Positioning New Zealand's primary industry to take advantage of opportunities presented with new and emerging technologies occurring in the production and marketing of food products

By

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Acknowledgments

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Executive summary

New and emerging technologies and their associated business models have the potential to massively disrupt our traditional farming methods and heavily influence consumer purchasing behaviours in the future.

Significant advancements are already being made in the development of plant-based meat and milk alternatives, big data, artificial intelligence and blockchain technology, to name a few. We are also witnessing the technical boundaries of research endeavour being extended further in the development of areas such as new sensory technology, lab cultured food proteins, nanotechnology and (with some certainty) other new technologies.

Technology-driven change is inevitable. While the agricultural sectors have largely been immune to the digital and technology transformation seen in other industries, this is changing and we should not underestimate the challenges faced by the agricultural and food sectors as technology developers and well-resourced investors focus their attention on transforming the way we produce, manufacture and market agri-food and fibre products.

The race is on, and if we don't learn to become more adept at identifying and exploiting new technologies and rapidly changing consumer preferences, then we risk falling behind current and new competitors in the market who potentially have greater capability to take advantage of the opportunities presented by new technologies than we do.

Instead it will be how we use, adapt and exploit new and emerging technologies more quickly and effectively than our competitors will be where the opportunities are for New Zealand's agricultural sectors, but this must be more than simply seeing new technologies as a way of sustaining our existing business models and practices.

Critical to this will be our ability to quickly build the capabilities of highly motivated and talented individuals and entrepreneurial organisations to sense, seek out and exploit opportunities in establishing a competitive advantage for New Zealand agri-food and fibre products within an increasingly dynamic market environment. To achieve this, a bold and radically different approach is required in building and developing capability within New Zealand's primary industries than exists today, including:

- Embracing and rewarding risk taking in pursuit of new ideas and leading edge innovations
- Providing space for individuals and organisations to 'breathe' in exploring and widening the scope of their awareness
- Creating safe environments to openly debate, discuss and test ideas
- Encouraging more 'mavericks' into the industry to challenge our traditional business models and patterns of behaviour
- Becoming 'match fit' to keep pace in the application and adaptation of new and emerging technologies on-farm and along the supply chain to the marketplace.

Background

In 2017, I was fortunate to travel offshore and meet with over 40 thought leaders, academics and industry representatives in the United States, Canada and Europe to discuss and debate the impact of new and emerging technologies likely to occur on-farm and through to the marketplace. I was also interested in exploring how New Zealand's primary industries could in the future better understand and exploit the opportunities presented by new and emerging technologies in the production, processing and marketing of our agri-food and fibre products.

Given the topic area is very broad, I adopted the following approach in undertaking my research topic:

1. Develop an enhanced understanding of new and emerging technologies and trends likely to impact on New Zealand's primary industries and its international markets;
2. Understand future challenges in producing and marketing agri-food and fibre products;
3. Explore how New Zealand's primary industry sectors responds to, and positions itself in the future, in the face of new technologies and changing consumer behaviours through the application of technology in the way food is sourced and consumed; and
4. Develop an expanded understanding of how to prepare and shift existing mind-sets in the sector to better respond to and exploit new opportunities presented by new and emerging technologies on-farm and into the marketplace.

Very early in my travels it became apparent that many of the individuals I met with were also struggling to understand how new and emerging technologies could potentially disrupt current agriculture practices and consumer food purchasing behaviours in the future. What I found in common was that we were all trying to make sense of what we were seeing and reading about, and then drawing our own conclusions on the likely effects on the agricultural sector.

Most I met agreed that technology-enabled change is inevitable, but what this might look like and the speed of adoption of new technologies on-farm through to the marketplace is uncertain, along with the associated impact.

Disruptive technology

In his book ‘The Innovator's Dilemma’, Clayton Christensen made a distinction between two different types of technology that affect businesses. On the one hand, he described what he called ‘sustaining technologies’; these are technological developments that help organisations make marginal improvements in what they are doing. They require only gradual change and allow the retention of current business models and established practices.

On the other hand, there are what Christensen termed ‘disruptive technologies’. By definition, a disruptive technology is one that could potentially displace an established technology, and it seriously disturbs the *modus operandi* of an existing industry or provides a ground-breaking product that could lead to the creation of a completely new industry.[1]

The theory postulates that it is easy for people and businesses to dismiss new technologies because they cannot foresee or accept change that threatens the status quo, but are then blindsided as the technology matures and gains market share. An often used illustration is the impact of mobile phones on fixed-line operators to demonstrate the destruction of an entire business model. A closer to home example is the impact of Xero cloud-based accounting solutions and how they have largely replaced book-keeping functions within rural and urban accountancy practices.

Disruptive technologies do not always hit the market with a bang, and often come into being from unlikely directions. They rarely emerge from established organisations, as they do not initially seem to offer a worthwhile new opportunity, or potential threat, to the existing business model which has been successful for those enterprises (or industry) over a reasonable length of time. From their perspective, there appears no reason to doubt that current assumptions and practices will not continue into the foreseeable future.

Some companies are aware of the constraints of their own business models to continually adapt and innovate, along with the limitations of established cultures that exist within the organisation. Instead, these companies prefer a strategy of acquiring and/or collaborating with companies that are developing innovative and leading edge products or services. The aim being to potentially mitigate the risk of being disrupted or displaced in their existing market or new developing markets. This essentially defensive approach does not occur only with the technology sector, but can be observed within the agriculture and food industries in the investments and acquisitions of recent times by multinational companies such as Tyson Foods, Bayer and Donane.

In this context, Christensen suggests that the best way for big organisations to harness the potential of disruptive technologies (which he now calls ‘disruptive innovations’) is to set up separate spin-off organisations, but reinforces the need for such offspring to have a very different culture from their parents and have a much higher tolerance of failure.

[1] The Economist, *What disruptive innovation means* [25 January 2015]

Acquiring or spinning off companies to focus on the development of new and innovative products and services is a resource-intensive business. It requires deep pockets and commitment to farsighted strategies which few New Zealand companies within the primary industry possess.

Participants in New Zealand's agricultural sectors have generally been quick adopters of new technologies that demonstrate direct improvements in the productivity and profitability of farming and/or processing operations. But this ready response has been more in the realm of 'sustaining technologies' where changes have been largely incremental through the adoption of existing technology (phone apps, internet, cloud-based solutions, automation, etc), as opposed to the development of ground-breaking products or services that create a new business model or an entirely new industry.

The development of leading edge and radical new technologies within the agricultural sectors is unlikely, given that the sectors do not normally lead the charge in reshaping technology boundaries in their own industry, let alone in other industries. Instead, it is the progressive and systematic adaptation of new technologies that have been tried, tested and proven successful in other industries that is most likely to lead to new technological changes within New Zealand's agricultural sectors.

In other words, it will be our ability to adapt and take advantage of new technologies more quickly than our competitors, and to implement them at scale, where the opportunities lie for our agriculture sector in the future. At what pace that transformation might occur remains to be seen as science and industries' response to technology-enabled change is often slow to get off the ground. This is largely due to the absence of a clear problem definition and a shortage of capable people, as well as the lack of public funding appetite to undertake high-risk research endeavours that have long-term horizons.

The technology effect

Over time, the primary industry has rarely hesitated to embrace new production-based technologies that clearly and overwhelmingly demonstrate improved ways to lift the productivity and profitability of farming operations and manufacturing processes.

While we can expect this practice to continue, what we are now witnessing is the roll-out of new technologies that could radically change the way food is produced, manufactured and consumed. It would appear that the technology sector and investors have set their eyes on the food industry and we should expect the pace of technology change and investment to accelerate substantially in future.

Already we are seeing rapid technological advancements in the development of plant-based meat and milk alternatives, 3D printed food and blockchain technology, to name a few. All of these new technologies could seriously challenge current business models that have served New Zealand's commodity producers and processors well for over 130 years.

But how much of this is 'hype' generated by the companies and investors directly involved with new food technologies, industry commentators and media through the effective and smart use of new media technology and social networking platforms (e.g. websites, blogs, multimedia, etc)?

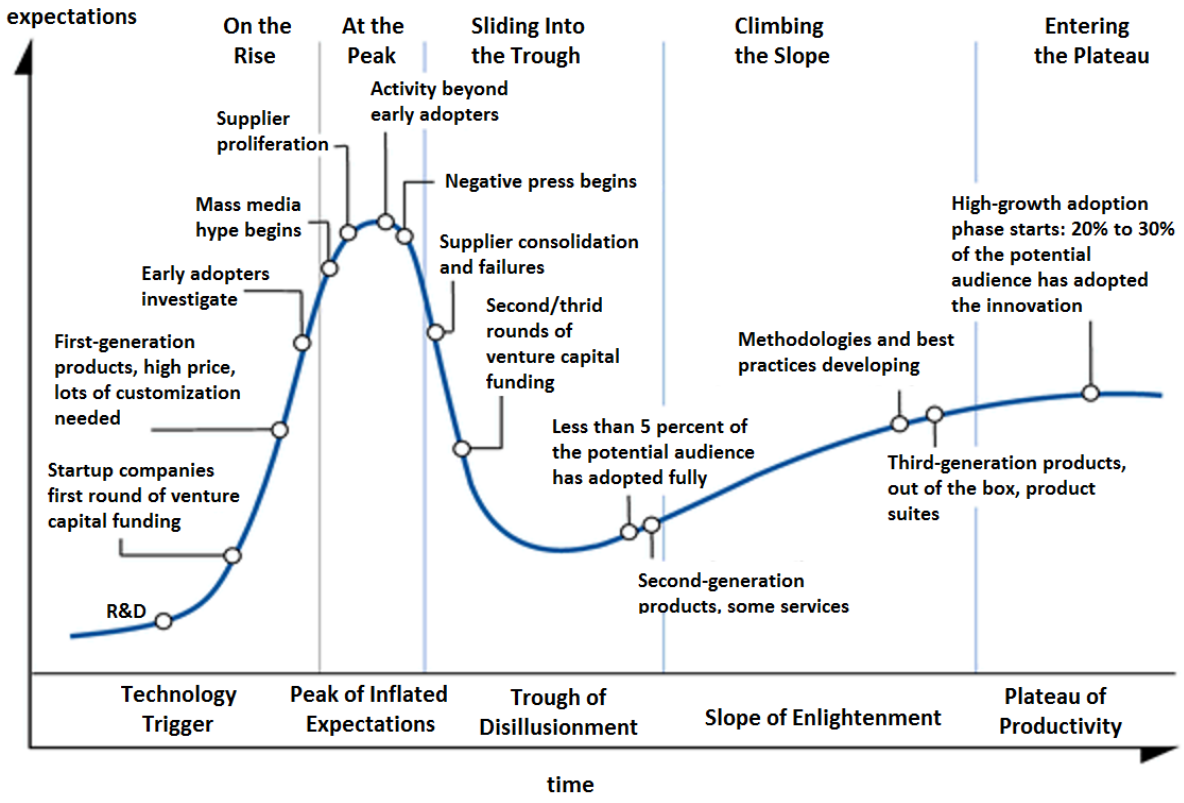
In forecasting the possible long-term effects of technological change, United States researcher and futurist Roy Amara coined the phrase:

> *We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run (2006).*

In what has now become known as Amara's law, this has been described as encouraging people to think about the long-term effects of technology. This is said to be best illustrated by the Hype Cycle.

The Hype Cycle – as highly subjective as it is – begins the five stage process with 'Technology Trigger' moving to 'Peak of Inflated Expectations' and subsequent 'Trough of Disillusionment' before reaching the 'Slope of Enlightenment' and 'Plateau of Productivity'.

Hype Cycle for Emerging Technologies



Source: Gartner Group

It can take a considerable time before a new technology is widely accepted and adopted in everyday use. A good example of this is the Global Positioning System (GPS). Originally designed for military and intelligence applications by the United States at the height of the Cold War in the 1960s, GPS started in 1978 as a constellation of 24 satellites placed in orbit.

In the 1980s, GPS was released for use in civilian applications after a United States civilian aircraft was shot down after losing direction and venturing into Russian airspace. It wasn't until the early 2000's that we started to see the application of GPS for everyday use. Now GPS is incorporated in hundreds of applications affecting every aspect of our daily lives – a journey that started 40 years ago.[2]

Consider, for example, the application of GPS within the agricultural sector. The development of precision agriculture is highly reliant on the application of GPS technology in many aspects of farming (e.g. variable rate application of inputs, irrigation systems, field and soil mapping, tractor guidance systems, etc), from the paddock through to the validation of food products en route to the marketplace.

As the GPS example shows, it can take a long time for the technology to establish itself in the market. But when the application and integration of a new technology is used to make our lives easier and clearly better, the momentum in the uptake of this type of technology is unstoppable.

[2] Rodney Brooks: The Seven Deadly Sins of Predicting the Future of AI

It is arguable where new and emerging technologies for agriculture and food industries feature within the Hype Cycle. Take, for example, alternative meat and milk proteins. Given the broad range of products under development, they could feature at various stages along the Hype Cycle. Plant-based meat and milk protein alternatives have been effectively servicing the needs of vegetarians and vegans over a considerable period of time and are most likely on the ‘Slope of Enlightenment’ as the appeal of these products attracts an ever-widening consumer base. In contrast, laboratory cultured animal proteins are still in the very early phase of research development and most likely fit currently in the ‘Technology Trigger’ stage of the cycle.

The challenge in many respects lies in the need to sift through all the noise and marketing hype to identify which new and emerging technologies are actually likely to have an impact on the manner in which we produce, process and market New Zealand’s agri-food and fibre products to consumers into the future.

In the next section I will explore common themes expressed by individuals interviewed during my Fellowship, and that have emerged from further research undertaken on my research topic.

New and emerging technologies likely to impact New Zealand's primary industries

The new and emerging technologies identified below (in no particular order) are widely reported in the public domain and were commonly mentioned by academics, thought leaders and industry representatives that I interviewed during this Fellowship. Insights freely shared and discussed serve to provide a strong sense of where interviewees see technological developments occurring within the agricultural and food sectors in the future.

Whilst most areas identified are generally widely known, what is less appreciated are the time horizons in which the following technologies could become readily accessible and subsumed into everyday life. This, of course, acknowledges the risk that some new and unforeseen disruptive technology may blindside the agricultural and food industry from an unexpected direction and this changes the game entirely.

Alternative meat and milk food proteins

Growing environmental, ethical and health concerns are often cited as the main reasons for increased interest in alternative meat and milk proteins, particularly among those deemed discerning and health conscious consumers. Already plant-based proteins are available that mirror the look, taste and feel of meat and milk products.

There has been a great deal of media coverage on alternative animal-based protein products. The Impossible Foods plant-based burger is often pointed to as 'looking, tasting and bleeding like real meat'. Unlike the Impossible Foods burger, which still has relatively limited reach, Beyond Meat has been successful in a wide-scale roll-out of its plant-based burger patties in 11,000 stores ranging from Walmart to Whole Foods.[3]

The market for alternative plant-based meat and milk products has experienced considerable growth in recent times, admittedly starting from low bases. Some very large global food businesses and investors are starting to hedge their positions on plant-based meat and milk products, particularly those close to consumers in the marketplace who can detect shifting consumer preferences, as well as those seeking to identify and protect future market growth opportunities.

In October 2016, Tyson Foods, the largest meat processor in the United States, took a 5 percent stake in Beyond Meat to tap into growing consumer demand for alternative sources of protein occupying critical retail shelf space.[4] Tyson Foods has since extended its stake through a fundraising initiative by Beyond Meat in December 2017. French-based Danone's acquisition of plant-based dairy producer WhiteWave Foods in April 2017 for over US$10 billion was said to be a response to slower growth in dairy consumption and an ambition to move into the faster-growing, higher margin area of soy and plant-based products that are thought to be popular among affluent and health conscious consumers.[5]

[3] Digital trends: From lab-grown steaks to plant-based blood, science is taking the animal out of meat [20 April 2017]
[4] Fortune: Why Tyson Foods Is Investing in A Vegan Startup [10 October 2016]
[5] Bloomberg: Danone Plans Cost Clampdown as Profit Growth Set to Slow [15 February 2017]

While plant-based meat and milk alternative product categories continue to grow, there are other companies looking at the application of even more advanced technologies to produce and replicate animal protein products.

In the latter context, 3D food printers continue to push technological boundaries. The potential to print food products containing a predetermined and controlled level of nutrients based on an individual's gender, age, lifestyle or medical condition has huge potential, particularly in the field of aged care facilities and sports nutrition. 3D food printers also offer the potential to create interesting and intricate food designs and decorations that would be difficult to replicate by hand.[6]

As the 3D food printing technology continues to improve to more closely resemble conventional food products, we could see wider consumer acceptance and uptake of this technology. This could particularly be so for consumers who see food merely as a protein fuel source for a busy lifestyle, and who are uninterested in food provenance or the ritualistic process of cooking a meal.

Research is also being undertaking in producing meat and milk proteins in laboratories through cultured animal cells. For example, Memphis Meats is growing cells extracted from living animals, and developing them through a process that involves feeding the cells a mixture of vitamins, minerals and plants. The meat is harvested after about two weeks when it reaches the desired level of tenderness. Often described as meat grown in a petri dish, Memphis Meats places emphasis on the fact that no animals were slaughtered in the process. The meat is still prohibitively expensive, costing around US$9,000 to produce a pound of Memphis Meats' poultry, compared to a bit over US$3 on average for a pound of chicken breast.[7]

In New Zealand it is interesting to observe the language that industries use when commenting on alternative meat and milk proteins. Often categorised as 'synthetic' or 'fake' meat and milk products – to somehow underline the artificial and inauthentic character of the products – generally speaking industries' response is to keep a close 'watching brief' on what is occurring in the marketplace.

We frequently hear industry commentators question the ability of alternative meat and milk proteins to truly threaten the position of naturally produced animal products on the basis of the large array of ingredients and refined processing techniques required to produce these types of products. Similar views were held by the wool industry in the 1970s in response to the rise of synthetic carpets and clothing made from petroleum and plant-based products, but these now dominate the market based on various price points and the versatility of these products.

The wave of new food manufacturing techniques will continue to get better and likely bigger, and reach some point in the future where alternative meat and milk proteins could potentially become indistinguishable from the real thing. While the production of alternative meat and milk proteins does not at present have the scale to seriously threaten animal products in the marketplace, alarm bells should be starting to ring.

[6] Digital Trends: From pixels to plate, food has become 3D's printing delicious new frontier [17 April 2017]
[7] Wall Street Journal: Clean Chicken: Never Hatched or Slaughtered [15 March 2017]

In Rabobank's report *Watch Out ... Or They Will Steal Your Growth!* it is noted that the market for alternative protein products will be much smaller than that of the animal protein market over the next five years. It goes on to say, 'However, it is not the total market size, but the growth rates that alternative protein products are witnessing – and are expected to continue seeing – that is the most significant.'

The report also notes that alternative proteins have the potential to 'steal' a material share of the growth in animal protein consumption in the European Union (EU) over the next five years, and is expected to represent one-third of total protein demand in the EU. Whilst a slight increase is expected across the United States (2 percent) out to 2022, Rabobank expects stronger demand growth to occur on the west coast of the United States and in parts of the north-east, as well as in certain metropolitan areas.[8]

Further to this, Roger van Hoesel of Food Valley NL, based in Wageningen in the Netherlands, say consumer demand for plant-based proteins is increasing fast in countries like Germany, Sweden, Switzerland and the Netherlands. At present, in the Netherlands, 37 percent of the average protein intake is plant-based, whereas 63 percent is of animal origin. More and more, targets are set to reach a 50-50 division between plant and animal-based proteins by 2025.[9]

The future consumption of alternative meat and milk proteins is expected to increase among consumer groups that actively choose not to consume animal products, and potentially price sensitive groups that are apathetic in their selection of protein sources. Should the production of alternative meat and milk proteins start to develop scale at multiple price points and more closely match the attributes consumers are seeking, these products will pose a serious threat to New Zealand's primary industries.

Big data

We are entering an era of big data – data sets that are characterised by huge volumes of both structured and unstructured data, received from multiple sources, at ultra-high velocity and variety on a day-to-day basis.

Farmers and agribusiness entities already have access to a wide range of information and data through a number of technology platforms including cloud-based systems, management and production software, data sensory technology, etc.

We can also expect that the amount of data available to farmers, processors and agribusiness – and by extension consumers – will continue to grow with the explosion of social networking sites, search and retrieval engines, data networks, media sharing platforms, stock trading sites and so on.

The challenge in many respects will be the ability to analyse and interrogate data sources to explore patterns and relationships hidden in large volumes of available raw

[8] Rabobank Report: *Watch Out ... Or They Will Steal Your Growth!* [November 2017]
[9] NZIPIM's *The Journal* March 2018: Roger van Hoesel, *Food Valley NL as a Guidance and Support Organisation for Innovative Companies*

data. In so doing, this will provide valuable insights and analysis that could ultimately lead to better on-farm and market-driven decisions.

A factor limiting the wider roll-out of big data in the primary industry is the sheer velocity of information generated, and the computing power required to quickly process high volumes and a variety of data, particularly in areas with limited internet access. But given how quickly technology is developing, this challenge may be of a short duration.

Ultimately, the value and effectiveness of big data depends on the capability of the human operators and increasingly sophisticated machine learning platforms tasked with the role of interpreting data, understanding how to integrate this within a system, and formulating the proper queries in extracting relevant information available from big data sources.

Machine learning and artificial intelligence

Machine learning is software that learns as it processes massive amounts of big data, allowing it to learn without being explicitly programmed by studying patterns that might not be apparent to human operators. Computer algorithms used by Amazon, Google, Trademe and a host of other online consumer platforms are detecting individual internet search patterns and adjusting their programme actions accordingly, thereby zeroing in on the targeted area of interest. Even in researching some of the information for this report, internet search engine algorithms would promote certain stories and websites over and above other information sources and populate advertising content into websites that provide this functionality.

The founder and CEO of Amazon Jeff Bezos clearly sees the future of his company as being machine learning and artificial intelligence, and believes this is key to improving Amazon's operations. He says it '… drives our algorithms for demand forecasting, product search rankings, product and deals recommendations, merchandise placements, fraud detection, translations, and much more'.[10]

As machine learning becomes more sophisticated, it will increasingly be able to synthesise greater amounts of input data, as well as self-training its programming functions along the way.

So what are the opportunities for cognitive technologies within the agriculture sector?

Machine learning and artificial intelligence can correlate huge amounts of big data from multiple sources. This will potentially help farmers and their advisors analyse such critical areas as weather patterns, temperature, moisture, soil information, market prices, social media feeds, and many other signals to help make better planning decisions to improve on-farm productivity and profitability, while also driving on-farm efficiency in the application of inputs and the use of resources.

Ground and remote sensors, high-resolution satellites, drones, real-time market information, and other tools have the ability to provide huge amounts of data on-farm

[10] USA Today: 'Disagree and Commit' – Jeff Bezos 'Words to live by in Annual Letter' [14 April 2017]

and further up the supply chain. This is estimated to increase over time. In the United States the average farm is expected to generate an average of 4.1 million data points every day in 2050, up from 190,000 in 2014.[11]

While machine learning and artificial intelligence do represent a significant opportunity, it will still take some time to fulfil the promise of helping famers make better on-farm real-time decisions. Cognitive technologies rely on algorithms to process data, and then adapt and learn based on the data received. The more inputs and statistical information collected, the better the algorithm will be at predicting a range of outcomes. But while this capacity normally functions well within a contained and controlled environment, farmers actually operate within highly variable biological production systems of complex interactions, affected by constantly changing and unpredictable environmental and climatic conditions.

So the problem with deploying machine learning and artificial intelligence on-farm is not necessarily the lack of willingness or resources to develop programmes and protocols in building the statistical base needed. Rather, the problem is that in most cases, no two farms or environments will be exactly alike, which makes the testing, validation and successful roll-out of these technologies more difficult than in other industries that operate in data-rich and controlled conditions.[12]

For machine learning and artificial intelligence technology to truly make an impact on-farm and further up the supply chain we need to appreciate that agriculture is one of the most unpredictable environments to manage. It follows that considerably more work is needed in collecting and building the statistically robust information within and across numerous biological systems and environments.

We also must be careful not to over-promise the application of cognitive technologies, without applying the huge amount of work and resources required to do this effectively. Otherwise, we run the risk of increased doubt and the slower uptake of machine learning and artificial intelligence within the agricultural sectors, potentially undermining the opportunities presented by this technology.

The Internet of Things

The Internet of Things (IoT) is the ability to interconnect computing devices to sense and collect data from the world around us, and then be able to share that data across the internet where it can be processed and utilised for other purposes. IoT provides accurate real-time data and information by connecting physical objects with sensing, networking and computing capabilities to other objects and services over the Internet.

As the interconnectivity of sensory technology improves we can expect to see more data gathered from an expanding range of ground and remote sensors, providing real-time information to help manage and improve on-farm productivity, and optimise the use of inputs.

[11] IBM: Five ways agriculture could benefit from artificial intelligence [December 2016]
[12] AgFunder News: The Challenges for Artificial Intelligence in Agriculture [January 2017]

Whereas big data can rest before it is used in any kind of analysis, IoT is real-time predictive analytics with the ability to trigger processes and actions within seconds after certain critical patterns have been detected in programmes.

The potential benefits that farmers gain from IoT applications are two-fold. First, IoT provides more accurate, real-time data that can be used by farmers to inform their decision-making processes to increase production. Secondly, IoT systems can also help farmers reduce costs and waste by optimising the use of inputs at critical times, providing better environmental outcomes.[13]

Given that data can be shared across the internet, there are opportunities for greater consumer engagement. Consumers could potentially track the product life-cycle from farm-to-plate through monitoring devices along the supply chain. This will potentially provide enhanced customer experiences, as well as a greater level of electronic transparency across the whole of the supply chain – ensuring the legitimacy and authenticity of New Zealand's agri-food and fibre products.

Blockchain technology

Blockchain is the technology behind bitcoin and an expanding range of other crypto currencies around the world. Blockchain is a massive decentralised digital ledger of transactions that has been defined as 'a distributed, shared, encrypted database that serves as an irreversible and incorruptible public repository of information'.[14] As a digital ledger, blockchain technology enables proof of ownership and the transfer of ownership from one entity to another without using a third party intermediary such as a bank.

While the most popular and well-known application of blockchain is crypto currency, experts believe that blockchain technology offers an array of other applications where trusted and secure transfer arrangements are required. One such application is within supply chain management.

Blockchain technology has the potential to provide digitally auditable records for producers, processors, suppliers and customers on the state of their products anywhere along the supply chain in real time. As an exporting nation of agri-food and fibre products, the application of blockchain technology in New Zealand could ensure greater levels of transparency, quality control and security in supply chain management, minimising the risk of errors, misrepresentation and fraud.

Given the decentralised structure of blockchain technology, it has the potential to disrupt the supply chain as well. In theory, blockchain technology could also allow companies to provide various goods and services at any point along the supply chain.

In 2016, Finnish start-up Kouvola Innovation received an EU grant to research the streamlining of the supply chains using blockchain technology. This included work on the placement of Radio Frequency Identification (RFID) tags to pallets that

[13] Hyea Won Lee, The World Bank: Agriculture 2.0: how the Internet of Things can revolutionize the farming sector [17 August 2017]
[14] Wright, Aaron and De Filippi, Primavera, (2017), Decentralized Blockchain Technology and the Rise of Lex Cryptographies: https://ssrn.com/abstract=2580664

communicated their need to get from point A to point B by a certain date. Carrier 'mining' applications would tender for the right to move the load of pallets. The RFID tag would award the business to the carrier that bests meets a shipper's price and service needs. As the pallet is transported, blockchain technology can continue to track and monitor the shipment until the destination has been reached.[15]

This research does raise an interesting question about how this type of technology could be applied to other areas of the supply chain, particularly in sourcing non-branded homogenous products or services in real time. This could prove very challenging to New Zealand's primary industries based on whether we are in fact able to provide products at scale, year round, and in quick time. Instead, the opportunity is in how we can use blockchain technology to engage directly with consumers who place a premium on sourcing high quality authentic branded food products, rather than through an intermediary.

As a back-end technology, most companies don't necessarily see the need to proactively invest in the adaptation of blockchain technology beyond crypto currencies.[16] We are also seeing the increased instability of crypto currencies that has the potential to undermine confidence in blockchain technology regardless of its merits as a digital ledger.

There could well be a long lag time before blockchain technology is more widely used and intertwined as part of our daily lives in the same way as GPS has done. But it is important that we better understand blockchain technology, particularly in its application to supply chain management, and actively explore how we might exploit the potential opportunities presented by this technology.

Automation and robotics

Automation within the agriculture sector is largely driven by the desire and/or need to improve the production and cost efficiency of the farming system and processing operations. The application of precision agriculture techniques has made significant progress in the use of automation in planting, growing, irrigating, harvesting crops, and much more. Yet despite the obvious advantage of these technologies, their uptake is still surprising slow.

In visiting The John Deere Technology Innovation Center located at the University of Illinois at Urbana-Champaign's Research Park, I noted that John Deere have been building self-driving tractors for over 20 years – some of which now reside in their museum. Even today as more and more self-drive autonomous equipment becomes available to the market, there is still a reluctance on the part of farmers to give up control and get out of the tractor seat.

The same could also be said about robotics. Take, for example, robotic milking; a decade ago it was set to revolutionise dairy farming, and indeed the innovators and a

[15] Steve Banker: Will Blockchain Technology Revolutionize Supply Chain Applications? [June 2016]
[16] Steve Banker: Blockchain In The Supply Chain: Too Much Hype [September 2017]

few early adopters have bought into robotic milking. But market share in New Zealand is still very small, with the majority of dairy farmers yet to be convinced of its merits.

In discussing this situation with Professor Henk Hogeeven of Wageningen University, he pointed out that 20 percent of dairy farms in the Netherlands have robotic milkers. Surprisingly these are not large-scale dairy farming enterprises, but small family owners seeking a better work-life balance.

We can expect to see greater use and application of automation and robotics within the primary industry in the future. However, the speed of uptake of automation and robotics on-farm and along the value chain could vary and will be influenced by a number of different factors. They include the capital investment required, the motivation of individuals and organisations to want to change and adapt their systems, labour market shortages, and for personal reasons (work-life balance).

Nanotechnology

From a theoretical perspective, nanotechnology has the potential to provide the smart delivery of active ingredients for the targeted use of fertiliser, chemicals and other inputs to enhance the ability of plants to absorb nutrients, and to detect and control pests and diseases. This process could optimise the plant's performance and yields, while minimising nutrient losses and chemical residues entering waterways and the environment.

Nanotechnology also has the potential to be used in food packaging, storage and transportation to help reduce spoilage and deterioration of products. It could also provide greater levels of traceability and security of food products traveling along the supply chain to market.

By definition, nanotechnology involves the ability to see and control individual atoms and molecules that are 1 to 100 nanometers. To provide a sense of scale, a human hair is approximately 80,000 to 100,000 nanometers wide.

Like many other industries, there is growing recognition by academia and industry of the agricultural applications of nanotechnology. Yet despite the potential advantages of nanotechnology, and the growing number of publications and patents in the area, agricultural nanotechnology applications have not yet made it to the market.[17]

In practice, the economics and production of nanomaterials developed within research laboratories may not be suitable for scaling up to industrial production, particularly for the economic production of food-grade nanomaterials on an industrial scale. Furthermore, the application of nanotechnology in agriculture will have to address the inherent complexities of farm biological systems, including the disposal of nanomaterials at the end of their life-cycle.[18]

[17] Nano Tech: Agricultural Nanotechnologies: What are the current possibilities? [April 2015]
[18] FAO/WHO technical paper: 'State of the art on the initiatives and activities relevant to risk assessment and risk management of nanotechnologies in the food and agriculture sectors' [2013]

There is also uncertainty about how different governments will regulate nanotechnology in the food supply. There is concern as well over consumers' perception and reaction toward food products and associated packaging materials that could contain nanomaterials, particularly where active ingredients of nanotechnology may still be present.

Of all the new and emerging technologies included within this research report, the application of nanotechnology within the agriculture sector would appear to be the most challenging. The rapid progress of nanotechnology in other industries at significant scale, and at a low cost point, would be required before the potential of this technology to the agricultural sectors could be seriously contemplated.

Uptake of new and emerging technologies

The technologies described above were widely discussed by academics, thought leaders and industry commentators interviewed as part of this Fellowship, and are consistent with many other reports and analysis written on the application of new and emerging technologies within the agricultural sectors. But more often than not these types of technologies are met with high expectations, often fuelled by savvy marketing, media fanfare and social networking platforms, and then they fail to live up to early promise.

Perhaps we shouldn't be surprised by this as it can take a long time for technologies to become integrated into our daily lives as the early GPS example shows. This was well summed up by the late William Gibson, a highly regarded science fiction writer of the cyberpunk sub-genre, who when asked to describe the future said:

> *The future is already here - it's just not very evenly distributed* (1993)

The speed of uptake in the application and/or adaptation of technologies on-farm and along the supply chain will inevitably be driven by highly motivated and forward-thinking individuals and organisations best able to use, adapt and exploit the opportunities presented by new and emerging technologies. In doing so, they are able to establish a competitive advantage for themselves within their industry sector and in the marketplace.

So how do we provide an environment and motivation for individuals to seek out and exploit the opportunities presented by new and emerging technologies to extract greater value for New Zealand agricultural products? Or perhaps encourage the emergence of some other new type of industry that we haven't even thought about yet? Those questions have occupied my thinking in completing this research report, and continue to do so.

Exploration of the opportunities presented by new and emerging technologies

New Zealand is generally regarded as a highly successful exporting nation of agri-food and fibre products. We have lead the way in the application of world class science and innovative practices in temperate grass-based farming systems underpinned by a relatively stable commodity market, which has largely served us well for well over a century.

However, since the start of the new millennium we have seen the erosion of our agricultural sectors' comparative advantage, marked by the loss of our internationally competitive position as a low-cost producer of agricultural products brought about by increasing input costs and expanding compliance requirements, exacerbated by high land costs.

While the farming community and wider industry have been commendably fast adopters of new production-based technologies, more often than not this has been through the pursuit of producing more of the same types of products at less cost, rather than necessarily developing higher value products or services able to attract price premiums in the marketplace.

New Zealand's agricultural sectors are facing some very stark choices. We can continue on our current trajectory and remain a low-value commodity player that will inevitably face diminishing ongoing returns in the future. Or we can look to trade-up and add greater value to our agri-food and fibre products that improve profitability and extract greater returns from the marketplace. Of course, this is very easy to say; there are innumerable reports from credible sources advocating the same approach.

So why do we find it so difficult to move beyond our existing business models and structures in seeking out new opportunities for our agricultural products? To explore this question further I spent time in San Francisco to develop a better understanding of what a vibrant, fast-paced and rapidly changing technology-driven environment looks like.

Powering up the innovation ecosystem

It is estimated that 50 percent of the world's start-ups are now based in the San Francisco Bay Area, most of which are chasing venture capital wealth, looking to access world-class universities and private research institutions, and connecting with highly talented people. All of which has created a unique and self-sustaining innovation ecosystem.

The energy and level of technological innovation occurring in San Francisco Bay Area is hugely impressive and incredibly fast moving. It seems that every second Uber driver I came across was involved in some type of start-up or developing a new tech algorithm. It's easy to see why so many New Zealanders gravitate to the area to seek out new business opportunities, connect with thought leaders and/or to expand their understanding on what drives the innovation culture in San Francisco (e.g. Te Hono Bootcamp).

In speaking with Tim Brown, the CEO of IDEO, he notes that the San Francisco Bay Area innovation ecosystem has a high tolerance for risk and doesn't fear failure. This allows start-ups to try out ideas and fail fast and move on quickly, thus accelerating the speed of learning. This has been made increasingly easier through the application of technology to test and prototype new ideas more quickly and cheaply through 3D printers, computer modelling and complex data analysis.

The start-up culture in the San Francisco Bay Area is truly unique. There seems to be a willingness by start-ups to test out new ideas with seemingly greater access to capital and highly capable people than would be seen anywhere else in the world. Should the start-up not demonstrate promise and/or prototypes fail, developers take on board the lessons learnt and move on to the next idea to present to another venture capitalist, or simply walk down the road to find employment in a different tech firm.

In his yearly Letter to Shareholders released in April 2017, the founder and CEO of Amazon Jeff Bezos discussed the decision-making process within his organisation. Amazon's goal is to make fast quality decisions, which often can be done when about 70 percent of the information you wish you had is available. Waiting for 90 percent means going too slow and Bezos advocates for 'disagree and commit' as a way to save time. His teams don't have to persuade him to take a particular route; they just have to convince him enough that he is willing to take a gamble.[19]

In a further variation to this, the 'maker movement' provides an environment for inventors (or makers) to crowd source information from their peers to make products. The maker movement has a DIY culture that intersects with the hacker culture, and revels in the creation of new devices as well as tinkering with existing ones. Rather than test and fail fast, and try something else, makers often redesign from failure following a process to 'iterate and change' → 'iterate and change' → and so on.

Dale Dougherty of Maker Media describes the maker movement as being based on community ideals, evoking the spirit and passion of building stuff yourself. The maker movement provides an opportunity for makers to share and develop their ideas, building greater connection points with other makers to develop prototype products. It would be interesting to see whether individuals tinkering in sheds and garages across New Zealand would be similarly open to crowd sourcing information and innovative ideas without the fear of losing any perceived intellectual property.

Dale notes that Real Vegan Cheese is an example of the maker movement in action. Real Vegan Cheese, with a team of 24+ biohackers and scientists, are working out of two open community labs in San Francisco. They are using synthetic biology to engineer yeasts into milk proteins which will ultimately be converted into vegan cheese and possibly other dairy products. Information from the work will then be open sourced and placed into the public domain for others to apply the technology into business enterprises.[20]

What this shows is a strong willingness by individuals and organisations to explore new ideas and test these within a highly supportive innovative ecosystem.

[19] USA Today: 'Disagree and Commit' Jeff Bezos 'Words to live by in Annual Letter' [14 April 2017]
[20] Real Vegan Cheese: https://realvegancheese.org/

In discussing the ability to replicate elements of the innovation ecosystem culture to other industries, Tim Brown noted that most organisations aren't really ready for change. They don't have the budget, structure or culture to do things differently, or the aptitude to take on risk and run with new ideas. To expand on this point further, he observed that cultures that have difficulty with failure:

- Struggle with early learning;
- Lack confidence to prototype and stick with ideas that initially failed;
- Are poor at learning fast (as they think they already know); and
- Leave the lead of learning to others, therefore running the risk of being subservient to others.

These points are disconcertingly familiar as they reflect many of the traits observable within the New Zealand agricultural sector.

As I commented above, the innovation ecosystem within the San Francisco Bay Area is unique. Despite the best intentions of various organisations in New Zealand and abroad to replicate elements of Silicon Valley through innovation hubs and the like, they don't have the same access to investment capital, the depth of talented people, world leading research or the right culture.

We also often look to the technology achievements of the San Francisco Bay Area as a relatively new phenomena. Yet an often overlooked factor behind its success has been decades of intensive and sustained federal government investment in research and development in the technology sector, which has been critical in building people and research capability in the region.

In traveling across the vast expanse of the mid-west of the United States and discussing the innovation ecosystem in the San Francisco Bay Area with leading academics in the mid-west, they noted that the appetite to take on risk by farmers is low. Their monoculture farming systems and considerable investment in infrastructure required to support this provides little appetite to take on risk. As one academic noted, 'they don't want to be the generation that loses the family farm', which is strikingly different to the DNA of Silicon Valley where risk and change are embraced and seen as a pathway to potential opportunities worth exploring.

Sustaining the condition of 'not knowing'

We have, in the New Zealand agricultural industry, been highly successful in implementing and codifying systems around the production and processing of our commodity products, which has contributed to the sector's overall success.

Our farming enterprises, processing and marketing companies, and education and research institutions involved in the primary industry, have become intimately and firmly established within this ecosystem, which has largely delivered familiar types of outcomes expected by the parties involved over a long period of time. We shouldn't be surprised by this as generally people and institutions like rules and predictability and to

know where the boundaries are. The risk, however, is that our intimate knowledge and closely-knit support structures within this ecosystem may in fact create resistance to rapidly changing circumstances that openly challenge the status quo.

I was fortunate enough to spend time with Bruce Corson of Corson Associates in Sabastopol, based in wine country north of San Francisco, where we discussed at length design thinking lead approaches and their effectiveness in shifting business models, and the mindset of individuals involved in the process.

> Design thinking is a methodology used to solve complex problems and rapidly prototype, test and validate desirable solutions. It draws upon logic, imagination, intuition, and systemic reasoning, to explore possibilities of what could be, and develops useful solutions and creates a desired future that fits the needs of the user, not the other way around. Design thinking allows for an iterative rapid-cycle approach to find a desired solution through prototyping ideas and products quickly with the end user in mind.

One of the biggest challenges Bruce sees within individuals and businesses is the level of willingness to acknowledge that they don't know everything and to move them from a state of comfort to one of exploration.

He notes that as we try to understand and address systems whose nature and extent are unclear, we routinely discover our models for understanding them are insufficient. In fact, and with disconcerting regularity, we discover they are clearly wrong. To be able to constantly adapt we must live in an uncomfortable state of chronic uncertainty. We grow accustomed to 'knowing' and with each passing year spent in such circumstances – where the overwhelming emphasis is on 'the answer' – we become less and less able to 'not know' – the fundamental condition of the creative process.

We have become experts and conditioned to finding familiar answers to problems without truly embarking on a process of discovery – looking for something that no-one is aware of – and taking the time and effort to fully 'name the problem'. To be effective explorers, we must have the courage to accept that our 'maps' are quite likely wrong.

Critical to the success of the design thinking approach is to undertake an expansive process of exploration to understand the actual scope and dynamics of the situation we wish to transform to 'name the problem'. This requires participants to be curious, give up what they know and move onto something new, collect information from different signals around us, and to use available information differently.

The design thinking process is challenging and requires the fortitude to robustly test deep set biases and familiar ways of thinking prevalent among individuals and organisations involved in the process. If facilitated well this process provides a framework for exploration and can be a powerful tool in creating a desired future state that fits the needs of the end user.

Shifting mindsets to enable new thinking to flourish

Given our exposure to design thinking lead approaches, and no doubt other types of solution-focused models that will inevitably follow, why do we not see step change occurring within New Zealand's agricultural sectors that are so often talked about?

Despite the protestations of individuals and industry sectors about the need to break out of the commodity cycle and aim further up the value chain, this is very difficult to achieve. This is particularly so when an industry has grown accustomed to operating within a relatively stable and low-risk commodity market sustained by an elaborate ecosystem to support this. However, this situation makes us highly vulnerable to disruption should a major disturbance or event take place within the primary industry, or some significant transformation occurs in the consumer purchasing behaviours of agri-food and fibre products.

So when a disruption does happen that challenges the way we operate, we often seem reluctant or even powerless to act until someone else delivers a tidy package containing a familiar type of solution or template that is consistent with what we expect to see and aligns with our mental models without fully exploring the extent of the problem and/or seeking alternative broader scale solutions.

So why is it that some individuals perform better and demonstrate greater resilience during times of crisis than others?

In looking at the art and science of survival Laurence Gonzales wrote that psychologists who study survivors conclude that the most successful are open to the changing nature of their environments – they are curious to know what's happening. He notes that as environments change, what is needed is versatility, the ability to perceive what is really happening and adapt to it. In such circumstances training and prediction may not be your best friend.[21]

Developing an acute awareness of the environment, being able to collect information and analyse this effectively, and then having the conviction to adapt to changing circumstances seem to be common attributes of survivors. Whilst this represents the harsher end of the spectrum in managing crisis situations, it does provide useful insights into some of the behavioural traits of individuals faced with acute adversity.

Operating within the relative comfort of our commodity market we can expect to see the types of outcomes that match our mental model in the production, processing and marketing of our commodity products. But this does not necessarily provide us with a heightened awareness of external factors that could impact upon our existing business models or equip individuals with the skills and confidence to become more adept and adaptive in operating in uncertain environments.

The weight of expectation to maintain the status quo – the foundation of our very success within the agricultural industry – is heavy. But does this potentially impact on our ability to deeply consider, discuss and explore radically different perspectives that challenge the status quo, and slow down the uptake of ideas and new technologies.

[21] Laurence Gonzales: *Deep Survival: Who Lives, Who Dies and Why* [2004]

Within the highly supportive and well-resourced innovative ecosystem system of Silicon Valley, there is greater willingness to actively explore new ideas and test these for the purposes of gaining a competitive advantage in the marketplace. This is a quality we rarely see within New Zealand's agricultural sectors.

Professor David Teece of the University of Berkeley believes that if we seriously want to move beyond commodities we need to be acutely alert and plugged into where food trends and values are occurring. That requires having a strong presence in the marketplace and directly engaged with consumers, as well as being tapped into world leading food technology centres. To be successful, he saw the need to develop a culture that wants to make a difference and is prepared to disrupt ourselves by embracing a range of competing perspectives and views, and the need to develop individuals' attitudes and aspirations to want to move beyond commodities. He believes more should be done to encourage 'mavericks' and new players into New Zealand's agriculture sectors to challenge existing business models.

David described my Fellowship as one of 'sensing' moving to 'sense making' in providing greater insights to better identify and seize new opportunities, something that he believes New Zealand's food industry is very poor at.

In many respects commodity producers and processors, along with our educators, researchers and regulators, are neither adept at sensing changes in consumer purchasing behaviour, nor have they the capability to effectively exploit new opportunities in the marketplace should they arise. Often heralded changes we hear about are more in the realm of marginal improvements and sustaining what they are doing already.

It is far too easy for industry, businesses and commentators to dismiss the impact of new technologies and potentially ground-breaking products because they cannot foresee or accept changes that might threaten the status quo, but in doing so they run the greatest risk of being irrevocably disrupted.

We should not underestimate the challenges faced by agricultural sectors through the rise of new and emerging technologies likely to impact upon the production, processing and marketing of agri-food and fibre products. The agricultural industry has largely been immune to the digital and technology transformation seen in other industries, such as in the medical care, manufacturing and service sectors. But this is quickly changing and we can expect to see greater levels of technology developments on-farm and at various stages along the supply chain through to the marketplace in future.

If we don't learn to become more adept at sensing and exploiting changes presented by new technologies and changing consumer preferences within an increasingly dynamic market environment, then we risk falling behind our competitors who have a greater capability to take advantage of the opportunities presented by new technologies.

The opportunity

New and emerging technologies described within this report mirror a lot of other reports and commentaries covering the same subject matter. But what they don't study in any great depth is how do we create environments to allow individuals and entrepreneurial businesses to seek out and exploit new opportunities presented by these technologies for New Zealand's agri-food and fibre products, or perhaps in some other industry we haven't even thought about yet.

Having taken the time to research the topic for this Fellowship, and the many tangents this has taken me down, I believe a radically different approach is required in building the capability of individuals and innovative organisations to become more adept in sensing and capturing opportunities within the marketplace, including:

Embracing risk

Seeing the innovation ecosystem culture prevalent in the San Francisco Bay Area that has a high tolerance for risk and doesn't fear failure is in stark contrast to the risk aversion we see within New Zealand's agricultural sectors that are often constrained by low margins with limited scope to invest in research and product development. But without taking on risks and experiencing this directly, we are less inclined to want to continually test out new ideas and innovations in developing new products and services.

Greater effort should be made in developing a culture that encourages and resources individuals and innovative businesses to embrace risk without fear of failure in testing out new ideas. In this respect, private and government-funded research programmes have a critical role to play in developing greater tolerance of risk in the way they invest in and sustain research projects and innovative business endeavours over longer term time horizons, particularly in areas targeted at building a competitive advantage for New Zealand's primary products.

This also requires a fundamental reset in the way publically funded research programmes are designed, as it seems a folly to want to continually invest in familiar types of projects looking at slight variations of existing bodies of research work, or worst still a constant repetition of existing research in a hope that it will produce different findings.

Moving from an environment of risk aversion to rewarding risk taking represents a significant cultural shift in the way the primary industries and research funding agencies function. However, this is needed if we are to increase the level of dynamism within the agricultural industry, as well as providing fertile ground to encourage more venture capitalists to invest in leading edge projects.

Providing space to 'breathe'

This Fellowship provided me with an opportunity to see information independently through an unadulterated lens, and to explore and understand what a vibrant and rapidly changing technology-driven environment looks like. Unfortunately, the opportunities for individuals to do this are very rare within New Zealand's primary industries (possibly with the exception of Nuffield Scholars, and leadership scholarships offered by AGMARDT).

Whilst technology and a constantly expanding range of tools have improved productivity and efficiency in the way we produce and process agricultural products, it has also filled out the edges of our personal and working lives, impacting on our ability to freely explore new ideas and areas of development or alternative streams of logic.

A reset is required in that greater opportunities should be given to highly motivated and talented individuals to 'breathe' – to devote more time and energy to exploring and widening their scope of their awareness in pursuit of new ideas and innovations within the agricultural sectors and the marketplace, or possibly a new industry.

By supporting and resourcing individuals and innovative business enterprises to independently expand their capabilities, it would better enable them to become more adept at sensing shifts and picking up signs of change in the marketplace, and in the exploration of opportunities in the adaptation and application of new technologies. This would require individuals to immerse themselves in particular areas of interest and in new and developing areas, rather than participating in another tightly scripted in-market training programme with defined outcomes where key learnings often get lost a few weeks after returning home to the routine of their respective roles.

Instead the opportunity lies in developing an independent scheme, or leveraging up existing schemes, to provide funding and development support to highly motivated and talented individuals and innovative organisations to seek out and/or take advantage of new ideas and innovations. This could be further supported by a team of talent spotters that have directly experienced success and failure in the marketplace, who can see the potential in others if given the opportunity and sufficient guidance.

Creating safe environments

Greater effort should be made in providing a secure environment for individuals and organisations to openly debate, discuss and test ideas. This is often difficult where individuals are seen to be swimming against the tide of prevailing views and practices – more so in a small and tightly-knit country like New Zealand.

It is far too easy to challenge, or at the extremes alienate, individuals for expressing views that don't necessarily align with mainstream thinking and established business practices. In some circumstances, this has been made worse where views and opinions are openly criticised through the anonymity that social media provides.

By creating safe environments we have an opportunity to strenuously challenge our existing business models and stretch test new ideas and concepts, because without the presence of doubt and a healthy level of scepticism about what we do currently, we have no incentive or motivation to challenge the status quo and find new means of advancing an industry.

Seeking more 'mavericks'

There are limitations with our existing businesses and industries being able to continually adapt and innovate, made more difficult by internal cultures and steadfast systems established over a long period of time. This has been made worse through the preoccupation of micro-managing risk across all aspects of business endeavour, thus stifling interest in testing and exploring new and leading edge ideas.

In accepting the confines of our own business models and the cultures that are within them, greater consideration should be given to reducing barriers and encouraging more 'mavericks' and new players into the industry to challenge the status quo and disrupt our traditional ways of thinking and patterns of behaviour. They could play an important part in pushing the boundaries of what we know, and what could normally be achieved, through our existing business models. However, we should not underestimate how challenging this will be in the face of fierce competition that will inevitably come from the market.

In encouraging more mavericks into the system, we should also consider what can be done to encourage and resource existing players who are strongly motivated to disrupt their own business models through establishing separate standalone units and/or organisations that push the boundaries in the development of leading edge innovative products and services.

Becoming match fit to keep pace with technology change

The speed of uptake in the application and/or adaptation of technologies on-farm and along the supply chain will inevitably be determined by highly motivated and forward-thinking individuals and entrepreneurial organisations best able to use, adapt and exploit the opportunities presented by new and emerging technologies – and by doing so establish a competitive advantage for themselves, an industry and/or in the marketplace.

The pace of change in the development of new and emerging technologies in the agri-food and fibre industries is accelerating at a faster rate than we have ever seen before. If we do not learn to become more adept in responding to fast-moving technology-driven change faster than our existing competitors and/or within a new product category, then we run the risk of following the same trajectory as the strong wool industry that was unable to shift quickly enough when circumstances demanded it.

As an industry we need to consider how we design and quickly build the capability within the agricultural industry to be better at seeking out, scaling up and exploiting opportunities presented by new technologies in the primary sector, through to the marketplace.

Central to this will be in our ability to sift through the noise and hype in seeking out relevant and insightful intelligence on the types of new and emerging technologies likely to impact upon New Zealand's primary industries and influence consumer purchasing behaviours of agri-food and fibre products in the future. And then having the conviction to rapidly apply and/or shift resources that builds the capability within the education sector, research institutions and industry to effectively respond and take advantage of the opportunities available in the application and/or adaptation of new technologies.

Conclusion

In undertaking this Fellowship I was interested to explore and develop an expanded understanding of the opportunities presented by new and emerging technologies in the production, processing and marketing of New Zealand's primary products, But as my Fellowship progressed I became more interested in what could be done in shifting the mindsets of individuals to become more adept at seeking out and exploiting opportunities presented by new technologies on-farm through to the marketplace.

The technologies described in this report provide a signal about some technological developments likely to impact on the agricultural and food sectors in the future. While these are widely reported, this does not account for the rise of some new and unexpected technology appearing from an unlikely direction and disrupting our business models.

The sheer scale of technological development now occurring within the agricultural and food sectors is moving at a speed we have simply not experienced before, which makes judgement calls on time horizons and the likely impact of new and emerging technologies extremely difficult to predict. But what is clear is that when a new technology makes an industry or business operations considerably more effective or consumers' day-to-day lives clearly better, the momentum in its uptake is unstoppable.

We have become highly proficient in the production and processing of commodity products, which have largely delivered familiar types of outcomes over a long period of time. However we should not underestimate the effect of advanced technology developments occurring in production and consumption of food proteins.

If we don't learn to become more adept at sensing and exploiting the opportunities presented by new and emerging technologies and become more attune with changing consumer purchasing behaviours, then we run the risk of falling behind our competitors who have a greater capability and scale to take advantage of these opportunities than we do.

I do have faith that the agricultural and food sectors will respond to whatever challenges are put forward, but this must move beyond the preservation of existing business models and requires a bold and radically different approach to what exists today. Undoubtedly this will represent a significant challenge for individuals and organisations involved within the agricultural industry, but as the great Winston Churchill said:

'This is no time for ease and comfort. It is time to dare and endure.'

Appendix One: Travel Programme

United States

Gregory Baker	Director of our Food & Agribusiness Institute	Santa Clara University	San Francisco	5/4/17
Tim Brown	CEO and President	IDEO	San Francisco	6/4/17
David Teece	Professor of Business Administration	University of Berkley	San Francisco	7/4/17
Bruce Corson	Visiting Prof. College of Architecture, Art and Planning	Cornell University / Corson Associates	San Francisco	8-9/4/17
Gower Smith	CEO	Swift	San Francisco	10/4/17
David Zilberman	Professor & Robinson Chair, Dept of Agricultural & Resource Economics	University of Berkley	San Francisco	10/4/17
Dale Dougherty	CEO	Maker Media	San Francisco	10/4/17
Randall Westgren	McQuinn Chair in Entrepreneurial Leadership — Applied Social Sciences	University of Missouri	Missouri	12/4/17
Annette Kendall	PhD student studying entrepreneurship	University of Missouri	Missouri	12/4/17
Cynthia Faullin	Assistant Director our Research Park	University of Illinois	Illinois	13/4/17
Laura Bliell	Associate Director — Research Park	University of Illinois	Illinois	13/4/17
Howard Gerwin	Manager, Advanced Connected Services	John Deere	Illinois	13/4/17
Megan Puzey	Associate Director — Office of Corporate Relations	University of Illinois	Illinois	13/4/17
Richard Vogen	Director of Planning and Resource Development	University of Illinois	Illinois	13/4/17
Steven Sonka	Emeritus Chaired Professor of Agricultural Strategy	University of Illinois	Illinois	13/4/17
Vijay Singh	Director — Integrated Bioprocessing Research Laboratory	University of Illinois	Illinois	13/4/17
Neal Merchen	Director of the Agricultural Experiment Station	University of Illinois	Illinois	13/4/17
Michael Gunderson	Associate Professor and Associate Director of Research	University of Purdue	Indiana	14/4/17
Mike Boehlje	Professor, Department of Agricultural Economics	University of Purdue	Indiana	14/4/17
Richard Lum	CEO	Vision Strategy Foresight	Honolulu	27/10/17

Canada

John Cranfield	Prof & Chair, Department of Food, Agricultural & Resource Economics	University of Guelph	Ontario	18/4/17
Aislinn Malszecki	Senior Associate	MaRS Discovery District	Toronto	19/4/17
Jamison Steeve	Executive Director	Martin Prosperity Institute	Toronto	20/4/17

Europe

Steffan Brunner	Global Key Relation Manager	Bayer, Crop Science	Monheim, Germany	24/4/17
Brite Tschentke		Bayer, Crop Science	Monheim, Germany	24/4/17
Alex Kirchhofer	Strategist	Bayer, Crop Science	Monheim, Germany	24/4/17
Samir Bennabi	Head of Alliance Manager	Bayer, Crop Science	Monheim, Germany	24/4/17
Frank O'Mara	Director of Research	Teagasc	Cork, Ireland	25/4/17
Pat Dillon	Head of Programme — Animal & Grassland Research and Innovation Centre	Teagasc	Cork, Ireland	26/4/17
Padraig French		Teagasc	Cork, Ireland	26/4/17
Kevin Tobby	Farmer	Ballynock	Cork, Ireland	26/4/17
Paul Ross		University of Cork	Cork, Ireland	27/4/17
Søren Madsen		Agro Food Park	Aarhus, Denmark	1/5/17
Mette Hoberg Tønnesen	Special Advisor, Food & Agriculture / Investor in Denmark	Danish Ministry of Foreign Affairs	Aarhus, Denmark	1/5/17
Frank Bakema	Corporate Director Education, Research & Innovation	Wageningen University	Netherlands	2/5/17
Roger van Hoesel	Managing Director	Food Valley NL	Netherlands	2/5/17
Henk Hogeveen		Wageningen University	Netherlands	3/5/17
Hans van Trijp	Department of Social Sciences —- Marketing and consumer behaviour	Wageningen University	Netherlands	3/5/17
Ankur Mathur		Accenture	Conference call	3/5/17
Jennifer Helle		Accenture	Conference call	3/5/17
Eduardo Barros		Accenture	Conference call	3/5/17

Appendix two: Dissemination

Leading up to the formal publication of this report on the Winston Churchill Memorial Trust website, I have disseminated the findings and key learnings of my Fellowship in the following ways:

1. Completed three Journal articles June, September and December 2017, and uploaded these in my blog (in the following order):
    - Lack of national strategy and scale undermines the potential to develop world class agriculture and food innovation hubs
    - Future role of rural professionals in a big data world
    - Are alternative proteins setting the pace in understanding consumer needs?
2. Completed a presentation to the NZIPIM Board Meeting on 17 May 2017
3. Presented a paper at NZIPIM's National Conference held in Lincoln on 8 August 2017
4. Interviewed by the Straight Farrow, with an article appearing in the December 2017 edition
5. Met with the Minister for Primary Industries, the Hon Damien O'Conner on 28 February providing key learnings from the Fellowship

I continue to draw upon and share the insights and key learnings from my Fellowship with others, and will continue to do so in the future.