, commercial general liability, personal and commercial property, transport issues, product withdrawal expense coverage and contaminated products insurance. These insurances offer robust protection against the key risks for those involved in the production and supply of food stuffs.

Contingent business interruption insurance for a supply chain

The wide variety and inter-linkages of contemporary supply chains makes it difficult for analysts to describe and frame specific “supply chains”, which in turn make it difficult for insurers to devise comprehensive packaged solutions. Contingent business interruption is part of an insurance product range approach to this problem and a product that allows companies to insure against supplier non-delivery.

The challenge contingent business interruption poses, is that for each supplier, or level of suppliers the policy covers, a significant amount of unknown risk may be aggregated because the company cannot necessarily monitor the flow of foodstuffs in real time. Underwriters respond to this by including limits in their policies. Access to better information from technologically advanced farm and processing equipment may allow these limits to rise.

Mandated insurance

Retailers in numerous industries require their suppliers to take out insurance to limit losses and help the supplier continue to function if it is struck by certain disasters. In this, the food supply chain is no different, but it may have more capacity for growth than other sectors. As a benchmark, one market member estimates the automotive industry to have 80-90% of suppliers on mandated insurance. Product liability and recall are the most common insurances required of food suppliers by retailers. Insurers continue to be interested in this sector, but as this report documents, the nature of the losses is changing, and insurers would do well to keep informed of how rapidly claims may grow.

The U.S FDA Food Safety Modernization Act 2014 (FSMA) addresses the sanitary transportation of human and animal foods. Implemented in 2017 it mandates record keeping and insurance in transport. The rate of compliance with this law is rising as inexpensive subscription services become available, e.g., Repositrak. Because FSMA reinforces best practices, it reduces risk, but what constitutes adulteration under this scheme

though, has yet to be defined. FSMA may be an interesting opportunity for insurers.

Cyber risks and insurance

As global food supply chains become more complex, cyber vulnerabilities grow through increased reliance on automated data-driven systems, smart devices, artificial intelligence and robotics. Even brief interruptions at critical harvest times or with critical infrastructure may lead to significant losses. Lloyd’s recent report ‘Cloud Down’ (2018) found that a 3-6 day of loss of access to cloud providers could result in an estimated \$251 million of ground up losses in the food and accommodation industry.



Cyber Scenario: Effect of a global ransomware attack

Global networks are now susceptible to unprecedented levels of cyber-attack and the incentives to launch this type of attack are growing. Ransomware can hide in carefully tailored emails that appears from a genuine source. Once a single employee has opened the attachment, a hidden executable may be able to run on the computer, downloading and spreading the ransomware worm:

....only minutes after the attachment was first opened, all data on computers sharing the network with that device were fully encrypted and each victim presented with a ransom message demanding \$700. The demand used an open-source cryptocurrency for payment; common in such attacks. To further its attack, the worm accessed email and forwarded the malicious email to all contacts within infected devices' address books.....

The mini scenario above is typical of the kind of attack which is on the increase, enabled by anonymous cryptocurrency transfers. In a scenario where only 1% to 9% of networked devices are affected the potential loss for the food and agriculture industry could be as high as \$3.5 billion in direct and indirect loss. More information is available about the risk of cyber-attacks in other recent Lloyd’s reports

(This section is based on the [CyRim Bashe Attack](#) report published by Lloyd’s in January 2019)

Insuring against class action lawsuits

There is an increasing risk of class action lawsuits filed against companies in the food supply chain, especially against “big” food manufacturing companies. Insurance may develop tailored products to provide industry with options to manage some aspects of this exposure.

As the world tries to handle a growing obesity and diabetes crisis, more scrutiny is being applied to companies that may be seen as contributors to the problem. In some ways this is like the accountability placed on tobacco companies for the health issues caused by smoking. In the food supply chain, retailers and processors are being closely scrutinized over the contents of their products and the impacts on health that they may have.

Insurance for settlement and legal costs in class action lawsuits can help offset large losses and reduces the uncertainty of losing an unspecified sum to a known premium payment, which can be factored into costs.

For example, McDonald’s settled a class action lawsuit in 2009 based on a 2002 promise McDonald’s made to reduce the use of trans fats in its cooking process. In the case, the plaintiffs claimed McDonald’s had not done enough to inform customers that it had retained the fats in its cooking process (IJ, 2005).

Over 2017 there were 145 class action lawsuits filed in the US, mostly around false labelling, a 21% increase on 2016. Such lawsuits are potentially costly and attract large settlements if won. This being both a threat and an opportunity for insurers. (See: Food Litigation 2017 Year in Review from Perkins Coie for detailed breakdown of sectors)

Parametric insurance in agriculture

Parametric insurance is an insurance policy that provides a predefined sum, if an agreed reliable and independently reported trigger is met. It is an increasingly popular product in agriculture, but there may be opportunity to extend its use to other parts of the supply chain. Current options are often connected to weather events, where policies are available for a range of crop damaging perils. This type of cover helps suppliers mitigate losses of a poor season, characterised by unusual weather events. While insurers are now offering it to individual producers, African Risk Capacity (AFC) has been providing this service over large portions of Africa for several years. In 2016 the AFC provided \$8m to Malawi after the modelling of a drought (the agreed trigger mechanism) triggered the policy.

Agricultural risk and insurance

Lloyd’s offers cover for agricultural risk for farms in many countries around the world. Lloyd’s recognises the value and importance of agricultural cover, but also the modelling services necessary to support major agricultural schemes. More information can be found in the Lloyd’s report ‘Harvesting Opportunity, 2018’ which deals directly with this topic of modelling losses in agriculture.



Insight: Food-related scenarios in the 2017 'Stochastic modelling of liability accumulation risk' study

A review of food-related scenarios carried out in the 2017 'Stochastic modelling of liability accumulation risk' study (Lloyd's and Arium, 2017), demonstrated that while there have been few recent large historic food-related events in the developed world, there appears to be potential for significant future losses (*see below examples*).

While casualty risks accumulate in a variety of different ways and may affect many lines of business, it remains important for insurers to approach casualty risk accumulation systematically.

Near misses: In the Sudan 1 red-dye loss, products were recalled before reaching the consumer. The UK 2013 horsemeat scandal turned out to be mislabelled food rather than harmful food.

Both "near miss" events demonstrate the cascading effect of ingredients through the supply chain and widespread distribution across national boundaries.

Formal analysis of the events and asking counterfactual questions about these near-misses could help underwriters get significant additional insights into extreme losses and reduce future market surprises (Woo, 2016)

Fraud losses in the less developed world: In 2008, a nitrogen-rich substance known as melamine was added to milk, particularly infant formula, affecting tens of thousands of infants in China.

Melamine had sometimes been illegally added to food products to increase their apparent protein content and it is known to cause renal failure and kidney stones in humans and animals (International Risk Governance Council, 2010).

Food industry losses in previous decades: In 1973, a fire-retardant chemical called polybrominated biphenyl (PBB) accidentally got mixed into livestock feed.

The accident was not recognised until long after the bags had been shipped to feed mills and used in the production of feed for dairy cattle. Studies estimate 70-90% of people in Michigan had some exposure to PBB from eating contaminated milk, meat and eggs.

The Michigan Department of Community Health (MDCH) says the "overwhelming majority of those who were exposed to PBB received very low levels". However, some individuals had higher exposure (40 years after toxic mix-up, researchers continue to study Michiganders poisoned by PBB, 2014).

Food-related emerging risks: There are several emerging risks related to food additives (e.g. phosphates and nitrate), to plasticisers used in food packaging (BPA), to other technology introduced into the food chain such as nutraceuticals and to changing society awareness such as the amount of sugar and salt in food.

Source: Lloyd's and Arium, 2017

The value chain

By mid-century, it is predicted that the world population will surpass 9 billion people and may even reach 10 billion. This increased population, that is also an increasingly affluent population, will naturally drive a higher demand for food.

To feed the current and growing population, the food supply chain, that is rather more a 'complex supply network', can be roughly broken down into five groups:

Producers

- **Farmers:** Agriculture is the cultivation of land and breeding of animals and plants to provide food, animal feed, fibre, medicinal plants and other products to sustain and enhance life.
- **Horticulturalists:** Horticulture is that part of plant agriculture concerned with vegetable crops and ornamentals, flowers, nursery stock and turf, as contrasted with forestry or agronomy (field crops, mainly cereals, legumes and forages). It is the branch of agriculture concerned with intensively cultured plants directly used by humans for food, medicinal purposes, or for aesthetic gratification.
- **Aquaculturalists:** Aquaculture is the breeding, rearing and harvesting of fish, shellfish, plants, algae and other organisms in all types of water environments (NOAA, 2018). For simplicity, we include commercial fishing and other harvesting of wild stock within this definition.

Transport of agricultural product to processor

- Commodities are transported from the farm to the processors' door. Grains are often bulked before transport to a processing facility or exporter.
- Transport may be accomplished by road, rail, air, ship, or even animal power. Each of these modes of transport has distinct risks. Every link in the network is vulnerable to accidental or intentional contamination, adulteration or simple loss, as well as losses due to interruptions caused by extreme weather, theft, equipment failure, labour and contracting issues.

- Some commodities may be stored before or after processing, awaiting more favourable prices, using future contracts and other instruments to maximize profitability. The deregulation of agricultural commodity trading has allowed speculation, which among many factors, can fuel price volatility. Hedging strategies may be necessary to protect the financial viability of certain commodity producers.
- There may be considerable waste of agricultural produce or biomass; a feature of food systems that is of increasing interest. There may be new risks as food waste is repurposed. Integrated energy systems, retrofitted into ageing processing facilities, may exacerbate problems as society demands better ecological performance.

Processors

- Food processing, also known as food manufacturing, is the conversion of agricultural and horticultural products into food products which are acceptable to consumers. This includes appropriate nutritional value, freedom from adulteration or contamination, and in the developed world, preservation to lengthen shelf life; fresh and organic produce excluded of course.
- Primary food processing is the conversion of raw materials to food commodities e.g. milling grains or milk pasteurisation.
- Secondary food processing is the conversion of ingredients into edible products – this involves combining foods in a way to change properties. Examples include bread, cake and ready-meal production (Janick, 1972).
- Food processing is extremely energy-intensive. Many efforts in the industry are now focused on integrated heat harvesting, using renewable energy and improving processes where possible.

Food distribution system

- Food distribution systems bring food products from the food processing facility to the final consumer-facing retail outlet. Food distribution systems can be viewed across many scales from household patterns, or seasonal patterns, to global systems.
- Contemporary food distribution systems are vulnerable to substantial interruption (high impact, moderate probability) through armed conflict, cyber-attack, weaponised misinformation and many other plausible situations. Less dramatic, but still significant and more frequent is of course the impact of extreme weather.
- Food distribution systems are both formally complex (dynamic, uncertain and evolving) and complicated. This makes them highly sensitive to volume (availability) and quality variations, local economic issues, cultural considerations and overarching market conditions. Radical changes in the food distribution system are also underway with a growing array of products, including an explosion of ethnic foods in mainstream grocery stores

This network of different entities must deal with food safety issues, nutrition deficiencies, postharvest losses, regulation inconsistencies and dynamic consumer attitudes, all of which must be met while maintaining food security and sustainability. However, due to the wide array of entities and interests involved; coupled with comparatively low profit margins, it is difficult for the industry as a collective to innovate.

Individual entities within these systems are however looking for possible methods to increase production. These may include using advancements in food processing technologies, nanotechnology, innovative food formulations and the use of genomic approaches. Contemporary examples include alternative protein sources, insect flour, nutrigenomics, 3D food printing, biomimicry, food engineering and emerging technology (SC-S, 2018).

Food Retail and Food Service

- Through any number of mechanisms, food ready for consumption is marketed to consumers through grocery retail outlets, food service counters or institutions.

In less developed economies, retail and service are typically by way of producer and wholesaler markets; which may be little more than collections of open-air roadside stalls. Developed economies feature grocery store chains, online sales and complex distribution channels.

- A grocery store or grocer's shop is a retail outlet that primarily sells food. A grocer is a bulk seller of food. Grocery stores also offer non-perishable foods that are packaged in bottles, boxes, and cans; some also have bakeries, butchers, delis, and fresh produce.

Large grocery stores that stock significant amounts of non-food products, such as clothing and household items, are called supermarkets. Some large supermarkets also include a pharmacy, and customer service points (including redemptions), homeware and electronics sections (Wikipedia, 2018).

Supply chain development

Since around 9,500 BCE, organised farming of crops and livestock, and the processing, distribution and retailing of foodstuffs (collectively “food supply chains”) to meet the nutritional demands of non-agricultural communities, has progressed through several phases:

Figure 1: Phases of food supply chain development

Phase	Food supply chain parameters	Characteristics of phase
1	Local producers supplying local markets that sell to consumers.	<ul style="list-style-type: none"> – Power^a lies with producers dictating seasonal availability and spot pricing. – Little consumer choice of supplier or product. – Little emphasis on food safety, integrity and protection.
2	Industrial food processor companies with branded products selling into networks of retail stores that sell to consumers.	<ul style="list-style-type: none"> – Power lies with the major processors. – Consumer reliance on brands for consistent and safe product content. – Little consumer price comparison or brand/product substitution. – Traceability and food safety is often improved, as is the diversity and value of food products – System is increasingly energy-intensive, among the most of any manufacturing processes
3	National and international supermarkets, with the development of supermarket own-label brands, that sell to consumers.	<ul style="list-style-type: none"> – Emerging supermarket buyer power yielding supply chain price deflation, pan-national sourcing and all-year round availability – Low price ‘consumer champion’ strategies adopted by the majority of supermarkets to attract business – Working capital squeeze on suppliers used to fund supermarket growth strategies.
4	Online grocery supply selling direct to consumers	<ul style="list-style-type: none"> – Online versus ‘Bricks & Mortar’ retailer power struggle. Producers and processors remain weak. – Slowing ‘Bricks & Mortar’ supermarket growth in mature markets, expect retailer consolidation. – Deep discounter retail model with limited product range increasingly appealing to a majority of (cost conscious) consumers, driving changes to mainstream ‘Bricks & Mortar’ retailer offerings. – Online retailer challenge is to balance higher pick, pack and distribution costs relative to property and labour cost savings, whilst maintaining product availability and choice.

Phase 4 is in its infancy. It is possible that the retailer winners in this phase will be those that successfully combine Bricks & Mortar and online sales channels.

^a The term ‘power’ in this report is used in the context of Porter’s 5 Forces model PORTER, M. 1985. Five Forces Model Competitive Advantage. The Free Press, New York, NY.

The focus on low cost food for the consumer results in high volume, low margin, just-in-time deflationary grocery supply. This deflation being a characteristic emerging in a Phase 3 market, where consumer buyer power has been placed by proxy in the hands of dominant supermarket retailers. The resulting power concentrated in a few (dominant) retail buyers over the many suppliers has consequences that impact every level of the supply chain. In particular, raw commodity providers are having to cope with sustained low global commodity prices.

The principal response behaviour in the supply chain to the power held by dominant retailers, is to scale up operations. This has led to consolidation; reducing the overall number of food producers, processors and independent retailers, while the scale of each remaining business is typically increased. One possible advantage from consolidation is it may drive improved quality practices as well as consistency throughout the supply chain.

Changes for consumers

Increasing waste

Food and drink are becoming a smaller proportion of household expenditure in developed economies (less than 10% compared with c. 40% a hundred years before). This has unintended consequences where consumers are less concerned about minimising food waste. Food waste currently runs at 1/3rd of all purchased foodstuffs in many developed economies such as the UK (DEFRA, 2018).

Increasing health risk

Over the past generation, there has been nothing short of a revolution in most of the developed world about the relationship between food consumption and dietary health. Excessive consumption per head is becoming an increasing problem, leading to obesity and other health problems in the population of developed economies (DEFRA, 2018). A feature of processed food is unhelpful in managing these problems, with its greater digestibility and calorific yield over the unprocessed constituent ingredients i.e. more processed foods are digested more completely (Tian et al., 2016).

Interest in novelty

Another trend of the modern era is the growing interest in novel foods as people use a proportion of their disposable income to engage in culinary experiences. The food supply industry has capitalised on this interest with premium products, sold at lower volumes, but with a higher margin.

Interest in source

In the developed world, consumer interest in agriculture has heightened significantly with major controversies

over many aspects of production including GMO labelling, animal welfare and pollution. This interest is an opportunity for producers and processors to demonstrate their food provenance and credentials to enhance price and margin.

Changes for retailers

Becoming both advocate and protector

With consolidation among retailers in developed economies, the top grocery retailers have risen to control large portions of the market. Consumer buying power is now held in the hands of a few companies, which allows them to drive their supply chains to ever-lower prices. However, consumers also come to see these large retail companies as the gatekeepers of safety and food standards. When contamination occurs, the retailers generally take a reputational hit and incur costs for recall, despite the event having occurred before the product even entered the store. Although on the other hand, retail practices are also part of the problem, driving some suppliers to cut costs inappropriately.

Changes for processors

Cutting corners

The complexity of manufactured foodstuffs and the low-price strategies adopted by supermarkets encourages lower-cost ingredient substitution by manufacturers to maintain margin. Consequent cost-cutting can only go so far before it lowers product quality, and at its worst can result in food fraud with deliberate mislabelling of product as seen in the 'Horsegate' case (Brooks et al., 2017) and occasionally with potentially lethal consequences (e.g. ground peanut shell misapplied to 'bulk-up' expensive ground cumin sold in US, Europe and Canada, (Agres, 2015).

The potential for legal action

As already mentioned in relation to consumers, excessive consumption in developed economies is becoming a problem as it leads to obesity in the population. This and other health issues raise the possibility of class-action claims; akin to those in the tobacco industry, against major food processors and retailers. For example, nitrates in processed food is becoming a potential health issue that may generate class actions lawsuits in the future, as society is particularly sensitive to links with cancer. Equally, but from a different perspective, claims of 'all natural' ingredients are frequently being successfully challenged, leading to the possibility of increased industry losses (Xie et al., 2016).

Changes for producers

Pressure to increase yields

Supply chain deflation means agricultural, horticultural and aquacultural enterprises are having to achieve productivity gains of 1 to 2% per annum to economically 'standstill' in terms of profitability and cash flow (Kaushish, 2015). This pressure means these enterprises can little afford unexpected costs.

Pressure to reduce price volatility

Producer-entities are increasingly using contracts (including derivatives) (Madre, 2016) to sell-and buy-forward to lock in prices to minimise price volatility shocks. This is one mitigation strategy, but insurance may be an alternative with at least one agent known to be offering such a product.

Rapid penetration of "smart" devices with large scale data transfers off farm

Low commodity prices coupled with increased complexity in farm equipment is forcing farmers in the developed world to realise they no longer can fix equipment on the farm. An equally modern problem is that producers do not control the streams of useful data their equipment can now provide. On the other hand, such changes in equipment management and the new source of valuable data provides new opportunities for insurers. Indeed, modern production is a capital-intensive operation with equipment such as robotic milking machines, planters and combines, all being potentially vulnerable to cyber-attack (Jahn, 2019). Equipment cover with access data triggering policies is now possible as is cyber protection cover.

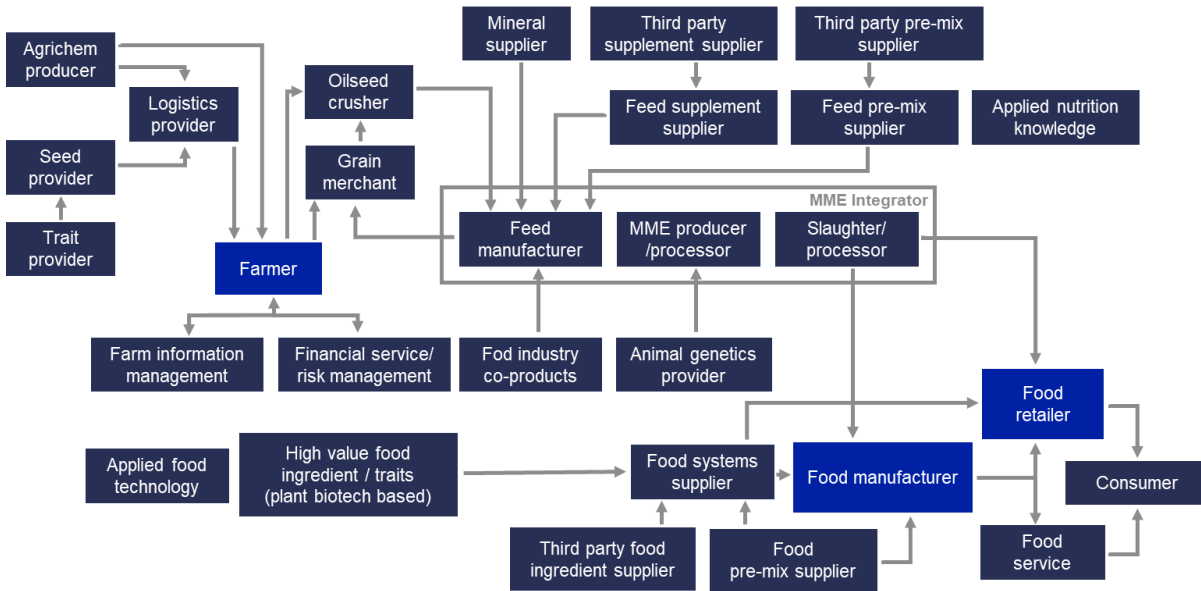
Looking forward, this investment in complex technology is also set to increase as producers make the most of innovative Smart Farming methods, utilising Artificial Intelligence (AI) and other technologies to maximise yield. Such developments may provide insurers with the information needed to enhance Contingent Business Interruption products which are currently data limited.

Supply chain and network

As part of their response to reduce costs, entities involved in food supply have developed larger, interdependent and more complex supply chains. In fact, the food supply chain is far closer now to a complex network and as such, is open to new dependency threats. This increased complexity is not limited to the food industry and the scenario of competing networks is well documented through extended enterprise research that started in the 1990s. During this time, industry also recognised the value of using systems analysis tools to understand the industry. The insurance industry may find systems approaches equally useful when considering customer needs and when developing new products.

From the risk aggregation perspective, networks transmit shock events such as drought, flood, heat wave, fire (including wildfire), mechanical failure, feed or water contamination, pests and disease more widely. The development of networks in food supply may also encourage retailers to switch from arms-length multisource of foodstuffs, to collaborative development. Such a move towards cost sharing and long-term innovative relationships with key suppliers is akin to that evidenced in the evolution of car manufacturers and their parts suppliers (Schwartz, 2000). Insurers should see this as an opportunity to provide risk sharing policies and other innovations aimed at a broad, information rich, networked industry.

Figure 2: An example of how the food supply chain exhibits network complexity



What the supply chain looks like now

To understand the opportunities for new and more profitable insurance products tailored for agriculture and food supply chains, it is important to have a good understanding of the forces at work in the real supply chain and not of some simplified, theoretical model. This means learning to fully appreciate how it 'actually' operates in developed and developing countries and how it is rapidly changing.

In developed economies, there has been a gradual transfer of power^b from producers to processors; and then from processors to supermarket retailers. This transfer taking place over just the last 100 years of development, leading to the present retail dominance:

Figure 3: Grocery market shares by sales

Country/ Region	Total grocery sales in area		Comment
	Top 4	Top 10	
USA	30%	40%	Largest Kroger US \$103.46bn revenue is c 40% larger than UK Tesco at 2016 rate of \$1.32: £1
UK	70%	96%	Largest Tesco £55.92bn revenue 2016/17
EU	29%	59%	Includes Tesco at no.1

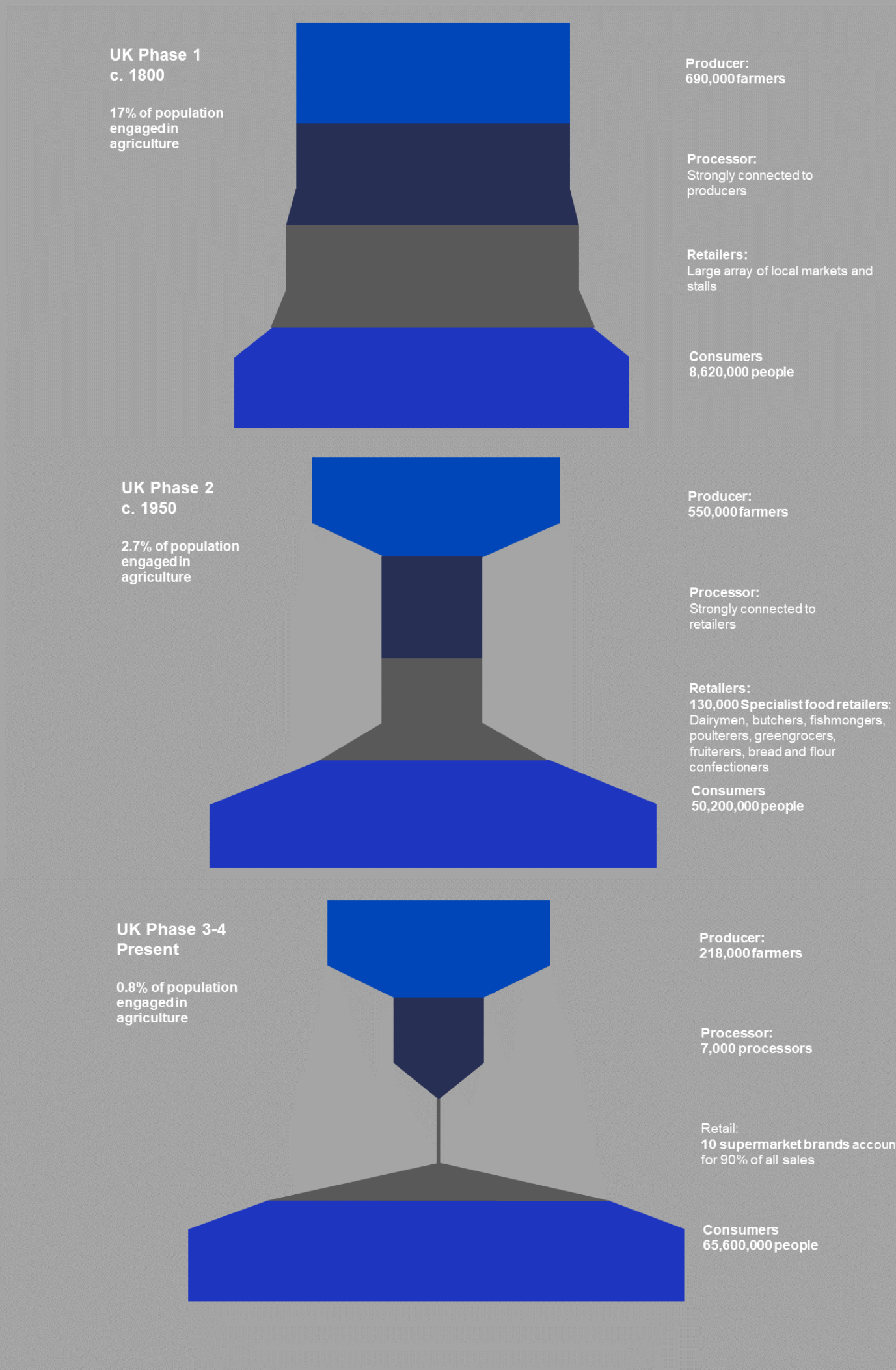
The emergence of giant retailers in developed economies places them at the head of the food supply chain and their hold on the chain below them is consolidating further. For instance, in the UK just ten supermarkets control 90% of all the trade to consumers. Retailers in such a position can dominate the market, acting as gatekeepers to both new and existing suppliers who are seeking access to a growing number of consumers.

In the EU and some US jurisdictions, laws are in place that help to protect producers from processors by trying to limit abuses of power. For example, stopping those who seek to place the risk of excess production back onto the producer through unfair contract provisions. These 'anti-abuse' measures help spread the risk of loss, or even shift it entirely on to processors. US states that operate such laws include Minnesota, Arkansas, Georgia, Illinois, Kansas and Iowa. Given this difference across US states, insurers must be familiar with liability and contract laws and regulations in any jurisdiction in which they offer policies.

Our choice of graphical illustration for this narrow channel of supermarkets, is the UK with its many suppliers and many consumers that may be likened to a rudimentary glass timer. The sharp angled sides reflecting how acute this imbalance of suppliers, processors, retailers and consumers really is.

^b Again, power is used with reference to Porter's five forces model

Figure 4: UK food supply chain development over the last two hundred years



This 'Glass timer' effect is also evident in Europe with just six hundred supermarket chains distributing produce supplied by over three million producers.

It is also evident in smaller developed economies such as New Zealand where seventy thousand farms supply less than a hundred supermarkets. These supermarkets being in turn supplied by monopolistic processors, for instance, Fonterra

Pressures on the food supply chain

The established dominance of a small number of retailers with huge buying power has driven several major changes in the industry. Unfavourable contracts on food suppliers have emerged and these contracts push down on prices while still demanding greater volumes of uniform produce. This has meant that at every level of the pre-retail supply chain, more production efficiencies have been required, amplifying risks for the early stage suppliers and accelerating the impact of risks. This also means increased farm closures in many parts of the world, and diversification of agricultural operations to avoid commoditisation of their products.

Acceleration

The pressure to yield more product and to produce it at lower unit cost has fundamentally changed agriculture. Animals are now brought to maturity faster and crops are more densely packed and grown quicker. Acceleration of production is particularly visible in poultry.

Chickens for meat are currently grown to market weight in six to seven weeks whereas fifty years ago it took three times as long. This acceleration is also reflected in average egg production. In 1990 it was eighty-three eggs per hen per year, in 2000 it had risen to more than three hundred eggs per hen per year. In major farm commodities, we can also see this yield acceleration. Yields for staples such as maize have increased by anywhere from 45% to 90% over the last thirty years. Despite these productivity achievements, there is evidence from around the world that the rate of increases in yield are hitting a plateau (Ken Cassman). In livestock, it can translate into animal welfare concerns. In arable farming, it can translate into concerns about the topsoil. It is estimated that at the current rate of degradation, all the world's topsoil could be gone within sixty years (Arsenault, 2014).

This acceleration of production also introduces other new amplification factors for risks. If for any reason a buyer stops purchasing supplies from a producer there is less time for the producer to respond due to the quick turnover of the industry. This can cause large losses from perishable stock for the producer.

At a food system level, the acceleration of production cycles has a more dramatic effect. Acceleration as a system wide process reduces supply chain resilience and any interruption taking place in parts of the supply chain will have a greater impact. This sensitivity to acceleration being specifically true of transport.

With the supply chain now effectively running on a 'just in time' model, should transport or storage not be available, it is very likely that perishable produce will be lost. Insurers should therefore, see produce insurance at production, storage and transport stages as a good insurance opportunity.

Integration

Increasingly farmers and processors are joining together to ensure they can get the most out of their food outputs and ensure the security of their supply. Working together to collectively insulate themselves against volatile pricing and availability of key ingredients.

Processors are also extending their role, no longer separating the different processing steps of turning raw ingredients into fully prepared products. Instead, they are integrating processing, so a single company can turn completely raw ingredients into a vast range of fully prepared ready-to-eat products. Insurers are already pursuing strategies to provide the full range of insurances required for such a vertical integration of the industry. In the US this ties into the implementation of the FSMA rule which requires all food's provenance to be evidenced, even if the food is otherwise proven to be safe for consumption. The overall responsibility for this provenance chain falls on the retailers, who must then impose controls on suppliers to ensure that the traceability criteria are met. The rising importance of provenance is discussed in more detail further down in this report.

Integration of producer and processing operations to single site processing facilities also adds risk to the supply chain. With single facilities now being entirely responsible for complex tasks, such as the complete breakdown of a cow, a single site can be responsible for the supply of hundreds of components. Components from these integrated operations are then typically added to a wide range of processed food products which are then distributed from the same site. The risk is that if the original product is contaminated it can spread across subsequently processed products far more quickly than in the past. Whereas smaller processings sites will complete the processing in batches that are then shipped to other processing sites, not only giving opportunities for detection but often limiting the issue to only small batches of product. In addition, in a single site facility, it can become harder to track where any contaminant came from, as broken-down products from multiple sources are also mixed together in these large facilities.

Consolidation, profit and loss.

Consumer needs are increasingly served by a smaller number of national and international processors with integrated 'field to supermarket shelf' operations.

Consolidation amongst global processors is on an orderly Mergers and Acquisition basis e.g. Mondelez (US) acquisition of Tate's Bake Shop (US) for \$500m in 2018; Danone (FR) acquisition of Whitewave Foods (US) for \$12.5bn in 2016, and Krafts (US) acquisition of Cadbury's (UK) for \$21.8bn in 2010. Mid-market consolidation is rather more opportunistic, driven mainly by financial failure of competitors. This consolidation makes it possible for food manufacturers, e.g., Danone Yogurt, to reach upstream and partner directly with producers, skipping the cooperatives that have historically bulked milk for processing. For the food manufacturer this gives full line of sight to all traceability, farming, labour, energy and other practices to ensure corporate social responsibility standards are met and verifiable. This consolidation process also allows the captive producers access to capital.

As large farming and horticultural businesses have developed, they have consolidated to reduce overall farm numbers. Over the last fifty years, the USA has seen a reduction of over a million unique farms and the UK has lost nearly half of its individual farms.

Alternative and co-strategies

With many selecting to consolidate to increasingly industrialised levels, investment in technology and

genetic advances to increase yields becomes possible. Other smaller processors and producers (and to a lesser extent, other grocery retailers) tend to adopt small niche lines where higher prices and margins may be achieved from a minority of consumers who are financially secure enough to choose to purchase premium foodstuffs. Ice Cream being a current popular choice following the past success of premium ice cream brands.

Greater loss potential

While consolidation can benefit the remaining businesses greatly, offering economies of scale not otherwise available, it also leads to a risk of higher losses.

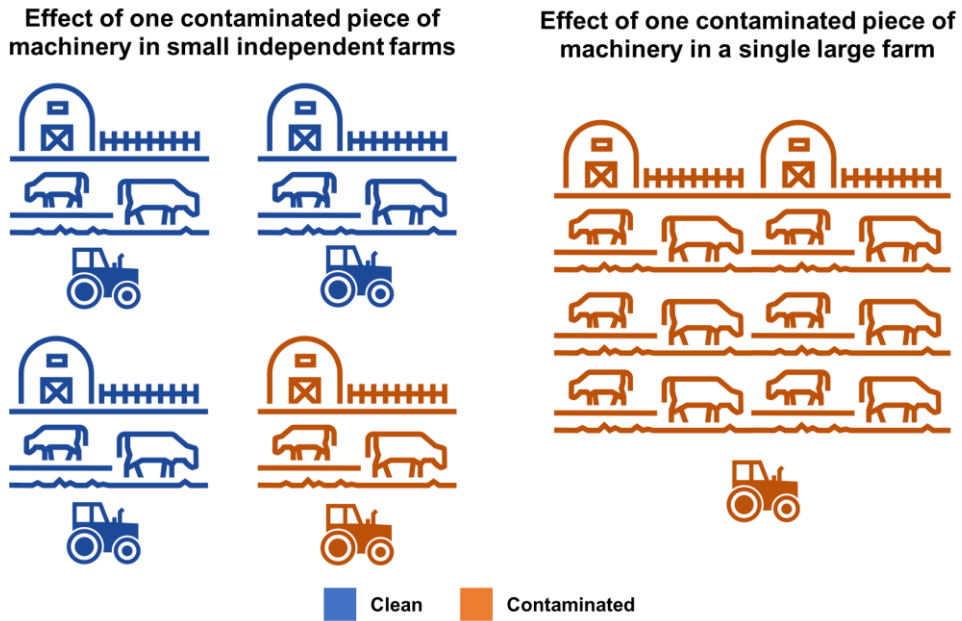
Large farms have the potential for widespread contamination through equipment or products that the whole farm uses, meaning one weak point can compromise the whole farm. While smaller farms also suffer from this issue, they are not likely to spread the contaminant outside their smaller operations. This issue compounds with the fact the larger farms have more produce to lose and are more complex; potentially hiding the source of the contaminant.

While the frequency of these events may well be reduced in more sophisticated and consolidated farms, when these events do happen the losses can be huge. The cost stretches not only to the destruction of contaminated stock but also the lengthy sterilisation and treatment of all facilities. If these facilities have insurance for business interruption covering the losses could require significant funds. This is in addition to the costs of decontaminating a facility of that size and recalling products.

Figure 5: Examples of consolidation

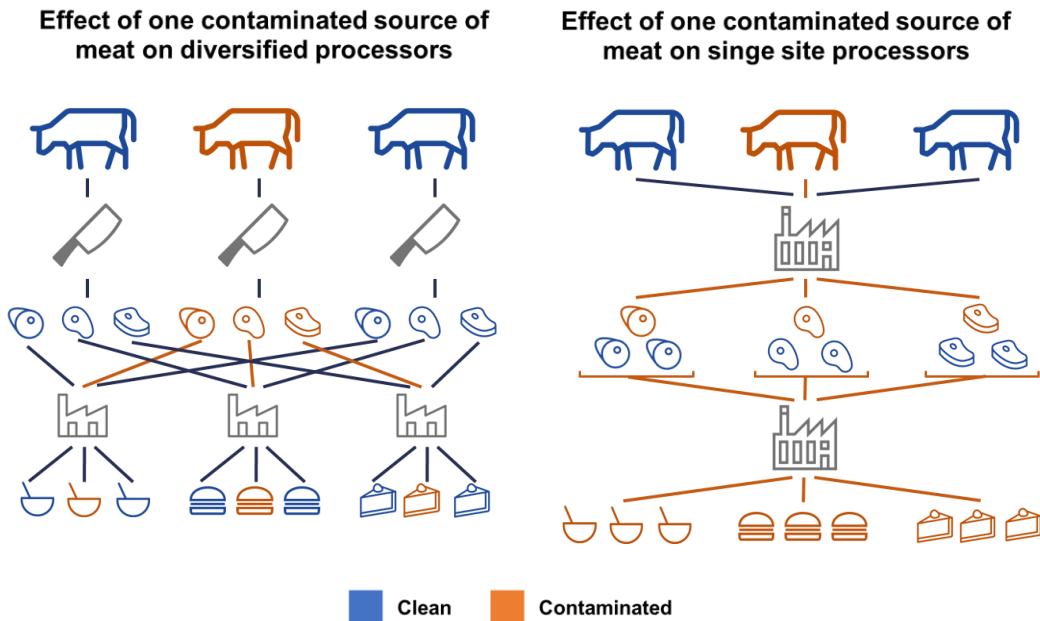
Country/Region	Approximate number of farming businesses.		
	1960	2010	% decline, +Inc/(Dec)
USA	3,253,000	2,149,500	(34) %
UK	422,000	217,000	(48) %
EU-28	N/K	12,015,000	N/K
China	N/K	201,000,000	N/K
India	48,900,000	115,580,000	+136%

Figure 6: Consolidation increasing risk in the supply chain



In the above graphic we can see how consolidation almost becomes a systemic issue. By increasing economies of scale companies are exposing a wider portion of their business to dependence on a single device or supplier.

Figure 7: Integration risk in the supply chain



In the above graphic we can see how the connectedness of the supply network becomes a problem. With increased connectedness we get increased complexity.

Increasing risk complexity

All the changes covered in the report so far, have the potential to generate more profit for each business entity remaining in the industry. Consequently, the risks are being accepted and managed by the supply chain. However, as the industry develops as a system, we also see a growing complexity of risk.

As technology and change takes us forward, new threats are emerging. Genome editing for example is becoming increasingly common, as is spread of antibiotic immunity. Both of which could become systemic risks for the insurance companies active in this market.

These new risks are also combining with existing threats that are already amplified through the processes of integration and consolidation; and these risks are being accelerated. This leaves the nature of risks faced by the food supply chain very different from just ten years ago.

Consider the case study labelled 'Horsegate'. Many factors led to the contamination of the beef meat supply chain. Profit provided the motive, but not necessarily the seeking of excessive profits. The spread of the problem is explained by factors explored in this report, but it is important to realise that to propagate as it did, the perpetrators also had to circumvent processes and procedures in place to secure this supply chain, making this a complex, systems level event, with commensurate, far-reaching economic costs.

As consolidation grows, companies with wider and higher volume product ranges, many of which are spread across international markets, are potentially exposed to huge losses. Direct losses may be in the form of massive products recalls, consumer or retailer litigation, or state intervention on misrepresentation, contamination or other health issues. Notwithstanding of course, the indirect impact on brand, which accounts for much of the value in today's corporate world. Such system wide events may be less frequent but will incur much greater economic losses. There are two risk factors here for insurers to consider; the potential for these 'fat tail' losses and the need to draw in information from the wider supply chain to accurately price the risk involved. Lloyd's has recognised this need and is exploring supply chain modelling research.



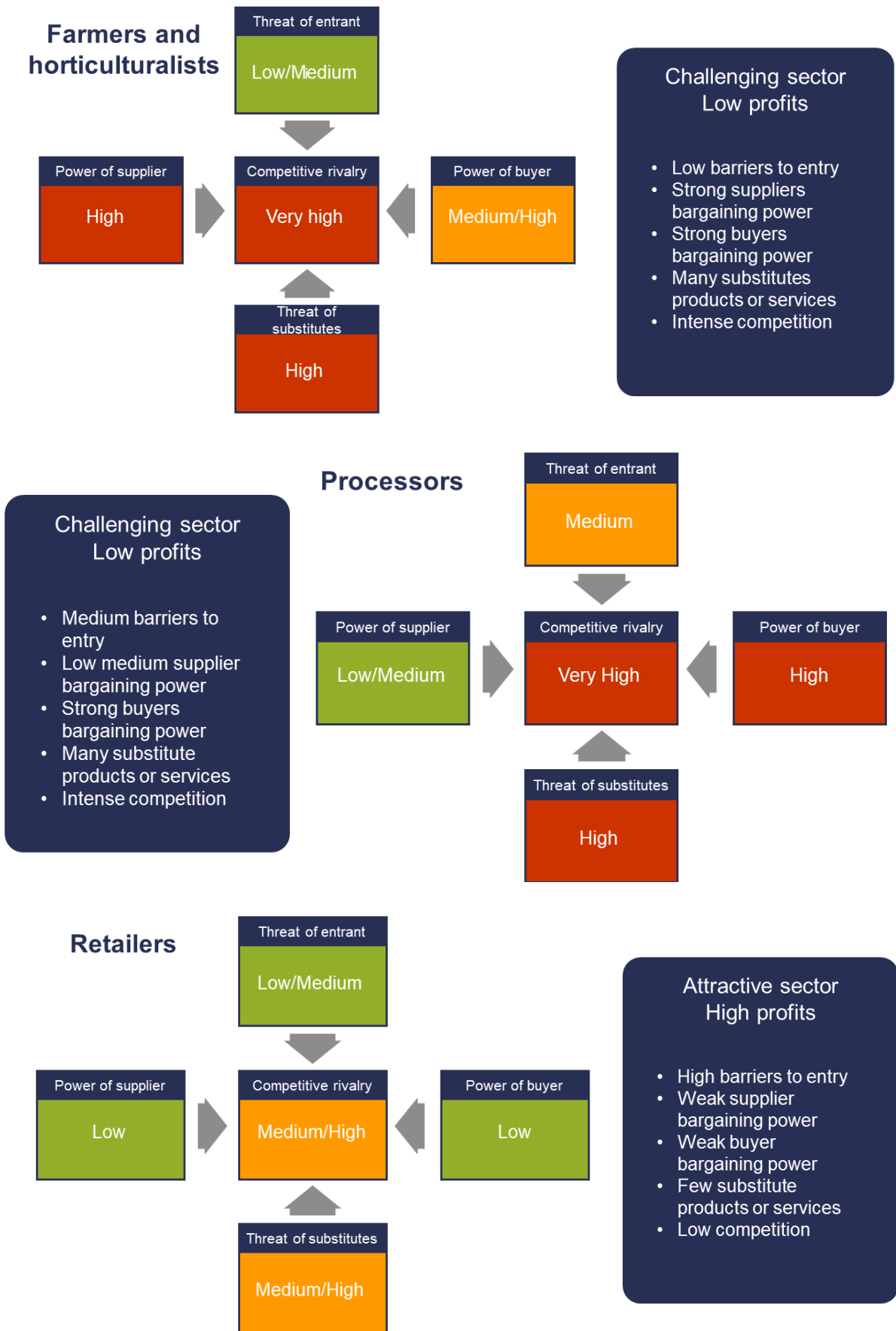
Amplified risk case study: Horsegate:

In January 2013, following testing by the Food Safety Authority of Ireland as part of normal proactive monitoring activities, the scandal known as 'Horsegate' broke. Horsemeat had been found in beef meat products sold in retail and food service markets throughout the United Kingdom (UK) and Ireland. Testing revealed beef products had been adulterated with horsemeat such that horse DNA was identified in 37% of beef burgers purchased from food retail stores including Tesco, Dunnes, Lidl and Aldi, all originating from three meat plants in the UK and Ireland.

In February 2013, UK company Findus and retailers Aldi and Tesco reported finding horsemeat in their lasagne, spaghetti bolognese, burger and meatball products, all of which were produced by a French supplier.

Following these revelations, the European Union (EU) launched an EU wide 3-month random sampling DNA testing programme for processed meats. Extensive testing was conducted throughout the then 27 EU member states. From these analyses, it was clear the crisis was not confined to the UK and Ireland but was in fact, an issue of much larger magnitude within the EU³⁵.

Figure 8: The competitive position of each food supply sector summarised using Porter's Five Forces



How different entities in the supply chain ensure business success

Logistics

As noted in the scope of this document, logistics are important to the supply chain, but is also a substantial topic to address in itself. Within this report, the focus is on the interaction between the producers, processors and retailers.

Food producers

Food producers are the first step in the supply chain, creating the raw materials used in the rest of the chain. Food production is a large industry sector particularly in developing countries e.g. India 23.82 lakh crore INR (£2.6bn) Gross Value Added (GVA) in 2016/17 (ST, 2019) representing 17.3% of total country GVA; and relatively less so in mature economies e.g. UK £10.3bn GVA in 2017 (ST, 2019) representing 0.6% of total country GVA.

Food production is also a labour-intensive sector. Despite innovations in automation in developed markets, an estimated one billion people world wide (ILO, 2014) are employed in the agriculture sector.

Mass production and niche markets

The evolution of the food supply chain has transferred buying power to the supermarkets; acting as a proxy for mass-market consumers. This process has polarised agricultural and horticultural business strategies. Driving businesses to become either mass producers of commodity products or niche producers of premium products or some combination of these two approaches.

Mass production

For producers seeking to meet mass-market demand, success requires:

- **Scale.** Achieved solely through consolidation or aggregation through ownership/acquisition

(horizontal consolidation) or cooperatives of like-minded producers.

- **Consistency of output quality.** Typically achieved through integrating with the processor. This allows the processor to specify and possibly supply the agricultural/horticultural inputs to its contractually tied food producers.
- **All-year-round availability.** Typically achieved through international cooperatives of like-minded producers and/or farming partnerships spanning continents. It can also be achieved through technological and intensive production developments that extend the growing season in one location.
- **Productivity growth.** This can be achieved through increased economies of scale and/or increased yield through technological and genetic developments. This is allied with consistent monitoring and benchmarking of key performance indicators to minimise adverse variances.
- **Flexible labour pool.** Critical whilst automated harvesting of output is in its infancy. Typically requires developed staff agency arrangements, zero-hours or piece-rate employment contracts, temporary accommodation and transportation capacity. This is an area of political and currency risk in developed economies where much of this labour pool comprises economic-migrant workers.
- **Contract growing or forward selling of outputs.** This method is used to reduce market price volatility in the producer's profit equation to 'lock-in' a reasonably certain profit level assuming quality, yield and timing of contracted outputs are achieved. This typically features in the supply aggregation achieved by buying and marketing cooperatives; owned by like-minded producers, established to deliver scale, output consistency and extended availability.

- **Technological innovation.** Identifying and harnessing technological developments to reduce labour and machinery inputs (e.g. robotic tractors) or to increase output yield (e.g. tailored daily feed rations to individual dairy cows). For example, in dairy farming the latest robotic milking parlors now enable 1 person to milk 400 cows/hour versus typically 1 person milking 75 cows/hour in the previous generation low cost /high efficiency parlor.
- **Process innovation.** Process innovation to improve yield (i.e. to produce more with less) is the principal means by which a producer can maintain profitability as retailers push down price. Failure by a supplier to innovate on process may lead to sales at below the cost of production to maintain turnover and/or reduced sales and ultimately to financial failure of the business. Controlled environment agriculture, also known as vertical farming is an example of process innovation. Growing food crops and other agricultural products in factory style facilities without natural resources such as soil and natural light which are instead supplied as water-based nutrient feeds and artificial lighting.

Niche markets

At the other end of the spectrum, there are producers seeking to identify and access niche markets in which consumers are prepared to pay a price premium, for which success requires a combination of:

- **Clear consistent articulation and demonstration of food provenance.** Articulation may be through product positioning (choice of retail outlet and product placement) and accreditation in the form of product awards and recognised production process (e.g. 'grass-fed', 'organic', 'free-range') and standards (e.g. USDA Quality Grades; USDA Organic, UK 'Red Tractor'). Demonstration may be through packaging and labelling content that is consistent with web-based and other messaging provided to prospective consumers by the product producer and product retailer.
- **Product brand development.** Either particular to the producer (e.g. Vitacress in the UK) or to the

product type (e.g. Wagyu beef from Japan; Champagne from France).

- **Efficient third-party distribution and storage logistics where scale is not developed.** This introduces minimum order value, delivery timing issues with highly perishable products and third-party liability considerations.

The common economic driver through these phases is quite simple; the majority of consumers typically make buying decisions principally based upon product price (Jvasinghe, 2016). This is changing in many markets where consumers are increasingly aware of where their food comes from and how it is produced.

An example of a niche market is the organic movement. The organic agriculture industry is now estimated to be 60M hectares globally valued at about \$90B. The organically farmed area is increasing. With this comes the potential for lawsuits between organic farmers and their conventional neighbours whose spray drift can cause major problems. The introduction of the herbicide, Dicamba in 2017 caused significant damage in the US through spray drift (Alves et al., 2017).

Waste management

A common requirement for success for both mass-market and niche producers is the need for good waste management routines. This minimises avoidable food losses during production and to control waste by-products which may represent health or contamination risks.

Typically, a 1/3rd or more of a commodity crop (e.g. carrots, lettuce, turnips, tomatoes) does not meet supermarket product standards. Successful producers use alternative outlets for this produce e.g. institutional caterers, food processors producing ready-meals, fruit and vegetable wholesalers and animal feed customers.

Good accredited waste management can be used to supplement fast moving consumer goods (FMCG) brand credentials (e.g. 'green', 'environmentally-friendly', 'sustainable') and supermarket own-label brand credentials through their corporate social responsibility programmes.

Opportunities for insurance may evolve as food waste evolves as a global issue.

Food processors

Food processors are entities that breakdown whole food products or take ingredients and reassemble them into a more desirable form, with some processors doing both. This sector is as diverse as the producers it relies on to supply it. Some companies continue traditional processes such as butchery, albeit using new methods, to companies creating wholly pre-packaged ready-to-eat meals using new recipes and processes.

Food processors mainly concern themselves with extending product shelf life and making food more appealing to the ultimate consumer, both factors that allow the processor to make a profit from the supply chain. Food processors are an important part of the modern food chain as increasingly consumers lack the skills or time to process food themselves. As with food producers, food processors typically lack the ability to sell directly to consumers and instead rely on retailers to sell the products.

Business tactics and risk management evident in food processing to maximise financial success include:

- **'Bolt-on' production scalability.** Increasing use of subcontracted (outsourced) manufacturers to provide the capacity to cope with fast-growing and/or volatile product demand. These agreements can also provide extended regional/international product reach. This introduces the risk of subcontractor hygiene failures and product hijacking (the contractor developing their own product based on their employer's intellectual property, e.g. recipes).
 - **Blockchain and other IT developments to support food provenance and traceability.** These tools can be used to reduce the likelihood of the processor falling victim to 'food fraud' in the procurement of ingredients. It also provides a benefit to the consumer reassuring them as to the quality of the processed product content.
 - **Assured supply chain quality and volume.** This can be achieved through aggregation of resources, for instance 'milk pools' comprising dairy farmers contracted to supply one milk processor which feature in USA, UK, Europe and New Zealand. Processors can also work to integrate with producers (e.g. poultry production in USA, Brazil and China) where the processor controls the inputs to the contracted farmers as well as buying their outputs. Any processor that has not assured its supply of key ingredients required for its outputs faces increased risk of input price volatility and shortages affecting output price margin, product availability and
- product quality (the last representing a heightened recall risk).
 - **Accredited food production processes.** Necessary to demonstrate processes accord with international, national and supermarket-prescribed standards. Failure in this area can be critical, resulting in product recall, product delisting (loss of market) and temporary or permanent cessation of production.
 - **Food ambassadors.** Persons who by virtue of fame (e.g. Gwyneth Paltrow and Jet Tila in the USA, Jamie Oliver in the UK, Amitabh Bachchan in India) promote certain types of cuisine and certain food producers. This introduces the potential risk of ambassadors' personal lives subsequently being found to be inconsistent or incompatible with brand values promoted by them, damaging the underlying product brand. This is an area where the Lloyd's insurance market is already offering products under the general title of 'Death and Disgrace'.
 - **Branding and new product development.** These areas are explored in how the supply chain seeks profits.

Food retailers

Retailers originated as specialist suppliers of types of food such as fruit stands, butcher shops and bakeries. Retailers have now increasingly developed into supermarkets that supply wide ranges of food. While specialist retailers can remain important in developing economies, in most developed economies they make up a very small portion of the food retail sector. The largest retail chains process a significant portion of national and international grocery spending, the largest global retailer, Walmart, reported revenue of \$485.7 billion for its 2015 fiscal year, with nearly 60% of that attributed to the USA (TET, 2018).

In western economies, food retail is a mature market, fully covered by the physical 'Bricks & Mortar' footprint of hyper/supermarkets and convenience stores. With scale being the dominant driver of profitability, this has consequently driven consolidation (mergers and acquisitions) to yield better economies of scale (e.g. Tesco/Booker merger UK 2017; and the proposed, but blocked Asda/Sainsbury merger UK 2018/19) and retail extension into emerging markets.

The drive towards a greater physical scale has partly been driven by traditional supermarkets seeking to defend market share in relation to deep-discounter grocery retail competitors ('discounters' such as Aldi and Lidl). These discounters operate with smaller store formats with limited own-label stock keeping unit (SKU) ranges (typically less than 2,000 product items as compared with a typical supermarket stocking 40,000 items). Discounters use own-label and extensive production runs of fewer products to achieve procurement cost advantages to undercut traditional supermarkets' average shopping basket cost. As most consumers are motivated by price they pose a risk to traditional supermarkets.

Another factor driving 'Bricks & Mortar' retailer consolidation is to defend market share against emerging pure online grocery retailers (e.g. Ocado and Amazon). In particular 'Bricks & Mortar' retailers are looking to successfully combine an online home shopping or 'click and collect' shopping experience with their own estate of physical stores and/or regional distribution centres (e.g. Tesco).

The threat of substitution of 'Bricks & Mortar' retail by online retail; and the converse opportunity, is such that certain 'Bricks & Mortar' retailers have taken to purchasing fledgling online retail operations e.g. Walmart's \$16bn purchase of Flipkart, Indian ecommerce platform in May 2018 to rival Amazon.

This trend demonstrating the phase 4 battle between 'Bricks & Mortar' and 'online' retail offerings and representing horizontal integration.

“U.S. customers that shop [with] us in-store and online spend nearly twice as much as customers that only shop with us in stores.”(Bowen. 2017)

'Bricks & Mortar' retailers also clearly perceive benefits if they also offer an online channel to become 'omnichannel' retailers.

Despite this diversification in their retail methods, there is little evidence of vertical integration i.e. of retail businesses owning agricultural and/or processing enterprises. This could be expected if security of supply and consistent product availability were of concern to food retailers. Rather the contrary, with retailer divestment of former vestiges of horizontal integration (e.g. Cooperative Group sale of farming division 2014). Instead, the benefit of secure and available supply is obtained through tight contractual arrangements with aggregated supply organisations such as large dairy cooperatives, where each is tied into many thousands of individual dairy farmers (e.g. Arla accounts for 12,500, c.5% dairy farmers across EU) and large integrated meat processors.

In 'Bricks & Mortar' food retailing incremental profit gains are also sought through:

- **Self-scan or no-checkout store formats**, the former relying on the customer to do the work, the latter on technology (QR code access with prepaid means established on retailer app allied with shelf weight/camera/computer tracking/billing systems).
- **Increasing sales per square foot of retail space**. Examples include using physical store estate and staff to provide online home shopping/delivery format (e.g. Tesco's with overnight picking/packing staff) as an alternative to separate 'dark store' estate of pick and pack online distribution centres operated by the likes of Ocado and Amazon.
- **Combining buyer power through strategic alliances with other major retailers**. This is to reduce key direct supplier margins on each product unit whilst offering the supplier greater product volumes in return (e.g. Tesco/Carrefour 2018).

In online food retailing incremental profit gains are also sought through:

- Automated pick and packing ‘dark store’ warehouses located on low-cost land with ready access to road transport links to major centres of population.
- Strategic alliances with non-food ‘Bricks & Mortar’ store operators and public transportation services (e.g. railway stations) to provide physical collection points for customers to use as part of the online ‘click & collect’ offering.

In both ‘Bricks & Mortar’ and online retail channels incremental profit gains are also sought by increased use of individual consumer purchasing patterns and individual consumer personal details to tailor marketing messages; sent by mail and electronically, to each consumer’s preferences.

Successful ‘Big Data’ use improves customer retention rates and increases sales. Amazon is widely regarded as a leader in this area as its websites utilise recommendation engines that analyse customers personal data including purchase history, shopping cart items, items ‘liked’ and viewing of other customers’ purchase recommendations (Bowen, 2017).

“Big Data” may increasingly be used as a tool to drive sales. For instance, by notifying consumers direct to smart- devices of immediate but time-limited promotions. Big Data may also be used to tailor price-drops based on a real time consumer location, their purchasing preferences and buying patterns.

On the other hand, reliance on data to drive sales does leave a company more vulnerable should those systems fail. As systems become more tightly coupled to profitability, even short periods of downtime or simple errors in the system could lead to significant losses. This makes ‘Cyber resilience’ a key requirement and offers insurers who offer cyber cover a sustained opportunity for growth.

How food supply chain participants seek profits

In the food supply chain, companies upstream from retailers typically work on very low margins. The high level of power that retailers have enables them to impact prices and pick their suppliers. This means that the other players in the supply chain need to come up with other strategies that enable them to be as profitable as possible without having overall control of end price. This profitability is sought through three main methods; reducing costs, adding value to products or creating new products to expand the market. This last strategy of product expansion may also allow for an initial premium pricing strategy to also be followed, exploiting the novelty of the product. As before, logistics are out of scope for this report and will not be addressed here in any detail.

Reducing costs

Productivity gains

Agricultural and horticultural producers are applying technological and genetic advances to achieve productivity gains and to improve quality, yield and resource use efficiency. Examples include:

- All year-round field mapping of fertilizer application compared with crop yield using tractors and harvesting machines with geopositioning satellite equipment to map inputs and comparative outputs to the nearest square metre of field area (Schumann, 2010).
- Genetically modified or otherwise hybridised seed selection of drought, disease and pest-resistant crops.
- Fully robotic milk parlors reducing the labour required to milk dairy cows, combined with rations delivered at feed stations. This targeted delivery of food allows the content mix to be tailored to the nutritional needs of each cow (Tranel, 2017).
- Use of drones to assist field mapping and in tracking/monitoring livestock movements and well-being in less favoured environments e.g. moors and mountainsides.
- Low till seeding (drilling of seeds) reducing soil break-up and loss caused by ploughing.
- Combine harvesters capable of lifting 32 tonnes of crop (in this example, barley) per hour (Bourgault, 2018) compared with 5 tonnes per day 60 years ago (Dunn, 2005).
- Hydroponic growing of vegetables on nutrient rich water used for producing farmed fish, with purified water being returned for the next batch of fish.
- Consistent data entry and data sharing between participants in the food supply chain of production processes and outputs 'from field to fork' facilitated by IT and blockchain technology. This data sharing enables robust traceability and provenance tracking (e.g. organic, free-range, 'free-from' and country of origin), while keeping costs down.
- Widespread use of cover crops to improve soil health and reduce erosion.
- Genome editing as a method to create more productive crops and desirable livestock. However, there are other threats associated with this, for more information please see the Lloyd's 2017 report 'A new lease of life'.

Single site facility

The push to reduce costs has led to the rise of the single site processing facility. At the factory floor level, processors; particularly supermarket own-label suppliers, face the same challenge as producers, of insufficient margin to justify capital expenditure for greater automation of production lines. That said, the economies of scale enjoyed by the largest processors means that

they are the businesses most likely to undertake such investment to yield further scale advantages.

This has led to more food production concentrated in fewer businesses operating ever-larger single site facilities. On the other hand, this can accentuate financial losses caused by unplanned events, including:

- Power shortfall or outage;
- Contamination from process; deliberate or accidental;
- Contamination from ingredient; deliberate or accidental;
- Loss of key market;
- Machinery failure/downtime
- Key ingredients shortage
- Deficiencies in factory build and infrastructure (e.g. composite panelling concerns) (Willis, 2017)
- Delisting in whole or part by key customer

More food production concentrated in fewer hands with ever-larger single site facilities also increases the risk of potential failure in:

- Storage of raw material held in transit and factory;
- Storage of finished product at a factory; distribution warehouse and supermarket;
- Mishandling during transportation with increasingly geographically extended supply lines;
- Contamination of ingredients or product in a factory. (e.g. 2-sisters, West Bromwich, UK 2017) (Goodley, 2017, Goodley, 2018, Penfold, 2017)

Insurers already provide support against some of these risks with business interruption insurance that covers losses from broken or unpowered machinery.

Contaminated products insurance also provides support should contamination be discovered at a facility or in its products.

Adding value

Through branding

The food processing sector is grappling with the acute Porter's five force challenge of dominant buyers shaping the sector. The forcing actors, often retailers, are causing a lack of profit margin in the producer and processor segments that is necessary for companies to substantively invest in capital expenditure (new equipment). This may affect the development of the industry going forward as such investment is necessary for the next phase of automation.

Retail buyer dominance is particularly evident in supermarket grocery in developed economies (e.g. UK 2016 total sales £65bn of which over 90% through top 10 supermarkets) and some extent in food catering and service (e.g. UK 2016 total sales £35bn of which over 15% accounted by top 15 catering companies). This dominance causes processors a dilemma; whether their foodstuffs for mass-market consumption are produced and sold under an FMCG brand name; or under a supermarket own-label (often referred to as a 'private-label') brand name; or under no brand (wholesale/white label) or some combination of these approaches.

FMCG brands are intended to positively influence consumer perception of product content in terms of quality and consistency to command a premium price compared with unbranded or supermarket own-label product. This added value is important as it allows an industry that is constantly under pressure to cut costs of its products to add value. It is possible to quantify this added value in financial terms, representing this 'goodwill value' (net present value) as the premium margin the FMCG brand can command.

However, this added brand value is fragile. FMCG branded products are part of the food supply chain that is facing increasing volatility across a range of business parameters from energy cost, to raw materials, and currency exchange rates. FMCGs not only share these general risks but also face their own unique vulnerabilities: the limited shelf life of food, existing variability in quality and availability of raw materials, long production throughput times, and the fact that many raw ingredients are susceptible to deterioration in quality as they travel along the supply chain, resulting in heavy reliance on chilled transportation all contribute to the fragile nature of these brands added value. This ignores specific risks to the supply chain such as product contamination (e.g. Perrier, benzene traces 1990) or accidental or deliberate ingredient substitution (e.g. Horsegate, Findus 2013).

Maintaining this added value component well can be key to a company's success and many of the largest food companies in the world are FMCG suppliers. To ensure that the products continue to have added value companies invest heavily in ensuring that every ingredient sourced is of the quality and content they expect. While this adds to the cost of maintaining the brand it reduces the risk of the brand being devalued through poor quality and contamination.

Through quality

Processors' added value often comes from their promise of quality. This 'promise of quality' is also intrinsically linked to the product being assured as safe which enhances value further.

Quality includes positive and negative attributes that influence a product's value to the consumer. Positive attributes that demonstrate good quality may be the origin, colour, flavour, texture and processing method of the food, while negative attributes may be visible spoilage, contamination, discolouration, unexpected odours or tastes. However not all unsafe foods may demonstrate bad quality, that is, unsafe food may appear to be of good quality, such as tainted meat disguised using bleach or strong spices. This distinction between safety and quality has implications for public policy and influences the nature and content of the food control system most suited to meet predetermined national objectives.

In developing economies consumers are willing to pay more for food products that are consistently and demonstrably of a higher quality and less likely to cause illness or death. Although as food supply has become more organised in developed economies, with established food safety regimes, some consumers more readily take food safety as a 'given'. This leads to individual product price and price-comparison predetermining their purchasing decisions to such a degree that food quality has become a secondary (hygiene) factor in supermarkets value-for-money equations.

Reputation at risk

Basing the added value of a product on quality means that the perception of quality by consumers needs to be maintained. If consumers decide quality has been lost, even if nothing has changed, potentially the perceived value and entire profitability of the product can disappear. Brand reputation is at risk from multiple sources. Products can become contaminated, in which event the consequent loss of trust can reduce the added value sought by the processor and permanently damage any brand associated with it. This happened with Blue Bell Ice-cream which was found to be contaminated with *Listeria*. The recall damaged consumer trust and

subsequent press attention exposed that they were no longer the quaint family brand that they had so carefully cultivated (Elkind, 2015).

Information about the sources of an ingredient used can also reduce the value of the product even if the content has not changed. Coke discovered this with Dasani, the brand lost value when it was discovered that it was just highly filtered tap water. Although initially successful, consumers felt that the source diminished its value, and the product and brand were eventually withdrawn from shelves.

Insurance of intangibles such as reputation is a growing area of interest. With intangibles, the key to success may be in the services that are packaged alongside the cover. With reputation damage, insurance products could offer support from specialist PR firms who can help mitigate the damage to reputation. This may be important for leading and established brands which may have many years of investment behind them. However, this kind of support cannot guarantee to restore lost brand value. Taking a 'systems view', a better insurance strategy would be to package services that offer help to secure supply chain resilience, as this will also reduce claims as well as provide an effective response to claims.



Impact of the 2008 Chinese milk scandal

This scandal involved milk and formula along with other food materials and components being adulterated with melamine. Of an estimated 300,000 victims in China, six babies died from kidney stones and other kidney damage and an estimated 54,000 babies were hospitalized. The chemical gives the appearance of higher protein content when added to milk, leading to protein deficiency in the formula.

The issue raised concerns about food safety and political corruption in China and damaged the reputation of China's food exports. At least 11 countries stopped all imports of Chinese dairy products. Several criminal prosecutions were conducted by the Chinese government. Two people were executed, one given a suspended death penalty, three people receiving life imprisonment, two receiving 15-year jail terms, and seven local government officials, as well as the Director of the Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), being fired or forced to resign (Wikipedia, 2008)

Creating new products

New product development (NPD) is seen particularly by supermarket own-label suppliers as a principal means to maintain, if not improve, gross margin. NPD spans product packaging, recipes and reformulations, storage and extended shelf-life solutions. Completely new product launches are rare, most NPD involves iterations of existing products. However; it is estimated that 2 out of every 3 new products fail within 3 months of launch. The overall failure rate for new products in the grocery sector is calculated as 70-80% (Atherton, 2017, Cecere, 2013).

Tim Lane of the Oxford College of Marketing (Blackburn, 2017) identifies five reasons for this relatively high failure rate:

1. A lack of independent and unbiased research into the market and target audience.
2. The product falls short of claims made and suffers bad reviews.
3. The product defines a new category and requires substantial consumer education – but they don't understand it.
4. Simple margin rules make a bad pricing policy.
5. Weak launch or poorly executed launch.

Whilst NPD is undoubtedly costly in terms of diverting scarce finance, technical and production resources, there has been little measurement of the total cost of NPD failures (Frohlich, 2014).

In 2012 it was estimated new product development failure costs the US food industry \$20bn per year which would appear consistent with the actual number of annual product innovation in the US:

“new products create additional interest in the category, a reason to advertise or promote (although one hardly needs a reason to promote these days) but from a very commercial point of view they bring additional value contribution at higher prices. It seems to have become the norm, as trade promotion giveaway has increased, and price wars have raged, a supplier's average portfolio 'price', reduces almost every month. What can replace this? New products at premium prices.... (Eales, 2016)

By joining the down escalator of price towards the top, rather than in the middle or at the bottom, new products, if successful, can bring a supplier's portfolio price up again, or at least hold it steady for a while.” (Deuninck, 2008)

Figure 9: Number and type of FMCG product innovations in the US market

Year	New product total	Foods	Drinks	Toiletries	Household goods	Mixed	Animal food
1992	15886	8159	1611	4625	786	254	551
1993	17363	8077	2243	5327	790	462	464
1994	21986	10854	2597	7161	704	293	377
1995	20808	10816	2581	5861	829	406	315
1996	24496	11072	3524	8204	785	467	444
1997	25261	10416	3424	9371	1177	291	582
1998	25181	10838	2985	9556	1002	361	439
1998	25928	11628	3069	9519	872	296	546
2000	31432	13373	3541	11747	1695	349	727
2001	32025	13200	3777	11597	2088	569	794
2002	31785	13452	3584	10979	2091	814	865
2003	33678	14812	3984	11139	1546	739	1458

Half of the top 10 biggest new product launch failures in the US involve food and beverage products (Frohlich, 2014). These failures expose the issue of NPD solutions for which there is no consumer demand, which could possibly have been identified long before launch through comprehensive early stage consumer focus group testing.

- **Price points and portion size revisions.** Processors are having to take great care to ensure their customer pricing strategies and price points net of volume discounts are coherent and justifiable. This is particularly important as consolidation takes place amongst supermarkets, wholesalers and convenience store chains in mature markets.

Part of the pricing strategy includes revisions to portion size to maintain margin in countries with weakening currency (e.g. UK post Brexit Referendum 2016) and to counter threats of anti-obesity legislation being introduced by politicians and public health policy-makers. Adapting to these demands may also reduce risk, as reduced portion sizes lead to reduced caloric content per unit. This may counter the rising risk of class action litigation being taken against food processors and retailers that stand accused of producing and selling foodstuffs that can damage consumer health.

- **Increased protection of brand and other intellectual property rights (“IPR”).** ‘Food fraud’ typically concerns processors as a key risk area that they must manage to avoid accidental or deliberate substitution of ingredients; which can on occasion pose a risk to consumer health.

Another risk that many processors in developed economies recognise is that of product of other

processors being ‘passed off’ as having been produced by them, this risk is particularly prevalent in the Far East where numerous health scares and product recalls involving local producers has caused consumer concerns and raised demand for FMCG products from the US, UK and European food processors.

The cost of legal enforcement of IPR and cessation of copycat producer activities can be significant (EUIPR, 2017).

- **Emerging market opportunities.** FMCG processors in particular see profit through leadership of developing supply aggregation and integration into the emerging markets of China and India. In these markets growing numbers of educated middle class, IT literate consumers; and a backdrop of high profile health scares involving local processors, provide early entrant advantage. Although political, legal and social constraints may yet prove to be significant obstacles in these markets; as is the high rate of NPD failure in better understood markets.

Insuring new product development

The development of new products carries significant risk. In the food industry 70% of new products fail, many before they ever reach shelves. However, NPD remains a big opportunity for food and drink manufacturers to expand their business (Atherton, 2017).

A good example of how insurance could support NPD is by insuring the stock cost of an unproven product. Many retailers demand a certain level of stock to be available before they list it. If the product fails, this stock may never be consumed, and the producer will be left with the cost. Insuring this risk could recapitalise producers to create new ideas. Again, this may be an insurance product area where services could also add value.

The importance of provenance

Profit creation in food supply involves substantial risks. Principally it enlarges the pre-existing risk of contamination, either in ways that force a product recall or if exposed, reduce brand value.

Food safety and security is a core concern for all those involved. If a company allows contaminated or mislabelled food to reach the hands of consumers it can not only lead to costly recalls, but also serious fines imposed by governments and litigation by those harmed by the product. In addition, if a company is found to be willfully negligent, these fines can vastly increase, and in some cases become punitive, such that insurance may not be valid, exposing the company to the full costs.

Ensuring food safety and security though is harder than merely placing a handful of checks in the system. The food industry is one of the few industries where the initial outputs are disassembled (sliced, diced and crushed) before reassembly into finished goods sold to consumers. Other industries of this type include oil and mineral production. All such businesses are capital-intensive with long return on capital periods, typically measured in years. However, non-food supply chains are dominated by large vertically integrated corporates and are consequently far less complex.

In a vertically integrated supply chain, it is easier for the producer/processor to demonstrate and reassure customers as to the provenance, quality and consistency of the output products. Should any event give rise to a product recall, the extent of control employed typically means the issue can be more readily identified and dealt with e.g. silicon contamination in supermarket fuel in 2007 with an estimated remedial cost of £10m. (Standard, 2007).

Whereas the complexity of the food supply chain makes product recall a more regular event, a more difficult one to deal with; and, on balance a costlier exercise e.g. the Sudan 1 dye contamination in 2005 affected over 400 food products and 300 food companies (Berke and Shieh, 2012), at an estimated cost of £100m.

Figure 10: Food supply chain

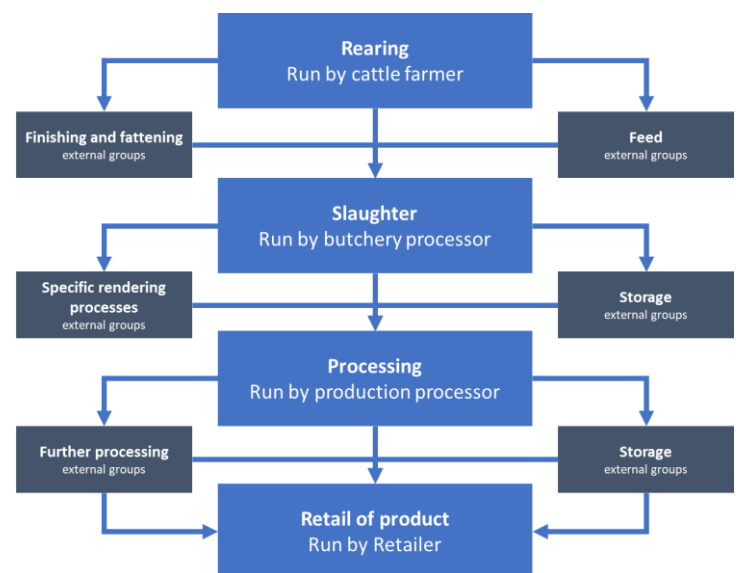
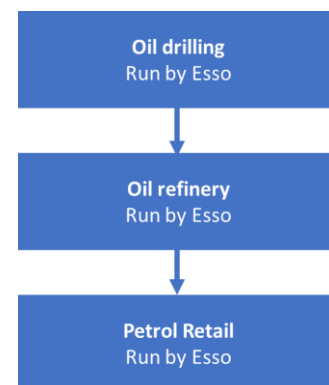


Figure 11: Oil supply chain. Esso for illustration purposes



The UK Food Standards Agency was moved to recommend stakeholder horizon-scanning to avoid contamination by minor ingredients of distant origin. These ingredients, unless duly identified, are considered as potential hazards in the food processing industry's Hazard Analysis and Critical Control Point (HACCP) plans⁴⁷. It is arguable that any food producer or processor that is not using the technological tools available to assess, assure and 'tell the story' of how their food outputs are produced represents a higher traceability/product recall risk.

The growth of such tools to ensure accurate representation of provenance also opens a window for insurers to better evaluate the risks in the supply chain. A barrier to obtaining insurance is a lack of clarity on the risks being faced, a challenge that is common in the food supply chain. A transparent food chain would not only increase customer belief in the story but also allow insurers to see that same story through the lens of risk. If more food suppliers create transparent chains, it will help those players and their insurers assess the potential remediation challenges. This can offer invaluable support for insurers who look to create useful policies.

Product recall, how insurance can support the supply chain

Product recalls pose a unique risk. Contamination or sub-standard preparation can threaten public health, exposing those parties involved with the original sale of the product to all sort of liabilities. To mitigate these risks and to comply with legal requirements a timely and effective recall is essential.

Effective recalls can place large, immediate costs on retailers and suppliers. This cost often stretches beyond the company at fault leaving others also with large costs. This is best demonstrated by a salmonella outbreak in 2009. The Peanut Corporation of America shipped salmonella-contaminated peanut butter across the US. When the peanut butter was discovered to be the source of fatal salmonella outbreaks, the recall costs bankrupted the company. However, this also left Kellogg, who had incorporated the peanut butter into its own products, with a further \$70 million in costs from the recall (McCoy, 2015).

Product recall insurance allows for insurers to support food producers and retailers, helping offset the large one-off cost of a recall and help to provide administrative expertise so the recall goes effectively. Other insurance products are available to cover business interruption and the adverse publicity that a recall might bring. These products all being of particular value to those companies who rely on a large range of suppliers and in the sharing economy, those that have established themselves as consumer level delivery brands.



New products for new markets

The sharing economy has led to a sharp increase in third party delivered food. As an example of how insurance can respond to new societal risks, Apollo, a Lloyd's syndicate offers an insurance product aimed at Business Interruption for delivery companies that have inadvertently delivered contaminated food to a consumer. The standard cover would respond for customer illness, supplier sourced contamination, government announcement of customer illness and adverse media publicity.

Aside from contamination and mislabelling, insurers should also consider loss of product provenance evidence through data loss, data corruption, and lack of access to the data or falsification of records. Maliciously caused or unfortunate circumstances, such data dependencies in a digital world create new product opportunities for insurance markets.



Provenance and product recall: Mislabeled eggs

Mislabeled eggs may happen by accident, but given the added profit in premium products, there is also the risk of deliberate mislabelling.

In one example a Preston farmer who mislabelled barn eggs as pricier free-range ones has been ordered by a court to pay back all of the £500,000 he was thought to have made through the mislabelling activity (PW, 2018). However, this is not the only example to be documented on false labelling of eggs. A source claimed free-range egg fraud could have involved 500 million eggs at one point, when a scam was discovered in which battery eggs from mainland Europe were passed off in Britain as free-range. This was more than fifteen times bigger than the number of mislabelled eggs thought to be in circulation ahead of this specific fraud's discovery (ES, 2007).

The future of the supply chain

Growing demand

The dominant paradigm of global food security is that humanity “needs” to increase food production by 50% to 100% by 2050. The consensus is that this is partly due to population growth, but mostly because this population is shifting towards more meat- and dairy-intensive diets.

Increasing total global food production, especially using today’s methods which often degrade resources such as soil, water and climate will not prove sustainable in the long term. In fact, attempts to address food insecurity by increasing crop yields, livestock productivity or nutrient use efficiency have resulted in chronically low commodity prices which are bad for farmers all over the world. Even when commodity prices are too low to sustain producers’ livelihoods, food insecurity and poor dietary health including obesity, remain stubborn problems tightly coupled with poverty.

In fact, the push to increase global food production may have a limited or even negative effect on the incidence of hunger and will certainly result in accelerated degradation of land and water resources. Food insecurity tracks poverty, not food scarcity. Food availability in rich countries, in fact, represents 150 to 200% of nutritional needs in caloric terms. If this includes indirect calories – those fed to livestock that could have gone to people – the figure is 300% to 400%. Despite limited availability in some countries, there are bigger surpluses in rich countries than ever before, yet food insecurity remains a major problem in some developed countries, for example the United States where one out of every 8 Americans is food insecure and it is estimated that one in five American children goes hungry in a year (Milman, 2018).

Automation

The developments in robotic machines; automation; and, integration of mass market focussed production and processing has created many opportunities. It is possible to conceive future farm husbandry; both of livestock and

crops, being undertaken without human intervention other than in the form of engineering set-up and maintenance. A future in which know-how, physical scale and data-management (particularly yield, quality and traceability) dominate.

The challenge for the mass-market food production and processing sectors to overcome is how to achieve payback from the extent of capital expenditure required when positive sales margin is both low and volatile.

Food provenance

The food chain is always evolving, adding new developments in technology to add to its potential output. The future of the food chain is reflected in changes we can already see taking hold in developed countries. It is likely that the key themes discussed in this document already will continue to develop.

These shifts will bring important changes in the structure of relevant commercial sectors. One major example from the 20th century is the rise of organic agriculture as a response to pesticide-intensive approaches, which is both agricultural practices and a brand for many different types of food products regulated by government standards.

There appears to be an incomplete approach to supply chain auditing (Ridler, 2018) and no information on total audit costs presently being incurred, so this may be an area that requires further opportunity and cost/benefit analysis.

However, ensuring the accuracy of initial data entry in blockchain to ‘tell the story’ will be a big challenge.

Labelling

Tied in part to the rise of the value of food provenance is the increasing importance of food labels. Labels are already relied on by governments to communicate essential information about health in addition to companies adding information to prove the premium

value of the food. As the demand for these aspects increases due to stricter health controls and savvy consumers the importance of accuracy in labelling food will also rise.

This is important to insurers as most of existing class action lawsuits against the food industry focus on mislabelled products. It is possible that the industry will see a growth in cases like these as the greater diversity of information on a label leads to more errors that leave producers liable.

As noted earlier blockchain may provide a basis for fuller transparency to all stakeholders (including consumers) of ingredient supply with proof of origin (possibly including DNA). This audit will create a clear trail through every stage of reformulation, packing and delivery to the retail shelf.

Changes in the food we eat

The food we eat is also changing, both out of necessity and through technological development. We are already seeing meat products which have not originated from an animal. Burgers grown in laboratories are already being sold by specialist suppliers.

While unlikely to have a major impact in the near future, various innovations in materials and food processing may result in 3D printed food products, and products that result from genome editing of raw produce, whether meat, fish, plant, fungi or microbe. A key feature of these developments is the “democratisation” of food production, moving from vast, highly consolidated traditional food systems, to systems that are much more distributed, complex and diverse.

Further, the advent of genome editing brings potentially unimaginable shifts in traits of agriculturally significant species, and species not yet domesticated for widespread human use as food. In contrast to first generation genetic engineering, genome editing can be done in much less demanding facilities, eventually allowing regular people working in very simple conditions to create virtually unlimited genetic variation in any organism, including humans. Regulatory issues for this technique, which leaves no footprint of the engineered change in DNA, presents many profound challenges of significance for insurance.

Social media changing expectations

Social media has already brought changes to the food supply chain, with pressure campaigns organised over websites motivating retailers and suppliers to change their processes and practices. This pressure can now bring sudden changes in demand, as the campaigns rapidly spread concerns about products. This can lead to reputational damage as well as losses as product demand dips causing the perishable stock to be destroyed by retailers or suppliers. Everyone involved in the supply chain of the products singled out on social media are left at the whim of these campaigns and can often do little to mitigate the impact. This is especially problematic if the objection to the product lies outside that part of the chain they control.

End of use for products and packaging

The environmental concerns of consumers and governments are not going away and the food supply chain and the large amount of waste that it produces are likely to see some form of regulation placed upon it in the near future.

While regulation is currently done under government schemes such as bottle return policy it is likely that some of the responsibility will be placed on the food supply chain itself. This will put the onus and cost of reducing waste on the supply chain and will likely require serious changes to how packaging and food waste is currently handled.

Food availability and social unrest

The provision of nourishment is unevenly spread around the world. Current food production appears capable of providing sufficiently for all if the agricultural output was processed without waste and distributed according to need, however, the world eats virtually all it produces every year, leaving vast numbers of people vulnerable if a major agricultural failure occurs.

Geopolitical risks

The uneven spread of food production and availability of food to a population also clearly represents a geopolitical risk. Whether through major state conflict or as a way that non-state actors look to control local and regional populations (Jahn, 2018). Agricultural breadbaskets in strategic locations such as Ukraine have been violently contested for centuries. This is due to the high impact of food shortages on any country’s citizens. A consistent lack of food can cause political turmoil internally and increase hostility towards external entities perceived to have contributed to the lack of sustenance.

Beyond food

Researching the food supply chain has offered a valuable insight into the complexities of the challenges that face those who operate within it. While much of the learning is specific to the food supply chain's unique nature some of the insights can be applied to the supply chains of other industries

Integration

Companies in many industries have or are integrating their businesses with others in their supply chain network. The headline benefits driving integration are frequently cited as; reduced costs, better control of the network and greater potential to innovate. However, as described above, integration increases threats as companies become more dependent on these integrated suppliers, not least as the competitiveness of integrated entities changes.

If the integrated network encounters issues in quality, access to any material essential for production, including power, or other problems within the network, the entire production cycle can fail. In addition, this failure can propagate through the integrated supply chain. This, in turn, can lead to business interruption for many of the integrated parts and potentially third-party liability, if the defective products produced by the integrated company reach customers. Motor, aircraft and shipping are perhaps three examples of lengthy vertical supply chains where integrated parts of the supply chain are carrying risk.

Also, by drawing comparisons with the food supply chain, we can see that when industries become tightly integrated and more dependent, lower tier suppliers can cause more disruption, particularly to retailer reputation.

Consolidation

Companies consolidate their operations whenever possible, taking advantage of economies of scale that would not otherwise be available. The process of consolidation, though, also has potential to increase risk

to the company, especially when consolidating facilities. Larger facilities whose normal production cycle is interrupted, either by simple issues such as delivery problems or one-off events, can lead to larger accumulated losses.

Where risk was once distributed between multiple smaller facilities, essentially an analogue configuration, these larger facilities are often extremely vulnerable to cyber-attack, whether for business intelligence, ransomware, or other purpose. These facilities pose a higher risk of loss from any type of single event.

Consolidated operations also have far more potential to damage a company's entire supply chain because larger facilities or businesses are likely to have a greater importance and are harder to replace. Consolidation in food supply chains is occurring at every level, including farms, manufacturing facilities, shipping lines, dealers and traders. Insurers offering cover to entities in food supply networks, should not underestimate how integral or valuable the remaining entities can become.

The case of memory chip shortages following the 2013 fire in China's SK Hynix factory, or the 2018 Maersk hack which affected all Maersk ships for nearly 10 days are cases in point. One important aspect of consolidated systems is the placement of a particular type of facility in a cluster, such as occurred with auto manufacturers when the Thai floods of 2011 hit clusters of businesses essential for auto and hard drive manufacturing. Similar concerns for agriculture have been highlighted in a number of studies from the Jahn Research Group on Multiple Breadbasket Failure (Janetos et al., 2017)

Amplification

Companies are consolidating, integrating and pulling on wider networks to get the competitive edge. This process is leading to larger companies which produce more, and, as a result there is more at stake. Aside from the obvious insurance risks of policies covering more in scope than

was intended and aggregation issues, there is an opportunity to amplify what insurers may be able to access.

One stop shop policies, all risk cover, and even parametric products selected to ensure losses do not exceed the capacity of integrated businesses become more attractive as organisations grow. Brands are particularly vulnerable as the markets grow and products marketed under the same brand family expand.

The case of the S8 phone from Samsung is a good example of losses from amplification, where direct costs were high and brand damage was globalised by the scale, size and publicity of the product's battery problem. This example also highlights how a major brand can be affected by a supplier of a single, unbranded component, possibly produced at low margin and previously thought to be insignificant.

Provenance

The provenance of any item incorporated into a product that reaches the hand of a consumer should always be of concern to companies. Provenance as a distinct and legally significant issue has risen in importance, both inside and outside food supply chains. Substandard components reaching unsuspecting consumers or putting lives at risk are the threats driving this issue, so lack of clarity on provenance, data loss or simply the inability to prove provenance may cause potentially insurable losses.

In the U.S., the FSMA of 2014 requires full demonstration of provenance. Retailers are liable if this cannot be provided, opening them up to losses caused by the actions of their suppliers. This comes in addition to rising class action lawsuits against companies who mislabel the origins of the product.

Distributed ledger and "smart" systems

There has been increasing interest in the application of distributed ledger ('blockchain') technology in food supply chains to enhance data security, improve efficiencies and transparency, reduce expenses and create an immutable audit trail of transactions through disintermediation of central entities or processes. While the potential of these approaches is significant, it also introduces significant new risks, including distraction and wasted resources.

As these technologies are more widely implemented, business models will shift from systems that depend on human-based trust to an algorithm-based trust model. This shift may expose firms to risks that they have not encountered before. To prepare for this type of yet uncharacterised risk, firms need a robust risk management strategy, strong governance of data and analytics, and strong internal controls.

Implementation of these systems could prove to be a boon for insurers though as it would provide invaluable data that will help to assess risk. With this additional information, existing policies could be more accurate and previously uninsurable risks could be fairly priced according to risk.

Conclusions

Food supply chains are some of the most vulnerable, extensive and complex supply chains we have on earth. Little wonder the industry is collectively worth so much and yet exposed to so many risks.

From brand management and product recall to cyber insurance and stock loss, the modern food supply chain akin to other non-food supply chains - offer substantial opportunities for the insurance industry.

Furthermore, the continued evolution of the food supply chain, to meet changing consumer needs and accommodate new business models such as third-party delivery, 'dark kitchens' and 'self cook' food boxes will give rise to new risks, new demands and new opportunity for innovative insurance companies.

Using the information in this report, insurance companies will also be able to foresee the needs of less developed food supply chains and adapt existing products to serve new markets. Insurance companies will also be able to apply some of the insight from the complex, food sector, to similarly evolving non-food chains.

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