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Science and Innovation in New Zealand Agriculture

We need to work Together, Nāu te rourou, nāku te rourou, ka ora ai te iwi

With your food basket and my food basket the people will thrive

By John Foley
2021 Nuffield Scholar
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1. Research Questions:

Science and Innovation in New Zealand Agriculture – We need to work together

The NZ science sector has been the subject of countless reviews, policy interventions, discussion documents and commentary. This report considers the economic imperatives that created the current science system, the incentives that drive scientific endeavour in this country and how these relate to NZ agriculture.

1. Is our science system fit for purpose as we negotiate climate change, environmental constraints and profound shifts in consumer preferences that are shaping food demand?
2. Why do solutions aimed at improving the NZ science landscape result in more complexity?
3. What incentives drive science and innovation in NZ?
4. We need to be smarter in how we link our science sector to innovators that give NZ food producers the best possible opportunity to capture value.
5. What could a reimagined science sector look like?

2. Executive Summary

The era of trade liberalisation and reform in the 1980's and 1990's left New Zealand (NZ) focusing on what it was good at – being efficient commodity producers, and NZ exploited its comparative advantages. This drive for efficiencies created the domestic agenda for science and innovation. For agriculture, to drive productivity gains, the focus was inside the farm gate. It is something of a paradox that, as the world was globalising and NZ was opening up its economy to competition, we became more localised in the things that created immense value for NZ. The world is changing, and to keep up, NZ needs to be world-class at research and value creation – innovation is the common denominator. We need to re-imagine our science and innovation models to give agriculture the best opportunity to contribute to a more prosperous NZ.

This report makes a case for change in the way research and development is conducted in this country. What we have today was the result of a massive reform agenda in the 1980's and 1990's, when market forces were introduced into areas of the economy that had traditionally been protected. In the 30 years since, there has been a series of policies attempting to 'fix' our science system; to roll back the unintended consequences of the reforms. These efforts have largely been 'small' and often on the edges of the big problems. It is almost as if the courage of government for reform has evaporated; the upheavals of the earlier era has left little appetite for fundamental change. So, we have a science system that is fragmented, siloed, and characterised by competing agendas and organisations. The structures and funding models drive perverse incentives such as, doing science to get published, to be able to get funding, and to get funding, in order to get published….

The government's role in science is complex. As a major funder it has an obligation to ensure the output is both world class, and benefits NZ. It must balance funding of the science sector with all the other demands on the treasury. The political reality of science is that there is little be gained from solving the sector's problems. The issues are complex, difficult to define, and changes hard to implement. Over the decades there has been a decline in expert capability inside government (Cook, 2004) – people who have depth and breadth of experience in their roles. Cost efficiencies and productivity became guiding principles (Cook, 2004) and a 'slimmed' down state sector still resonates with the electorate. This in turn, has lowered the ambition of governments and reduced the experience held internally (Mazzucato, 2021).

Policy change at any level becomes difficult, making substantial reorganisation or visionary change to the status quo, very complex. When we try and 'fix' the issues we enter into what is known as the complexity paradox (Mazzucato, 2021), where layers of policies drive the creation of silos that begin competing with each other. Thus, rather than 'fixing' the problems they are further entrenched. We need to do much better. Whilst it's broadly true that innovation happens close to consumers, in value chains, in science institutions, private enterprises and on farms – all across the economy, governments do have an important role in creating the framework and policies, that encourage innovation.

The crux of the problem for NZ's science sector is that everything is viewed in the short term. Everything, almost everywhere, has been reduced to time periods, – governments can't wait, the Performance Based Research Fund can't wait, the science can't wait, the funds are annually contestable, and businesses want quick wins for reporting purposes. The system doesn't allow science enough time to figure things out. Election cycles influence funding horizons that determine project lengths, and scientists' time horizons are limited to the length of the project they are working on, and their careers are limited to the project duration. Everyone needs quick wins to survive. Incentives are misaligned and fragmented, all players are responding to 'their' incentives and few groups share the same ones. Long term strategies underpinned by investment in R&D have created some of our most successful businesses. The long-time horizons associated with Māori business is a compelling reason to build relationships with Māori and may be the catalyst for our science sector to recapture its long term view.

NZ does efficiency very well because it is 'in market,' but the innovation is localised and hard to scale to other markets. Pine and Gilmore proposed a model of progression of economic value (Gilmore, 1998). They argue that as economies evolve, an increasing share of the value is captured at higher positions in the value chain and as these value chains evolve, the next iterations become the place of maximum value. The 'innovation for value' is at the edge of this continuum however, our economic system has created a very different role for NZ agriculture and its innovation mindset – we localised into an efficiency and production model. The challenges are bigger than the science system and indeed agriculture – creating change with a 'sector-only' focus won't create a wealthier NZ. We need a science system built on collaboration within itself, with government, and with the private sector. It would have a new mandate: to create value for NZ and, for agriculture, the research and development must create value for farmers, for agribusinesses, for exporters and wealth for NZ, beyond the production-efficiency status quo.

Mission Orientated Innovation is an approach to solving complex challenges within sectors and across societies. A central pillar of this framework is collaboration, *"Nāu te rourou, nāku te rourou, ka ora ai te iwi"* – "with your food basket and my food basket the people will thrive". This report proposes three missions for agricultural science and innovation for New Zealand.

Mission One: Creating internationalised researchers and businesspeople.

NZ needs in-market innovation and expert people. The guiding objective is to develop NZ's linkages into key markets. We must be strategic - building knowledge, facilitating technology transfer back to NZ and out to the world, building understandings of markets and societies, providing student exchanges to foster cultural understandings and professional links. We need to be building capability at multiple layers. Currently, there is little strategic development of people in a broad, coordinated sense, for example, developing programmes for researchers, food innovators, consumer trends, policy areas, and offshore capabilities.

Mission Two: Creating the opportunities for technological convergence.

The convergence of ideas is the basis of innovation and often these ideas are completely unrelated. The convergence of technologies requires collaboration and there are many impediments to this in our current science system. New Zealand needs a culture change, in its research sectors, educational institutions, government departments and the private sector, to foster the convergence of ideas and technologies. The solution is not just structural, it's also about developing the people capable of fostering technological convergences – the translators, and having businesses capable of adopting new ideas – the absorptive capacity. In the new economic era, agriculture is going to need focused, applied research, and agribusiness and the levy paying organisations will need to shift their efficiency-productivity mindsets, and they will need help to do this.

Mission Three: Creating a world-leading agricultural institute.

The Te Ara Paerangi Future Pathways green paper has signalled that the CRIs and Callaghan Innovation are up for review. The outcome of this review should be a bold reorganisation of our science landscape. The CRIs associated with the land-based industries, i.e., Plant and Food Research, Ag Research, Manaaki Whenua - Landcare Research, and Scion could be rolled into a new entity with Lincoln University at its centre. This would concentrate applied agricultural research and excellence. Each entity would keep their independence and the cluster would be marketed as 'Lincoln University.' The mission is to become the leading food and agricultural university and to create the reputation that NZ agricultural science is world leading. It would attract world class researchers to NZ, and together with our local talent, foster the development of world class science and innovation.

3. Acknowledgements

I am extremely proud to have been a Nuffield scholar, it's a very special programme with a great history and run by great people. To say the experience has been immensely rewarding seems like an understatement – I can't speak highly enough of my Nuffield experience. To come out the other side and write this report could not have happened without the willingness of people to help, support and encourage me throughout. I would like to thank Lisa Rogers and Chris Parsons for everything they have done for us over the last 18months. Keeping us motivated, engaged and enthusiastic on our Nuffield journey, whilst Covid-19 threw curve balls one after another, was outstanding and we absolutely respect your immense contribution to the programme. To Craige Mckenzie, a big thanks for encouraging me to apply and offering insights and wisdom during my Nuffield year. Thanks to Hamish Gow, our academic supervisor, whose enthusiasm for everything, couldn't help but inspire. I would like to acknowledge John McKenzie, CEO of PGG Wrightson Seeds for supporting my scholarship application and giving me the time I needed to focus on my scholarship, this was very much appreciated. To the office: Murray, Richard, Millie, Simon, Will, Jack and Kevin who kept everything going in my absence and showed that things carry on just fine without me. To the 2021 scholars: Lynsey, Dave, Ben, and Dan, it was an absolute privilege being a scholar with you. I have a lot of fond memories from the trips we made together, especially the 'van talk' and the laughs. To the 2020 scholars: Phil, Shannon, Ed, Tracy and Ben a big thank you. Phil, for sharing your wisdom and our visit to see Ruth Richardson was an absolute highlight. Finally, a big thank you to my family; Anne, Thomas and Grace, and Mum and Dad. To my wife Anne, who was my 'editor in chief' and whose encouragement and support throughout the scholarship has been absolutely awesome, I am really grateful for this.

COVID-19 ensured the 2020 and 2021 Nuffield scholars had very different experience to previous scholars – rather than an international programme, ours was domestic focused. One of my abiding memories of the travels we did throughout NZ was an appreciation of the number of outstanding people and businesses we have in this country.

This report is based on interviews of people from across the science sector, agriculture, and academia. I am truly grateful for them giving their time and offering their insights. I have been left with a strong impression that we have outstanding people in our science sector, contributing amazing things to NZ agriculture, our economy, and society.

My interest in NZ's science sector developed during our 'Nuffield World Tour of NZ' in February and March 2021. One of our earliest visits was to NIWA's King Fish Farm near Whangārei where I heard for the first time the word 'Grantsmanship' and the huge amount of time and money invested in funding applications that statistically had little chance of success. Throughout the rest of the trip we heard many anecdotes around the challenges of science in the agricultural sector and the wider economy: it was siloed, hyper competitive, full of duplication, focused on the short term, often disconnected from the needs of agriculture and how the scientists lacked security in their jobs. Un-packing these comments, and understanding how we have ended up with the science sector we have, is what is reflected in this report.

4. Introduction

Innovation is turning future possibilities into a reality

– Hamish Gow.

In 2011, Sir Paul Callaghan gave a speech to at a StrategyNZ workshop where he gave a blunt assessment on New Zealand's place in the world. Sir Paul, who was suffering terminal cancer at the time, could have offered insights from an illustrious career but instead chose to lay out a challenge to NZ - that it needs to do better. 'New Zealand' he said, 'wasn't as clean and green as we thought'. We also worked harder and longer than other developed countries for less money, we have high and rising inequality and score poorly on many other measures. He singled out tourism as an example of how New Zealand has focused on industries that produce low wage jobs.

According to Sir Paul, the average revenue generated across the economy per job was NZ$120,000/year, tourism was just $80,000 so increasing the size of the tourism sector was making NZ poorer. The dairy industry, he said was an impressive success story with $350,000 revenue per employee. High-end manufacturing companies such as Fisher and Paykel Healthcare, who produce respiratory devices and technologies, generating $232,000 revenue per employee were similarly impressive and this was where he believed NZs wealth creation was concentrated, and where we should be focusing our research investment. These companies had found manufacturing niches and exploited them globally. At the heart of Sir Pauls inconvenient truth was that New Zealand's science investment doesn't create opportunities for a wealthier NZ. We chronically under invest in research and where we direct what we invest is almost always in the wrong places. Biotechnology was one example given, where 63% of new economy research money between 1999 and 2005 was directed towards this area, a far greater proportion than almost any other country and almost nothing was achieved. He noted that we don't have enduring science missions that build value, rather we seem to jump on the latest trends, invest heavily and then abandon it for the next trend, the New Zealand space agency is likely to be to be the latest example. Sir Paul's vision for New Zealand was to create "a place where talent wants to live" (Callaghan, 2011).

Climate change, environmental degradation, resource scarcity, stresses on global supply chains, geopolitics, and the COVID-19 pandemic are all profoundly reshaping our world. 2021 was the year when all these threads appeared to come together – the future disruption has arrived and is likely to be ongoing. In fact, politically and economically, we may be moving into a new normal where the multilateral rules-based globalisation of the post-war period gives way to a mercantilist order in which the rules favour the strong. This new order will re-route supply chains and potentially cause New Zealand to make tough calls between its security and economic interests, something we have not had to do since the end of the Cold War. New Zealand and its agricultural sectors have been one of the big winners of globalisation. We have become renowned for our efficient farming systems and high-quality food and fibre products. We are a developed, export orientated nation at the end of global supply chains and we have much to lose in this emerging landscape.

In economics, the price for a commodity is modelled using a 'perfect market' scenario where price equals both the average cost and marginal costs (Gallant, 2021). When costs rise for one group of producers e.g. NZ farmers, then they become less competitive and less able to sell their commodities. If we can no longer intensify our farms and orchards due to environmental limits, then how do we remain financially viable producers of food when only costs can rise? Human endeavor is about improvement – if you can't grow a business, why would people invest in it? In the new normal, where increasing the efficiency of production is no longer the prize and where sustainability and the localisation of food systems changes the perceptions of food and growing practices, if NZ agriculture is to survive, or thrive then we must become leading food innovators. The future story of NZ agriculture is to capture the real value of "brand NZ".

Research is either invention or innovation. Invention is what we associate most scientific effort with e.g. the creation of new knowledge, new ideas and new technologies. Innovation is taking existing knowledge and technologies and repurposing them for uses in other ways. Science is by nature risky and measuring outcomes difficult, especially when there is a chance of failure. One of the most consistent measures of scientific output is publishing in scientific journals and is a metric that is easy to understand. Consequently successive governments have favoured science investment with measurable outcomes – publishing for impact. It also means universities dominate the science landscape and the CRIs look like universities without students i.e. publishing is an important output of these organisations. Using these measures makes it easier to determine funding priorities and drive a competitive science sector. The problem with this is that publishable science must meet certain criteria – being both novel and theoretical and thus difficult to commercialise. To put it another way, NZ is doing the invention well, it's the innovation– the repurposing of existing technologies and science into new/novel uses, that is difficult in the current science landscape.

Thomas Kuhn said that shifts in scientific understanding happen through paradigm shifts where an alternate idea or theory is put forward that is counter to the prevailing view (Kuhn, 1962). A body of evidence is built around the new idea and then the idea becomes mainstreamed (Kuhn, 1962). Scientific progress is not linear in the incremental way it is fostered through project funded science and the ranking of academics and institutions based on their publishing records, but more random and spontaneous. By this he means that the science system, however it is structured and funded, needs to allow people to think and act independently. In this view knowledge accumulation drives knowledge advancement, but paradigm shifts are different, they require convergence of ideas and technologies that are unlikely to happen in tightly managed, siloed science.

What we have in NZ is a complex science system that doesn't appear to be well aligned with the ideas of Thomas Kuhn. As Sir Paul Callaghan noted, our science system reinforces the status quo, "we keep investing in the things we think we are good at". Instead of transforming society and businesses – we fund and research the status quo, we get incremental gains, the knowledge accumulation instead of the paradigm shifts. We have "research-capture" by funding entities, sectors and agribusinesses. We have a funder-facing science environment where countless hours are spent on funding applications instead of using this resource for improving society or innovations that makes NZ a wealthier country.

There is no easy path to building a more effective, collaborative science sector. However, the challenges facing agriculture, and indeed society, cannot be solved using our current approach to science and innovation. The government through Te Pae Kahurangi, the review of the CRIs and Te Ara Paerangi, the Future Pathways Green paper on the research, science and innovation system acknowledge this. Fundamental change is required, and this change needs to be driven by bold visions for the future. This what Sir Paul Callaghan was proposing in his 2011 speech – a new economic model that reworked capitalism into a mission-based economy (Mandow, 2021). Mission Economics is an emerging field of economics. Globally championed by Mariana Mazzucato, this is the 'how' to create a new science sector for NZ, where the end result - the goal rather than the means is the key. In mission economics, government and society set the missions and undertake these through partnerships between government and the private sector. The Apollo space programme that took humans to the moon is the most celebrated example of mission economics. However, climate change, freshwater quality, methane reductions, capturing more value for NZ agriculture, ending child poverty and the housing crisis, to name but a few, are all worthy missions for the NZ science sector.

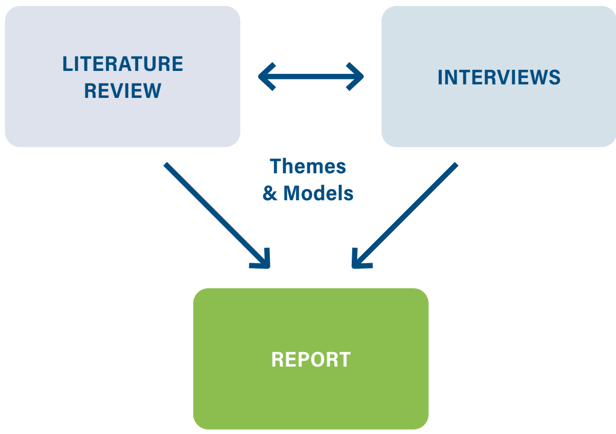
The transition to value is often suggested as a solution to NZ's dependence on commodity agriculture. What this exactly means and how it is to be done is not clear. What is clear, however, is the need to change: environmental degradation, climate change, labour supply issues, the localisation of food systems and the fragility of global supply chains are significant head winds for NZ and our agricultural industries. The future path for NZ agriculture will be about capturing more value for its products, this will require science and innovation to play a leading role.

4.1 METHODOLOGY

This report is based on interviews with people involved right across the science and agricultural sectors. Eighty-Five interviews were conducted through 2021, approximately 50% were face to face and the others via Zoom. The interview notes were analysed for major themes and key insights that have formed the basis of the narrative. A fill list of interviewees is listed in Appendix A.

A wide search of the literature including government publications, industry reports, scientific publications and books were used to source additional information and to provide context to the qualitive analysis that is the basis for this report. A full list is presented in the reference section.

Figure One: The Report's Logic



This report uses five models:

The Flip Thinking Model, was developed by Berthold Gunster in Holland during the 1990's. The methodology requires deconstructing the problem(s) and restating them as a fact.

More details at: https://omdenken.com/flip-thinking/

The Three Horizons Growth Model developed by Bill Sharpe, has become a key tool for creating forward thinking in organisations. This model allows organisations and sectors to consider growth-orientated futures without taking their eye off the current state. Its ease of use and its ability to present complex problems in a simple manner, means it has become widely used in business strategy.

More details at: Three horizons: a pathways practice for transformation http://dx.doi.org/10.5751/ES-08388-210247

The Diffusion of Innovations Theory, developed by E.M. Rogers in 1962. This theory explains how ideas or products overtime gain momentum and become adopted (diffused) within a group, sector, or population.

More details at Behavioural Change Models: https://sphweb.bumc.bu.edu/otlt/MPH-Modules/SB/BehavioralChangeTheories/BehavioralChangeTheories4.html

Mission Economics as proposed by Marian Mazzucato in her 2021 book Mission Economy, argues that in order to solve the big crises of our times we need to use collaborative, mission orientated thinking. "We must rethink the capacities and role of government within the economy and society, to recover a sense of public purpose" (Mazzucato 2021).

More details at Mariana Mazzucato (2021). Mission Economy, a Moon-shot guide to changing capitalism, Penguin Publishing, Dublin.

A Progression of Economic Value from Commodities to Experience, developed by Pine and Gilmore in 1998. This model explains that sources of economic wealth in advanced economies has shifted from commodities, to processing of the commodities to making goods, then to offering services, and now to staging positive, engaging memorable experiences. In the upward progression through these layers greater value is created and captured.

More Details at: Inspiration from the 90's – The Experience Economy: https://customerthink.com/inspiration-from-the-90s-the-experience-economy/

5. Findings

5.1 THE ECONOMICS

The economic doctrine in the western democracies shifted in the 1980s & 1990's to incorporate the power of the market into public policy. Governments were thought to be poor judges of the economic direction for economies and unable to 'pick winners' (Mazzucato, 2021) this was the job of the private sector (Mazzucato, 2021). The market, through its constant recalibrating, was the best way to decide the most efficient allocation of resources, in other words, market forces would 'pick the winners'. Governments roles were reduced to ensuring the efficient operation of markets, removing red tape and bureaucracy and stepping in to correct market failure such as the quantitative easing during the Global Financial Crisis. Margaret Thatcher famously said, "the rising tide floats all boats", this analogy was used to help shift the economic orthodoxy away from Keynesian school of economic thought (Keynes, 1935) to the *laissez-faire* of the free market.

New Zealand was a keen adopter of the free market ideology and during the period 1984 -1999, underwent the deregulation of industries, the privatisation of state-owned assets and public utilities. Competition was brought into our science, health and education sectors, public-private partnerships became common and subsidies were removed from agriculture (Lewis Evans, 1996). After 1984, a massive programme of restructuring and reforms created a much more market orientated economy where the pursuit of efficiencies was rewarded. The value play was to become ever more efficient, to create the maximum production per unit of input (Lewis Evans, 1996). The reforms of the 1980's ushered in a new phase of economic development, a time of government retreat and private sector dominance. Margaret Thatcher's rising tide actually increased social injustice and inequality, led to the fragmentation of government services, and in the NZ context, led to farming systems that pushed beyond sustainable limits in the pursuit of maximum productivity (Richardson, 2004).

Table One: NZs economic development in four broad time periods:

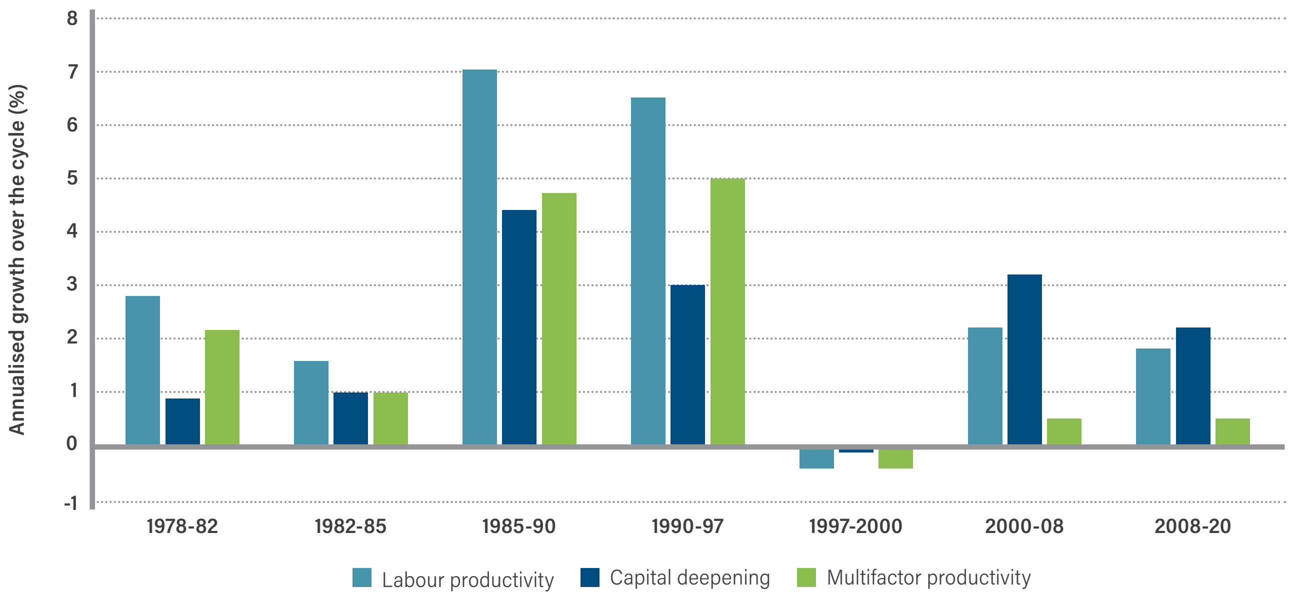
1. Pioneering (to WW2), Development of the nation and primary sectors. Tax system advantaged land development and increasing the production base.
2. Arbitrage Era (WW2 – 1984). Government and industries active in the procurement of industrial resources and the marketing of NZ exports overseas. Research and industry collaboration was strong and NZ was active in off-shore markets (producer boards etc) Model helped NZ become a developed economy.
3. The Free Market (1984 – 2020) – deregulation of the economy and structural changes reduced everything to an efficiency and competition framework. Sectors became silos. Paradoxically, science became localised and farming became focused on efficiency and production maximisation.
4. The New World (2021 -) Ushered in by COVID-19, the 6th UN Climate Change Conference of the Parties (COP26) and the European Green Deal. Economics now needs to incorporate social licenses and the externalities of efficient production maximisation, the localisation of food systems within our interconnect world are significant challenges

Adapted from conversations with Prof Hamish Gow

The opening up of the New Zealand economy through the removal of tariffs and subsidies was part of a global trend towards trade liberalisation in the 1980s &1990s. The Uruguay Round for trade (1986 to 1993) negotiations was a key juncture, it brought agriculture fully into the General Agreement on Tariffs and Trade (GATT). The agreements reached in the negotiations set rules around domestic subsidies and other protectionists trade tools and this helped global trade in agriculture commodities (The Uruguay Round, 2021). The Uruguay Round also laid the foundations for the creation of the World Trade Organisation (The Uruguay Round, 2021). Trade liberalisation ushered in the era of globalisation where countries exploited their comparative advantages in primary industries, manufacturing or service sectors. Supply chains became global and new lucrative markets emerged for NZ exporters in the USA & Japan in the 1980s, with the Asian 'Tigers' e.g. Malaysia in the 1990's and then in China after 2007.

New Zealand's comparative advantage was, and still is, pastoral agriculture. The pursuit of greater efficiencies and production during this period locked NZ into the role of producers of commodities. Being efficient producers became the major driver of value creation in NZ agriculture; animal and pasture genetics, stocking rates, production per head, production per hectare, as well as processing and supply chain efficiencies all contributed to huge productivity gains. Figure Two below shows how fast farmers embraced the efficiency model, with significant gains in the decade after subsidies were removed. This drive for efficiencies created a domestic agenda for science and innovation, for agriculture, the focus was inside the farm gate to drive productivity gains. It is something of a paradox that as the world was globalising and NZ was opening up its economy to competition, that we became more localised in the things that created immense value for NZ.

Figure Two: Primary Industry Productivity Improvements



Source: Productivity by the numbers May 2021, New Zealand Productivity Commission Report: https://www.productivity.govt.nz/assets/Documents/productivity-by-the-numbers/Productivity-by-the-numbers.pdf

Note: Growth rates are average annual percentage changes in labour productivity, capital deepening and MFP in the primary industries. 2008-20 is an incomplete growth cycle.

The productivity gains shown in Figure Two were the product of farmers having to adapt to remain viable as businesses – "the burning platform". It is also likely that science and innovation played its part and its interesting to note that productivity gains dropped away after the reforms of the science sector in the mid 1990's.

5.2 THE GOVERNMENT AND SCIENCE

Table Two: Governments Science Investment by the Numbers

The government is a major funder of research in NZ and directly contributes about 20% of the total investment, and this is about average in international comparisons (GovERD in the Table Two below). The government has set a target to increase R&D investment across the economy to 2% of GDP (Te Ara Paerangi Future Pathways Green paper, 2021) and it currently sits at 1.41%, up from 1.25% in 2009. Our total investment in research and development is much lower than the OECD average of 2.37% (Table Two below), this highlights a long-term feature of the NZ economy – comparatively low levels of R&D investment, particularly in the private sector. The amount the government spends in the science sector has been increasing in dollar terms over the last 10 years, up by 23% since 2010 (The Government and Science: The Research, Science and Innovation Report, 2021). However the government's investment as a proportion of GDP has actually decreased (The Government and Science: The Research, Science and Innovation Report, 2021). This highlights the dilemma of government science funding where economic growth means extra funding needs to be committed just to maintain the status quo. This is particularly difficult when there are multiple competing demands for government funds such as health and education.

Table Two: National science expenditure -2018

Measure	$NZ for 2018	% of NZ GDP for 2018	% of OECD GDP Average for 2017
BERD - Business enterprise sector R&D expenditure	$2,150m	0.76%	1.64%
HERD - Higher Education R&D expenditure	$960m	0.34%	0.47%
GovERD - Government intramural R&D expenditure (Government agencies and institutions, except tertiary education institutions)	$784m	0.28%	0.26%
GERD - Gross Domestic Sector R&D **(BERD + HERD + GovERD)**	$3,894m	1.41%	2.37%

Source: New Zealand's figures from the Statistics NZ R&D Survey 2018 and OECD Main Science and Technology Indicators Database 2017, referenced from https://sciencenewzealand.org/about/new-zealand-science-systems/

The government's role in science is complex. As a major funder it has an obligation to ensure the output is both world class, and benefits NZ. It must balance funding into the science sector with all the other demands on the treasury. Successive governments, since the science reforms of the early 1990's, have tended to operate at "arm's length" to the sector: If the government wants to change the science sector, it is done through policy interventions – what's the evidence? what's the logic? Governments must be careful when they play with the model as results are slow to materialise due to the nature of science. Defunding previous government's policies and creating change for the sake of change is never going to be good for enduring science. The sector is complex, with multiple competing agendas, and it is easy to create unintended consequences with science policy. The R&D tax credit (RDTI) is supposed to encourage greater private sector investment in R&D (Research and Development Tax Incentive, 2021). Most of NZ's businesses are small to medium enterprises who don't have the resources to undertake the type of research and development that qualifies for the tax credit, so the policy benefits large organisations and there are fewer organisations participating in R&D so the policy really favours the strong (The Government and Science: The Research, Science and Innovation Report, 2021).

The prevailing economic theory of the era has played its part as the government has been reluctant to push through changes to a system that has established the primacy of the market – "governments can't pick winners and that the private sector will always allocate resources more efficiently and create more value than governments" (Mazzucato, 2021). Hence the near 30-year belief that the private sector will set the agenda and direction for science and innovation even though the science is too expensive for most NZ companies to fund. The reforms of the science sector in the 1990's were all about increasing private sector investment in science and so any steps taken to increase the governments input either through funding or structural changes could potentially be seen as crowding out private enterprises (Mazzucato, 2021).

The voting public tends to be supportive of science and innovation and thanks to COVID-19, NZ enjoys a high degree of trust in its science sector (McClure, 2021).However, people don't tend to vote for it. There is not a lot to be gained or lost politically on science. If the budgets allocated to science were doubled, it would unlikely have any impact on the government's standing. Malcom Turnbull as Australian prime minister, led his coalition government into the 2016 election championing a transformative economic vision through science and technology. This vision didn't resonate with voters and his government suffered a large loss of support (Koziol, 2016). Indeed the allocation of the Research, Science and Technology spokesperson's role to Judith Collins in Christopher Luxon's reshuffle of the National caucus speaks volumes as to where science sits in the political pecking order. Judith is the lowest ranked member of the shadow cabinet at No 19 (Lynch, 2021).

The political reality of science is that there is little to be gained from solving the sector's problems. The issues are complex, difficult to define and changes hard to implement. Significant changes could occupy a lot of a governments policy agenda at the expense of more pressing or high-profile needs, such as, the COVID response or climate change legislation. Furthermore, managing change in the science sector would require significant time from ministers and senior policy advisors. The Hon Dr Megan Woods is a senior minister who holds the Research, Science and Innovation portfolio, she is the 4th highest ranked minister in the current government (Ministerial List, 2020). High ranking and effective ministers tend to get more to do so having a high-ranking minister in charge of science doesn't necessarily mean it will get the focus it needs. The Hon Steven Joyce was the science minister in the previous government and was similarly tasked with the oversight of multiple portfolios. There is no Ministry for Science and Innovation (MSI), the ministry that used to carry this name was incorporated into the Ministry of Business, Innovation and Employment (MBIE) in 2012. There are 18 ministerial portfolios and 14 ministers with responsibilities to MBIE (Our Ministers, 2020), it is large complex ministry.

To make progress, the government needs to operate in the right place from a policy point of view – too ambitious in terms of broad initiatives and nothing changes as there is not enough time or capacity for radical change, too conservative e.g. small changes, then new funding is syphoned away in the existing structures. One of the challenges recent governments grapple with, is where is the right place for government intervention to improve the science system? Private sector investment is clearly an area where NZ needs to improve and so the Primary Growth Partnerships (PGPs) of the previous government and the Research and Development Tax Incentive (RDTI) of the current government are policies designed to encourage greater private sector investment.

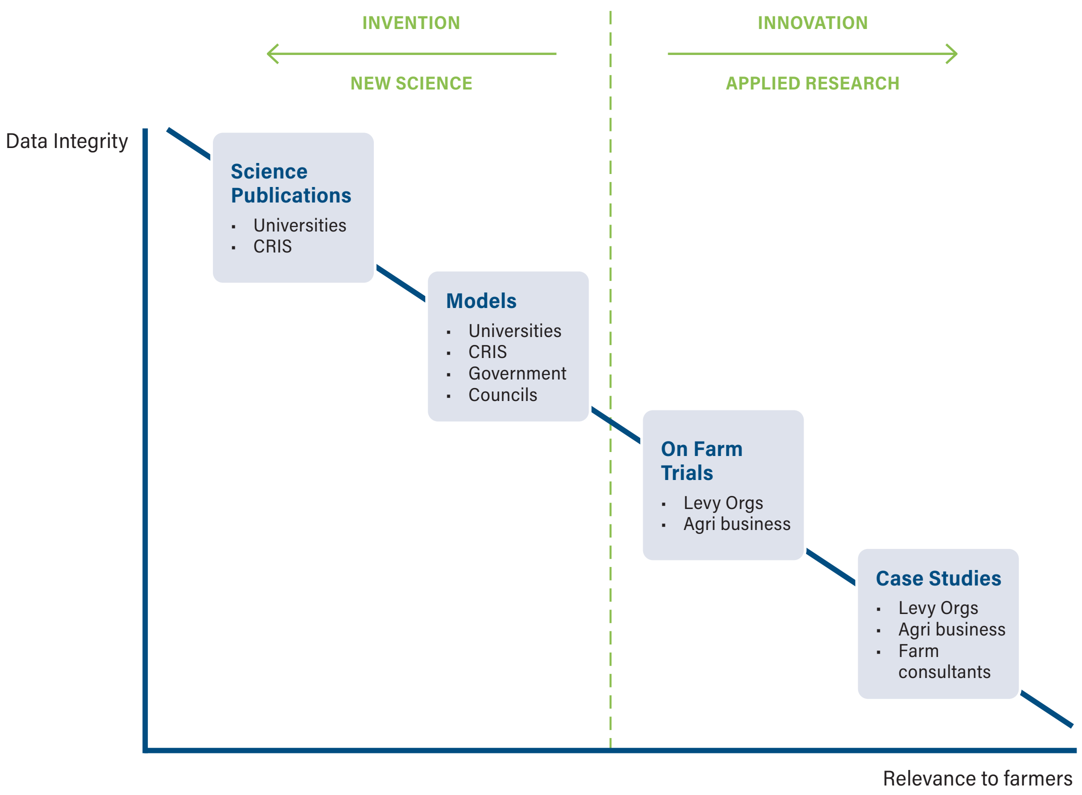
Furthermore, science is often captured by the politics of the government of the day e.g. Biotechnology rather than building long lived, enduring science programmes for New Zealand. Longer term visions don't resonate with voters, ideological conflicts and the speed of the news cycle means everyone is dealing in the short term, none of these factors bode well for enduring science policy. Election impacts are huge. A government has three years to get 'runs on the board' – in time for the next election. This means science initiatives at a policy level have a 6-9-year life, assuming a two or three term government (New Zealand Governments, 2021). Levy paying organisations such as Beef and Lamb, operate in a similar space: Six years to make a difference, the science they invest in needs to deliver in the short to medium term. There is criticism of policy capture, where public policy decisions are directed away from the public interest towards special interests (OECD, 2020) or towards the latest trends. There often appears to be a focus on quick wins that have measurable outputs (publishing) and these are almost exclusively run through project-based research (time and resource limited). Change takes time and governments are always short on time.

Science is an area that needs bi-partisan support to reform the sector, fix systemic problems and create enduring science polices. There is recent precedent for this, the housing accord between Labour and National that established common agreement on changing planning rules to allow housing intensification across NZ cities (Resource Management Enabling Housing Supply Amendment Bill, 2021). The outcome would be a more settled political view on housing. Te Ara Paerangi Future Pathways Green paper states the case for sector reform, its not clear yet to what extent the opposition parties support the proposed changes, stable long term polices is what the sector needs.

5.3 THE CROWN RESEARCH INSTITUTES

In the early 1990's NZ was well below the OECD average for investment in science. To break this down further, the government contribution to science funding was comparable with other small advanced economies, it was the private sector's investment that was lagging (Monica Cartner, 1997). The restructuring of the NZ science sector aimed to increase private sector investment and their engagement in science (Monica Cartner, 1997). The creation of a competitive framework for science through funding was implemented. The idea was to create competitive tension that would channel funding, and therefore scientific effort, into the areas of greatest economic need. These reforms were initially welcomed by many in the science and industry alike. Whilst the old Department of Scientific and Industrial Research (DSIR) and Ministry for Agriculture and Fisheries technical (MAF Tech) structures had excellent scientists and a strong academic culture, the problem was they weren't particularly commercial. There wasn't enough engagement between science and industry end users, the reforms were intended to drive closer relationships between science and commerce.

Figure Three: Where to play in the Science Space?



Graph above adapted from discussions with Professor Derrick Moot

In 1992 old government science structures such as the DSIR and MAF tech were reorganised into Crown Research Institutes (CRIs) and these were broadly aligned with the major sectors, Table Three below lists the CRIs with their purpose. This reorganisation had merit, such as the creation of AgResearch all the right people were in one place (instead of DSIR, Grasslanz, Ministry of Works, MAF). In the new model, deep science would continue to be funded by the government through the universities and the newly created Crown Research Institutes. One of the great strengths of NZ science was in applied research, New Zealanders are natural problem solvers and pastoral agriculture was very well served by this. In the new model this research would be industry funded and as a consequence, government funding for applied research became much more difficult to get. Many long-term programmes were discontinued over the coming decades, plant breeding activities in AgResearch being one example. The reforms created an enormous gap between science and agriculture. Figure Three above, highlights the point. In the new model, the government funds the invention end of the science spectrum, where the output is publications and models are developed. These often require applied research programmes to convert the invention into innovation that can be deployed commercially. Without well-funded applied agricultural research NZ agriculture is missing the opportunity to absorb new ideas.

"Pure research in NZ is funded by the government, it's a feeding frenzy for the money"
– A New Zealand Scientist

Table Three: The CRIs and their Purposes

AgResearch	AgResearch's purpose is to enhance the value, productivity and profitability of New Zealand's pastoral, agri-food and agri-technology sector value chains to contribute to economic growth and beneficial environmental and social outcomes for New Zealand.
Institute of Environmental Science Research (ESR)	ESR's purpose is to deliver world class knowledge, research and laboratory services to help New Zealand get the most out of its investment in science and innovation. ESR use the power of science to help its partners and clients solve complex problems and protect people and products in New Zealand, and around the world. ESR's science lies behind the decisions that safeguard people's health, protect our food-based economy, improve the safety of our freshwater and groundwater resources and provide the justice sector with expert forensic science.
Institute of Geological and Nuclear Science (GNS Science)	GNS Science's purpose is to undertake research that drives innovation and economic growth in New Zealand's geologically-based energy and minerals industries, that develops industrial and environmental applications of nuclear science, that increases New Zealand's resilience to natural hazards and that enhances understanding of geological and earth-system processes.
Landcare Research	Landcare Research's purpose is to drive innovation in New Zealand's management of terrestrial biodiversity and land resources to both protect and enhance the terrestrial environment and grow New Zealand's prosperity.
National Institute of Water and Atmospheric Research (NIWA)	NIWA's purpose is to enhance the economic value and sustainable management of New Zealand's aquatic resources and environments, to provide understanding of climate and the atmosphere, and increase resilience to weather and climate hazards to improve the safety and well-being of New Zealanders.
Plant and Food Research	Plant & Food Research's purpose is to enhance the value and productivity of New Zealand's horticultural, arable, seafood and food and beverage industries to contribute to economic growth and the environmental and social prosperity of New Zealand.
Scion	Scion's purpose is to drive innovation and growth from New Zealand's forestry, wood product and wood-derived materials and other biomaterial sectors, to create economic value and contribute to beneficial environmental and social outcomes for New Zealand.

Source: https://www.mbie.govt.nz/science-and-technology/science-and-innovation/agencies-policies-and-budget-initiatives/research-organisations/

The reorganising of NZ's science landscape with the creation of the CRIs had the potential to deliver a world class science sector. It was the funding model that created tension; misaligned incentives drove poor behaviours and undermined the promise of the reforms. The sector ultimately became purely commercial and hyper competitive – CRIs, universities and other research institutions were now competing with each other. The CRIs, reporting both to the Companies Act and the CRIs Act brought ambiguity to their missions – were they to make money or deliver science? (Te Ara Paerangi Future Pathways Green paper, 2021) To fit science into a business model many good people were lost from the sector, old programmes that created strong international linkages were forgone and the reforms lost the 'global view' of what was good for NZ (personal communication, July 21, 2021).

Engaging with a CRI to undertake scientific exploration became cost prohibitive, in a perverse irony, private sector engagement was less after the reforms (Personal Communication, July 2021). The levy paying organisations such as Dairy NZ began to do more applied research 'in house' because the cost of doing science with CRIs became too expensive. The charging model used by the CRIs, particularly AgResearch, was on a fully costed basis including rented lab and office space – NZ became the only country in the world where a scientist is fully costed (personal communication, July 21, 2021). Science became a consultancy with chargeable hours to projects being undertaken, this meant if a scientist didn't have a funded project, then there was no job.

The competitive funding, plus a fully costed science model that made private sector engagement too cost prohibitive, starved the CRIs of funds. Business managers were recruited to engage with the private sector and to secure contestable funding. The overheads of the science sector, and CRIs, ballooned as more layers of management were added. The revenues couldn't keep up with the increasing cost structure and resulted in near perpetual restructuring where programmes were discontinued, and staff redundancies are common. After initial success, by the late 1990's, the CRIs started shrinking their science capacity which further reduced their ability to meet their science objectives. In 1992 the newly created AgResearch had 1100 staff plus approximately 140 from Wool Research of New Zealand (WRONZ) and the Meat Research Group. Today there are just 600 (personal communication, July 21, 2021).

The ability of the CRIs to carry out their scientific programmes has been much diminished. Many long-term programmes were abandoned as financial imperatives shifted the focus to short-term, project-based research. Funding mechanisms also shortened the time horizons for science, funds were allocated on a project -by- project basis and few endured more than five years. The success of projects became a key KPI for science. Scientist's career success began to be tied ever closer to project success. The unfortunate outcome has been less risk taking, as a failed project could be terminal for a career. Having latitude to take risks is the space for the paradigm shifts Kuhn's theory discusses. New Zealand's political and societal attitudes don't help either, key technologies that could create both large productivity and environmental gains are not available to NZ science (Rowarth, 2020). Gene editing technologies such as CRISPR-Cas9 when used in genomic selection could halve varietal development time to 5 years. It would allow for the rapid inclusion of multiple beneficial traits such as carbon sequestration, drought tolerance, lower methane production in ruminant animals and enhanced nutrient utilisation in a range of pastoral species (Gallegos, 2019).

The consequences of New Zealand's science funding model is that the sector is siloed, time horizons have shortened, and there needs to be a high likelihood of success before embarking on the research. Long term research projects i.e. ones that require multidisciplinary approaches and those that require expertise from different research institutes, have become the exception, rather than the rule. Some of the biggest advancements made in pastoral agriculture research, such as novel endophyte technologies – a decades long project would almost certainly not happen in our current environment (see Case study in Table Four Below).

Table Four: The AR37 Endophyte Development Story – A long Term Project

The majority of New Zealand's agriculture exports are derived from animals that consume pasture. Perennial ryegrass is the most common component species in these pastures and consequently is NZ's most valuable plant species. In 2015 (the most recently available data), the calculated GDP contribution of ryegrass was $14.6 billion. To put this in context, the same report calculated the value of Pinus radiata at $4.4 Billion (Nixon, 2015).

Ryegrass has played a key part in the development of NZs efficient pastoral farming systems; it is both highly productive and high quality (Caradus J L. S., 2013). One of the reasons behind the success of ryegrass is its adaptation to New Zealand's environment and this is largely due to a symbiotic relationship between an endophytic fungus and the host plant. The fungus gets its nutrition from the ryegrass and the ryegrass gains protection from a range of key pasture pets, as well as enhanced drought tolerance and protection from over grazing. This protection comes from a series of chemicals (alkaloids) produced by the endophyte, however some of these are known to be toxic to grazing animals. Animals can experience heat stress, elevated blood pressure, 'grass staggers' and poor performance (Caradus J L. S., 2013). The problems caused by endophytes have been researched by NZ scientists for over 40 years. Furthermore, well established linkages between farmers and researchers meant that managing the issues of endophytes were well understood. The economic cost in terms of lost production attributed to 'wild type' ryegrass endopytes has been immense.

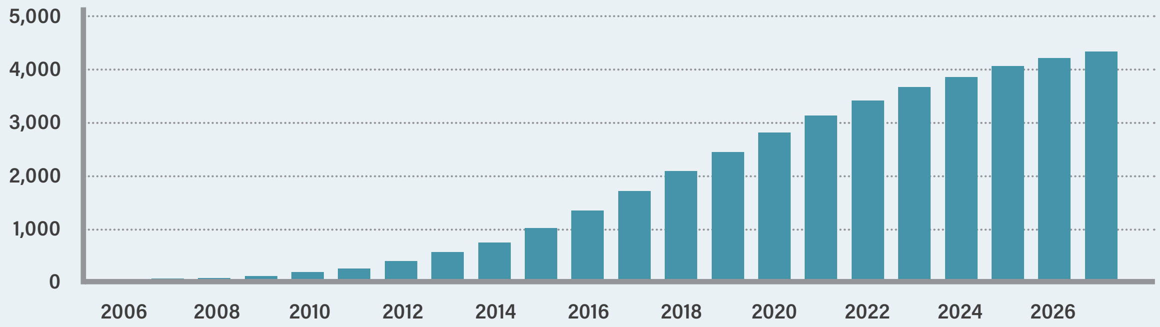
Scientists in AgResearch and its predecessor organisations (e.g. DISIR) began working on possible solutions almost as soon as the link between ryegrass endophytes and the animal health issues was established (Caradus J, 2014). In the 1980's a series of endophyte strains were discovered that potentially conferred the protective attributes of the 'wild' type endophytes with enhanced animal safety. One of these, AR37 was especially interesting – it produced either none or very low levels of the problem alkaloids, and was also found to have a completely novel compound called epoxy-janthitrem (Caradus J, 2014). This gave tolerance to insect pests, such as the Argentine Stem Weevil, black beetle, root aphid, pasture mealy bug and porina. AR37 also provided increased ryegrass tiller numbers, root mass and depth, persistence and higher yields at critical times of the year (Caradus J, 2014).

AgResearch and Dairy NZ's agronomic trials showed significant benefits of AR37 such as, improved pasture and animal performance (Research, Science and Innovation Systems performance Report, 2018). This research built a solid body of evidence and work by seed companies Agricom and PGG Wrightson Seeds, further demonstrated key benefits of this technology. AR37 was commercialised in 2006 and with a strong Intellectual Property (IP) story it was patented, protected by Plant Variety Rights, and Trademarked.

AR37 is an outstanding example of collaborative applied science. Uniquely, the requirements of farmers (pasture persistence and performance) were recognised by scientists working in well-funded, long term applied science projects within AgResearch and its predecessors. In addition to this, there were significant contributions from both levy paying organisations, especially Dairy NZ and private companies namely PGG Wrightson Seeds and Agricom. These strong linkages and broad support of the technology lead to the successful deployment and subsequent uptake by farmers.

The research and development programme for the AR37 endophyte has been costed at $12million. The pay back on this investment in terms of economic benefit to NZ has been immense. The net present value of AR37 has been calculated to be $3.658 billion through to the end of the patent period in 2027 (Graph One Below). The cost benefit-cost ratio for every dollar invested is $83:1 (Ryegrass endophytes case study, 2018)

Graph Two: The Cumulative Real Net Value of AR37 ($m, 2017dollar value)



Source: Caradus et al, Acil Allen Consulting

5.4 TE ARA PAERANGI FUTURE PATHWAYS GREEN PAPER 2021

The sector's problems are well known and well documented (Rowarth, 2020). Over the last 30 years a myriad of reports published by the government, industry and think tanks have highlighted the challenges facing the science and innovation sector in New Zealand. The current government has signalled a major overhaul of the science system is on its way and recently published a green paper: Te Ara Paerangi Future Pathways highlighting the issues and the potential scope of the reforms.

Table Five: A High-level look at Te Ara Paerangi Future Pathways Green:

In October 2021 the government unveiled its Te Ara Paerangi Future Pathways Green paper into research science and innovation (RSI). The government has had a long standing commitment to reviewing the RSI sector and the green paper follows Te Pae Kahurangi, the independent review of the CRIs in 2020. A key take out from this review was that the current science system incentivises fragmentation of research effort and unproductive competition between researchers and institutions.

It also found that the CRIs where struggling to adapt to a changing world and the type of science and research required to meet these challenges (Te Ara Paerangi Future Pathways Green paper, 2021). In comments to the media at the Green papers launch, Dr Woods said the current system was "now characterised by a significant amount of fragmentation and unproductive competition" (Editorial, 2021).

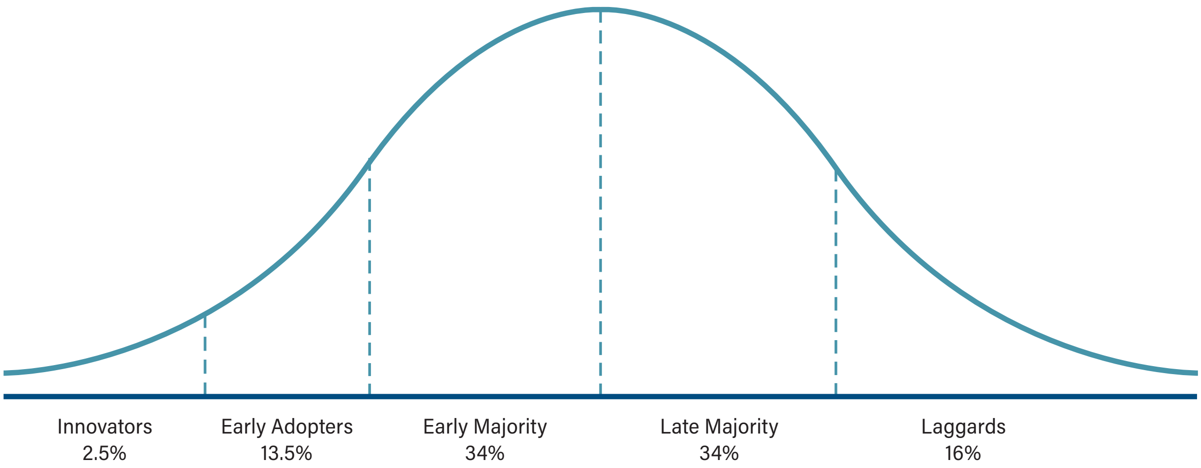
The Future Pathways paper represents the start of the largest overhaul of NZ science system in the 30 years since the CRIs were created. The Green Paper has an ambitious scope that includes a review of the CRIs and the role of Callaghan Innovation. It also includes reviews of science funding, research priorities, the science workforce and infrastructure. A key part is how the modern New Zealand science system can honour Te Tiriti obligations and explore Mātauranga opportunities (Te Ara Paerangi Future Pathways Green paper, 2021).

It is clear that the CRIs and Callaghan Innovation are in for a major shake-up that may include merging entities and creating new institutions. As Dr Woods notes, the CRIs were set up with a focus on the traditional areas of the economy such as the food and fibre sector. The review is signalling a broadening of the public good research into other aspects society and the economy as well as having a firm eye on the 'future economy'. The National Science Challenges are also up for review and appear unlikely to be funded beyond 2024 when their 10-year funding period finishes. The Green Paper also discusses using Mission led approaches to science delivery so it's likely the 'best' elements of the NSCs will be retained. The paper signals a goal for NZs R&D expenditure to increase to 2% GDP (currently 1.41%), so this will require a substantial increase in both public and private sector investment.

5.5 THE BUSINESS SECTOR AND SCIENCE

Diffusion of Innovation (DOI) Theory, developed by E.M. Rogers in 1962, is used to explain how, over time, an idea or product spreads through an organisation, sector or population (LaMorte, 2019). The model is broken into five sections representing adoption profiles: Innovator, Early Adopter, Early Majority, Late majority, and Laggards. These groups are based on the standard deviation under a normal distribution curve (Figure Four Below). As the idea or innovation becomes adopted, larger portions of the area under the curve is accounted for and these groups are said to have adopted, this is known as diffusion (LaMorte, 2019). The practical use of this model ranges from determining the rate and uptake if an innovation, if it is likely to be successful, product life cycle analysis, manufacturing capacities, and competitive behaviour. The model is also very useful in putting a value on science. If research is diffused into society as an idea or innovation, then it is successful in the broadest sense. Assuming the model is typical for most ideas and products then the genesis is the innovation part, and innovation in the New Zealand context, is the applied research portion of science. This is the problem for agriculture, applied research is expensive, fragmented and not supported by the government.

Figure Four: The Diffusion of Innovation Theory Model

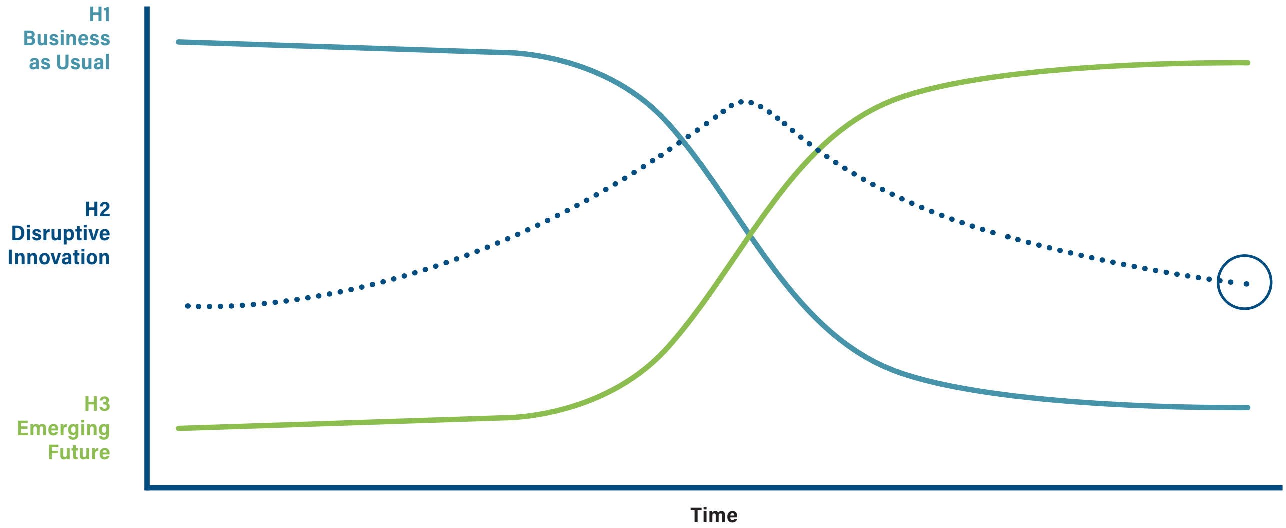


Diffusion of Innovation (DOI) Theory Model, Source: http://blog.leanmonitor.com/early-adopters-allies-launching-product/

Requiring industry to fund their applied research activities in hindsight was unrealistic, particularly for agriculture. This expectation undermined the CRI model and expecting farmers to step up and fund applied research at scale when it is a commodity dominated sector was always going to be problematic. The underinvesting has undoubtedly reinforced the efficiency/productivity focus rather than pursuing other avenues of value creation.

Bill Sharpe's Three Horizons Growth Model (Figure Five Below) is a useful way of thinking about innovation driving change in a business, sector, or economy (Daniel Christian Wahl, 2017). Horizon Three of the model (H3) represents the future state after transformational change e.g. robotic fruit picking. Horizon One (H1) represents the status quo e.g. the current orchard and Horizon Two is the strategy. This either creates transformative change e.g. planting 2D orchards in anticipation of robotic technologies, or ones that maintain the status quo of H1 e.g. continue to plant and configure orchards with a reliance on labour. Applied research is where the private sector generally plays and where the government has retreated from over the last 30 years. Innovations that confer transformational change: The H2+ in Sharpe's model are risky and costly for business, without government playing its role, the risk adverse path has become the default, most innovation is really portfolio management and playing within the existing paradigm.

Figure Five: The Three Horizons Growth Model



Horizon 1 (H1)	The current business, as time passes and things change, its relevance decreases. In the long run, organisations stuck in H1 will fail.
Horizons 3 (H3)	The theorised future state. It represents profitable growth in the future through business activities not yet commenced, but identified in H1.
Horizons 2 (H2)	The bridge where business decisions either enable the H3 future, or reinforce the H1 status quo. As decision-makers, we act from the H2 perspective - choosing either H2 positive innovations (that enable H3) or H2 negative innovations (that prop-up H1).

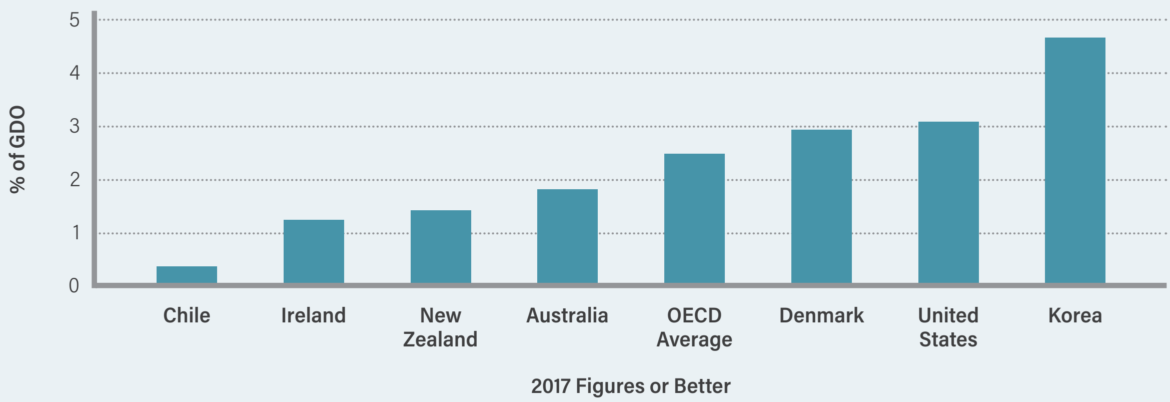
Adapted from Three Horizons, International Futures Forum: https://www.internationalfuturesforum.com/three-horizons

Private sector investment in R&D is overwhelmingly in product development (The Government and Science: The Research, Science and Innovation Report, 2021) that is creating or commercialising products that meet the current market, H2- in the model. Very few Small to Medium Enterprises (SMEs) can take the risks of moving towards H3 in the model as the business costs are too great. The science sector's role is to create the innovations to help get them to H2+. The problem is science as it stands is H2-, that is, the status quo (H1) is constantly being reinforced. This was one of Sir Paul Callaghan's main points in his 2011 speech. NZ is 'stuck' in its highly efficient and productive farming systems when the economic system is moving into a new era.

Table Six: The Private Sector's Contribution to NZ's R&D Investment

The business sector's R&D investment is where NZ comes up short in international comparisons. We invest around 0.76% of GDP compared to the OECD average of 1.64% (The Government and Science: The Research, Science and Innovation Report, 2021). Figure Six below, using OECD data, shows NZ's over all R&D expenditure to be lower in comparison to other countries. It is the private sectors contribution, low by international standards, that puts NZ below average for developed nations (OECD). Over the years there have been many initiatives from government to try an encourage greater private sector investment, the R&D tax credits (RDTI), primary growth partnerships (PGPs) and the National Science Challenges (NSCs) are the most recent policy examples.

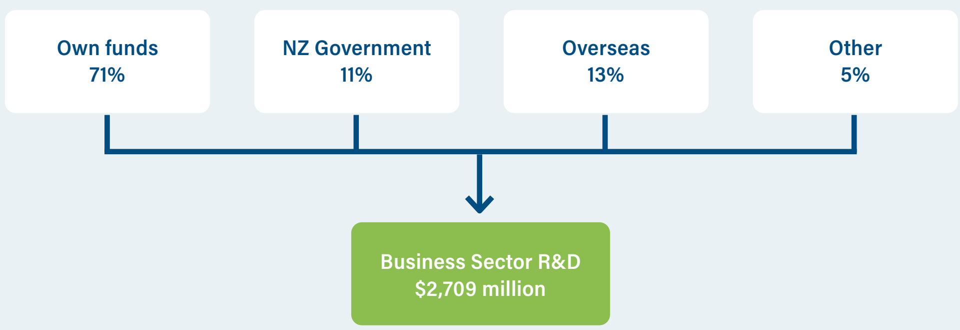
Figure Six: New Zealand's R&D expenditure international comparisons



Source of graph: OECD data, Gross domestic spending on R&D: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

Total research and development spending in NZ has been increasing over the last decade. Between 2010 and 2020 it increased by 90%, with the largest growth from the private sector, this has been steadily rising over the last decade, albeit from a very low base. The business sector is the largest contributor to NZ's R&D investment and in dollar terms was $2.7 billion in 2020. In percentage terms, this was 60% of NZ's total R&D investment in 2020, compared to 41% in 2010 (The Government and Science: The Research, Science and Innovation Report, 2021). Figure Seven below shows the breakdown of contribution to the NZ business sector's R&D investment. About 11% of the total, is government investment into private sector R&D activities and a similar amount comes from off-shore.

Figure Seven: Sector Contribution to NZ R&D investment 2020



Sourced from Research and development survey, 2020: https://www.stats.govt.nz/information-releases/research-and-development-survey-2020#text-alt

Part of the reason for low private sector investment is how this contribution is measured. Undocumented innovations occur economy-wide and undoubtedly contribute to productivity gains and value creation. Many successful innovations in small and medium enterprises (SMEs) happen as part of 'business as usual', for example, farmers who improve the operation of their farms are innovating. The structure of the NZ economy as mentioned earlier, also plays a role in the level of research activities, the New Zealand economy has broad, shallow sectors, such as agriculture and these businesses don't typically attract the scale of investment required for deep science sectors. The pharmaceutical industry, for an example invests up to 90% of revenues in research and development compared to 0.5% of the food sector's revenues (Callaghan, 2011). Our exports are primarily commodities and whilst NZ has become hugely successful in producing these, commodities have many alternative sellers and therefore it is hard to attract a premium to pay for innovation.

There are some 530,000 SMEs in the New Zealand economy. We are a nation of small business and these make up 97% of all firms (Small business in New Zealand, 2020) and for this reason alone, private sector investment has lagged. SMEs generally don't have the balance sheet to sustain formalised R&D and many of their business models are very similar. They are moving into a market 'gap' rather than innovating so their position is not easily defendable from competitors. This why many SMEs find it difficult to scale up, so driving costs down, and being highly efficient, are all important. True value creation is in redefining the current system and if costs are being driven down, then there simply aren't the resources for SMEs to invest in innovations.

Government policy aimed at increasing private sector R&D investment follows the logic that the increase will translate into productivity improvements across the economy (Pacheco, 2021). However, just doing the R&D doesn't necessarily translate into economic growth. Sectors and businesses need the 'absorptive capacity' to translate these ideas into economic opportunities. Re-gen is an example of an innovation, initially dismissed by many, but adopted by a few who had the absorptive capacity to take on new ideas. Absorptive capacity can involve investing in people who 'get their heads' around new ideas. If businesses are focused only on costs, then these types of people are unlikely to be found there. Furthermore, business-as-usual has been good for many businesses, they live in the Horizon One of Bill Sharp's Model, orientating the business on a different trajectory by investing in innovation, is a risk many aren't willing or able to take. This is why government leadership and partnerships are critical to driving private sector innovation.

Large businesses on the other hand, those defined as having 500 or more employees, do have the resources to fund R&D at scale. These firms represent 73% of private sector investment and just 100 businesses account for 85% of this (The Government and Science: The Research, Science and Innovation Report, 2021). The number of all business innovating by investing in R&D is declining, down to 46% in 2019 from 53% in 2009 (The Government and Science: The Research, Science and Innovation Report, 2021). This suggests NZ business is not prioritising R&D investment, it may reflect a lack of long-term strategic thinking or the effect of increased foreign ownership where R&D activities are being off shored (Authors Comment).

An alternative government policy could be to co-invest in private sector research. Unlike previous policies the government investment would come with an ownership stake in the commercialised output, this is common practice in the university sector where the institutions retain an ownership stake in innovations created by students and academics. In the UK University system, the size of the stake varies from 5-60% ownership depending on the amount of university resources used (Elaine Eggington, 2020). The idea is for the universities to capture some of the value of the IP created in their institutions and build an alternate revenue stream. At a government level the revenues could be redirected back into science investment helping to lift over all R&D activities as well as demonstrating value to the taxpayer for their contribution to private sector incentives.

If the goal for greater private sector R&D spending in terms of GDP show an increase, then the policies of the last 10 years have worked extremely well. If the policies have been to increase the number of businesses participating in R&D as a proportion, then the results have been disappointing. The evidence for these two positions is not clear, however if the generation of Intellectual Property (IP) is a measure of output, like publishing for scientists, then the conclusions are not favourable. The number of patents granted in NZ has declined 79% since 2009 to just 94 patents in 2017 (The Government and Science: The Research, Science and Innovation Report, 2021). The RDTI will further advantage large business as they often have the financial resources to leverage the maximum amount of spending within the scheme and there is a the risk that companies will spend money on things that don't matter just to get the tax credit.

Businesses struggle to obtain the scale required to become an enduring business. A much-quoted anecdote suggests that successful NZ entrepreneurs 'cash out' early from the opportunities they have created and invest in the 3Bs - Boat, Bach and BMW (Watt, 2009). For some entrepreneurs this was always the end goal, but for others, there were no other viable options to grow their businesses further. One explanation is that New Zealand business struggle to scale ideas through a lack of capital and/or the business skills to grow. Often businesses that achieved scale fund low risk incremental research where they see near term commercial opportunities i.e. creating products for existing markets. Funding is directed towards problems or opportunities that have already been identified and there is little appetite to capital fund anything that isn't business-as-usual (The Government and Science: The Research, Science and Innovation Report, 2021).

5.6 THE MĀORI ECONOMY AND PERSPECTIVES ON SCIENCE

The Māori economy is a huge opportunity for New Zealand to create value. Māori bring a unique view to business and is something that differentiates NZ from competitor countries. The long-time horizons associated with Māori business is a compelling reason to build relationships with Māori. Many businesses and parts of the science sector have lost a long-term view. The focus on short-term earnings has shifted businesses to quarterly, half yearly and annual reporting cycles and strategies are cached in these cycles. Few companies invest in projects that won't deliver strong earnings quickly. The focus on the short-term reduces the ability of the business to adapt. In the Western world over the last 60 years, business life-spans have been shortening, in 1958 it was an average of 61 years, today it is just 18 years (Garelli, 2021). Science, likewise, has incentive structures that channel thinking towards short-term deliverables. Grants expire meaning the projects are often shortened to meet the funding duration (Julia Belluz, 2016). Enduring science programmes are an exception rather than the norm. Māori businesses have never lost their long-time horizons, and this give them a unique opportunity to scale enduring businesses and even become New Zealand's next multinationals. This lens creates competitive advantages: long-term research and development programmes in addition Māori businesses appear well aligned. Successful, enduring NZ businesses such as Gallagher's also share this feature. Many of them invest in research and development that drives long-term thinking.

The Te Ara Paerangi Future Pathways green paper has made honouring Te Tiriti o Waitangi obligations and exploring Mātauranga opportunities in the NZ science sector a central theme. Mātauranga Māori is a different perspective to western science and, in a globalised world, is uniquely NZ, and therefore there is an opportunity to do innovation differently and create value. However, it also notes a number of challenges - western science excellence, through the likes of the Endeavour Fund, make it difficult for Mātauranga Māori projects to get funding. The report noted that not a single large-scale Māori-led project had been funded in 27 years (Te Ara Paerangi Future Pathways Green paper, 2021). Working with Māori is a partnership and requires long-term commitment. Another criticism of the science sector that its engagement with Māori can come across as transactional and focused on the researcher's needs rather than consider those of Māori organisations. In another words, co-design should occur from the outset (Te Ara Paerangi Future Pathways Green paper, 2021). To this end, science is desperate for Māori capability -the current capacity is spread thinly across the sector and is limiting the opportunities described above. The CRIs and universities are trying to improve this for example the University of Canterbury (UC) is putting significant effort into developing Māori academic capabilities, co-design of research and ensuring authentic research outcomes for Māori. In addition to this, it has jointly created the UC Ngāi Tahu Research Centre (NTRC) - an initiative between Ngāi Tahu and UC with the goal of offering scholarships and creating intellectual capital and the development of Ngāi Tahu. UC also has strong linkages with the local Hapū, Ngāi Tūāhuriri (Māori Research Partnerships, n.d.).

5.7 THE INCENTIVES THAT DRIVE SCIENCE AND INNOVATION

Incentives matter because they drive human behaviour, it's what makes us work towards shared goals. What's good for me? versus what's good for the collective? When these align it's the classic win-win. Misalignment of incentives, even when the goals are broadly supported, is common and leads to poor outcomes. Misaligned incentives can have huge consequences, for example, the 2008 global financial crisis was partly caused by bankers' incentive structures that favoured risk-taking in the pursuit of ever-increasing banking sector profits. Closer to home, the sale of diesel utes have skyrocketed as people try to 'beat' the "feebate" scheme designed to encourage the purchase of electric cars, introduced as part of NZ emission reduction initiatives (Taunton, 2021). Markets are rapidly readjusting themselves sometimes faster than incentive structures - the online world, lockdowns and the shift of consumer preferences change quickly. Failure to understand these hurt our ag sectors. For example suit manufactures closing down in response to the casualisation of workplaces, whilst quality specifications for wool remain (Peers Comm).

The right incentives in science push research towards an appropriate pathway whether it be social, commercial or publication. When incentives in science misalign, the system becomes dysfunctional – silos and competition occur instead of collaboration; self-interest drives decisions and the outputs suffer. The wrong incentives mean agriculture gains short term, incremental science instead of enduring research that adds genuine value. With the right incentives, there is a huge opportunity for collaboration in NZ science. This would however require a fundamentally different approach to how things are done at present. For example, the pastoral sector does not give AgResearch clear signals as to what it should be doing so it struggles to secure funding. The Levy paying organisations and large agribusinesses who share the same sector as AgResearch, are all doing their own thing responding to their own incentives. When they do engage with Ag Research, it's in joint-venture relationships (JVs) or through contracting services instead of funding programmes. Some organisations such as Dairy NZ have built significant research capability that has moved into AgResearch's traditional area of strength – applied research in pastoral agriculture.

Why? Because their incentives are different, this misalignment drives different behaviours. If AgResearch does the industry-good research, even if funded by the levy organisations such as Beef and Lamb tends to do, then farmers will question what value they are getting from the levies they pay. The levy paying organisations control the messaging to demonstrate value to ensure re-election. Likewise, agribusinesses when engaged with CRIs, seeking commercial advantages by locking down the IP to prevent competitors duplicating the innovation. The JVs between CRIs and private companies have helped secure long-term funding and therefore longevity in programmes. However, they have also excluded other sector players from what are publicly owned institutions.

The misalignment of incentives can also result from the influence of lobbyists and special interest groups. People well organised, and with access to politicians, can gain influence in shaping both public opinion and public policy. Lobbying is primarily about self-interest at the expense of the collective good. You don't have to look far to see many examples of this. The inability of successive governments to sort out the fundamental flaws of the energy market, where the major generators are also retailers of electricity, allows them to influence the whole-sale power price in a way that discourages new entrants into the generation and retail space. In the long-run, lobbyists' positions often become self-defeating. Before this happens, years and sometimes decades of market privilege occur. The supermarket sector, dominated by two players, makes extraordinary profits due to market power. This situation has existed for decades and effective lobbying has, until recently, maintained the status quo. The political winds have changed, and genuine reform of this sector looks likely. Being re-elected is a powerful force influencing decision making in politics and levy-paying organisations and is the reason why minority views are often accommodated. The science sector is fragmented and siloed, maintaining the status-quo benefits organisations, that have structured themselves to be successful at securing research grants. Any changes to science funding is likely to attract lobbying from groups and organisations in order to maintain the existing state of affairs.

5.8 THE UNIVERSITIES AND INCENTIVES

"Universities are important to create people to go out and create"

– Hon Pete Hodgson, Minister of Research, Science and Technology: 2007 - 2008

New Zealand's eight universities make up a significant part of the science sector. Whilst they offer programmes common across all universities, like CRIs, they specialise in subject areas. For example: Massey and Lincoln Universities for land-based sciences, Canterbury University for Engineering, and Auckland and Otago Universities for medical research. Universities have an important role in society: They foster the socialisation of young people into society (likeminded etc), there is the pursuit of scientific thought, and are bastions of academic freedom (Serlin, 2006). Another important role could be the commercialisation of research.

The Performance Based Research Fund (PBRF)

The PBRF invests in science in the university sector. However, assessing scientific impact is difficult given it is a long journey from experimentation to discovery, and there is a risk of failure. The PBRF uses a ranking system, for academic staff and their institution, to determine the allocation of the $315 million fund (Webster, 2021). The PBRF aims to reward academics and institutions that are producing world class research. This goal, whilst aspirational, has created a misalignment of incentives favouring publishing over applied research. Consequently, academics and institution's publishing history becomes a key benchmark to measure success. Publishing in high impact journals increases the prestige of the scientists, and the institution they belong to, and this makes securing funding easier as reputations have been enhanced. Research that meets the criteria for publishing in high impact journals is often locked behind paywalls and removed from use for real-world problems and therefore much science has a low uptake in society and the economy (Julia Belluz, 2016).

Table Seven: The Performance Based Research Fund (PBRF)

The **Performance Based Research Fund (PBRF)** is the government's primary research fund for determining investment in its tertiary institutions. The level of funding is determined by the performance of institutions research and this is assessed by the application of three criteria:

1. Reward and encourage the quality of researcher (55%)
2. Reflect research degree completions e.g. PhDs and Master's degrees (25%)
3. Reflect external research income— (20%)

All academic staff are required to submit a record of their research outputs, contribution to research environment, and peer esteem. They are then assessed as A, B, C or R category. The A indicates international standing, B national, C local and R research inactive or active at a lower level.

2018 PBRF Ranking of New Zealand's University

Rank	University	2018 PBRF Score
1	Victoria	29.19
2	Otago	26.09
3	Canterbury	25.92
4	Auckland	24.94
5	Waikato	21.76
6	Massey	19.5
7	Lincoln	17.64
8	AUT	15.78

Notes to Table:

- These results are based on the AQS(S) - average quality score, based on the number of teaching and research staff in a given tertiary education organisation, and is now the primary measure of research quality.
- Table represents the latest PBRF ranking data, due to COVID, next update is not until 2025

Adapted from: Performance based research fund: https://en.wikipedia.org/wiki/Performance_Based_Research_Fund

The linking of science funding with academic performance, using publishing as its benchmark, has resulted in a drift away from applied research. There is now an enormous gap between the 'science' and what is happening in agriculture, industry, and society. Few academics can take the risk of doing research that directly benefits farmers, as their careers depend of maintaining a high PBRF ranking (A of B). Publishing for impact has become all important, so the incentive is to publish in journals that carry prestige. Publishing drives the h indices, or impact factor, of the research. This is a derived metric that ranks individual authors on the basis of the journal where the research was published and the number of times the paper has been citied (Hirsch, 2005). For a high h value the author needs publishing in a high-ranking journal as this has a higher readership and this increases the chances of it being citied. Journals with high reading and citations get a higher ranking. The incentives are wrong for anything other than pure science. Important work is not published because the topic will have low reading in journals and journals don't want low readability (numbers) or publish to narrow interest topics because their ranking depends on the opposite. Rockets and paediatrics are highly readable, these get published in highly valued journals, they are therefore high impact topics and attract high h indices (Hirsch, 2005). It's a win-win for the journal and the author (and their institute). Agricultural journals are ranked far below pure research journals, so the incentive for the researcher, even in agriculture, is to do work that gets published in higher ranked journals. Creating a situation where agriculture scientists and their institutions get funded for doing research that is of little benefit to NZ agriculture. When the government talks about high-impact science, it is publishing that is the outcome, not the betterment of society.

"The publication record is a way of surviving in such a bloody competitive landscape"
– NZ Scientist

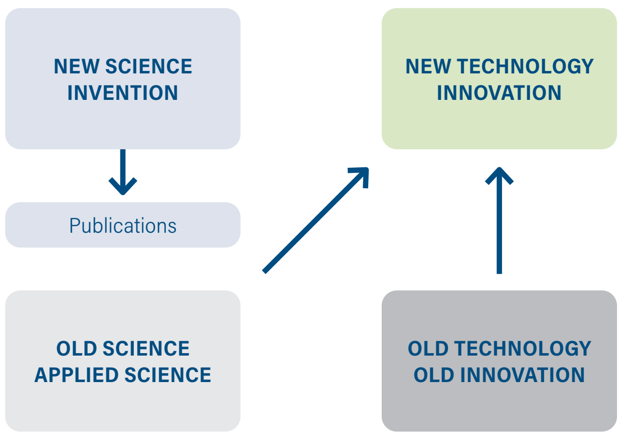
If universities were a smaller part of the system, then the focus on the h index and how it drives the PBRF wouldn't be a problem. NZ is different to most other advanced economies because the universities are the dominant players. The total scale of the CRIs is equivalent to one of NZ's large universities (Peers Com). The scale of universities allow them to influence the science criteria for the investment funds and the people recommending what gets funded are drawn from academia. For example 82.5% of Marsden Fund Panellists (Marsden Fund Panellists, 2021) are drawn from the university sector. Another criticism is that there are structural biases with a narrow range of academic disciplines represented on the fund review panels. (Howard, 2017). Having academic expertise does however, sound reasonable as their standards undoubtedly ensure high quality research. The problem is that excellence means impact (h indices) and this means publishing in an American journal. This plays out in reality where publications per million dollars invested is higher in NZ compared to other small advanced nations (Research, Science and Innovation Systems performance Report, 2018): the incentives are driving unintended consequences.

"All the incentives for science are misaligned with commercial outcomes – that is they don't align at all. Why is the system deeply defended? The leading academics who have been successful with the status quo want it to continue. Passionate defence of the current world and if you try to change it the blow back is immense"
– NZ scientist

Further to this, the sector is becoming more reliant on MBIE funding thus the above standards for science impact are being applied ever more. The test for getting money from the funds is the publishing record – this is the influence of the universities. Scientists chase projects that get published in higher ranked journals meaning what isn't done is the 'everything else', including most of the applied science that is critical to agriculture.

The science outcomes diagram below (Figure Eight) shows the research conundrum. The incentives that drive science for publishing impact, also create a disconnected science ecosystem. As a country, we are investing heavily in the invention aspect of science. This is the deep science, blue sky research and the creation of new knowledge, that gets published in journals, determining the all-important *h* indices. In 2020, this accounted for approximately 70% of the total amount invested (The Government and Science: The Research, Science and Innovation Report, 2021).What creates new opportunities and value for New Zealand is the innovation aspect, this is the repurposing of old science and old technologies into new solutions. New Zealand has historically been very good at applied science and because the incentives are misaligned, it lacks focus in the current science framework.

Figure Eight: Science Outcomes



Adapted from conversations with Professor Garth Carnaby

The question then, is what is the role of the universities? From first principles, they exist as educators for tomorrow's workforce as well as having an important role as a critic and conscience of society (On Academic Freedom and Responsibility, 2021). Good lecturers also tend to be good researchers so having well-funded research in these institutions is critical. Is it reasonable to expect the universities to commercialise their research? A survey carried out in 2008, polled academics at Canterbury and Lincoln Universities, and found that 85% of respondents had no interest in the commercialisation of their research. They saw the primary output from their efforts as the creation of new knowledge and teaching (William Kaye-Blake, 2008). KiwiNet the commercialisation arm of the university system, estimates about 20% of research from partner institutions is commercialised (Dr James Huchens, CEO KiwNet). Universities' role as educators and advancing knowledge is vital to New Zealand. The commercialisation of this knowledge is important, but secondary to the main objectives. With this in mind, why not let the universities focus on fundamental science and then institutes and businesses e.g. the CRIs undertake the applied research and access the competitive government funds? By treating the universities separately and funding them accordingly, the MBIE funds could be reorientated towards applied research - let the CRIs slip the noose of the h indices and focus on creating value for their sectors. This focus on applied research - the invention, won't get scientist published in the "A" class publications, but it will get them into B&C ranked ones, where agriculture currently sits. A new way to measure scientist's and institutional performance will be needed, fortunately the government already has experience in this through the National Science Challenges (NSC).

5.9 THE NATIONAL SCIENCE CHALLENGES

"Ask someone what they want, and you will get short term thinking. The mindset should be to do something that solves a problem or ask is there a need for the research"
– Sally Davenport SFTI

The National Science Challenges (NSC) were set up under the last National government and were championed by Sir Peter Gluckman, Chief Science Advisor to the Prime Minister (2009 to 2018). There were 11 challenges established in 2014 and each of these were created with the intent of building enduring public benefit to New Zealand (Gluckman, 2013). Uniquely, $680 million of funding was allocated for the challenges over ten years – in the age of contestable science funding, having secure funding over longer time horizons was innovative (National Science Challenges, 2020). The challenges were governed by key performance indicators (KPIs) tailored to each challenge, none of which related to the commercialisation of scientific output, but rather to meet economic metrics important to NZ as well as incorporating Mātauranga Māori into the research (National Science Challenges, 2020). One interesting feature of the NSC is the breadth and ambition from environmental, technological development through to social sciences. NSC's core drivers were the building of enduring innovation capability, and this meant finding out what problems or opportunities need to be focused on for example the Science for Technological Innovation (SfTI) who are developing automated harvesting technologies on mussel farms.

The NSCs were intended to be mission-led. 'Spear-head' projects were established, and these guided the other research activities. They are interdisciplinary, work together under one umbrella. This was an attempt to move away from the siloed and hyper-competitive environment that has blighted the science sector since the formation of the CRIs. Added to this, the challenges were set up with longer time horizons and committed funding - basically enough time to figure things out.

The NSC at their best, have built capability, created enduring science, and deployed new innovations through commercial partnerships in their respective areas. The fate of the NSC is uncertain with funding only committed to 2024. The current government has made no decisions about their future, and almost certainly they are viewed as a legacy policy of the previous government.

There is however, general acknowledgement that the concept of the NSCs, i.e. mission led science, is solid and key learnings from these need to be taken forward and incorporated into any new mission-led science policies. Agriculture in particular, would benefit from mission led science. There are obvious missions such as climate change, farming within limits, and greenhouse gas reductions. He Waka Eke Noa, the partnership between government and the primary sector, to reduce on-farm agricultural greenhouse gas emissions and adapt the sector to climate change, is a classic mission science opportunity.

In researching for this report, I was fortunate enough to conversations with senior scientists in some of the National science challenges and have summarised key take outs from one of them in the case study below:

Table Eight: Notes on a successful Mission led programmes: Science for Technological Innovation
Kia kotahi mai - Te Ao Pūtaiao me Te Ao Hangarau

"The Science for Technological Innovation National Science Challenge aims to tackle New Zealand's high-tech challenges to grow the economy. To enhance the capacity of New Zealand to use physical and engineering sciences for economic growth".

The NSC Challenges has two related components:

- Technical capacity for bold and ambitious research
- Human and relational capacity to ensure researchers work with industry and businesses so science is not left 'stranded in the lab'.

To maximise impact, engagement is critically important:

- Industry – where problems /opportunities originate
- Early user identification – for prototyping
- Invite industry partners to see what is happening,
- Invite industry feedback/insights and make sure engagement is on-going.
- Multiple work streams to ensure project continuity and to shift resourcing from failing streams to successes.

Strategy is a partnership – industry people with ideas plus the universities who have the technology. Scientists need to develop these relationships; it is how new ideas get adopted. Scientists don't generally supply products or develop markets so working with industry is critical.

Develop a science strategy to address these two questions:

1. What are the industry issues?
2. What are the industry problems?

Out of engagement with industry comes new ideas that sustain the research – it creates its own momentum; the mission has no end point.

The ability to absorb new technologies – who the science teams' partner with is critical, they must be willing to adopt new ideas and technology. This is the absorptive capacity so establishing early adopter networks and educating both the scientists and industry participants is very important.

Not just the growers or the farmers – you need the whole supply chain to get the idea going. Missions also need the manufacturer of the technology as part of the project.

Content from interviews and NSC website: https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/national-science

5.10 FUNDS AND INCENTIVES

From many accounts the reformed science sector of the 1990's was reasonably successful. Funding was always an issue, particularly getting private sector investment. The CRIs were launched with clear purpose, however as discussed the fully costed science model priced them beyond the reach of most SMEs, and only large business and sector groups could afford to engage (White:, 2012). This funding gap plus contestable funding led to cycles of restructuring. In the reform period the government created a funding system with two government entities. The first was the foundation for Research, Science and Technology (FRST) that set the direction for science. The second entity was the Ministry of Research, Science, and Technology (MORST) and this funded the science. Government departments and agencies purchased the science that they needed from FRST and this helped set the priorities for science in NZ. FRST had a sense of where the country needed to invest. Having the funding and science direction in separate entities created an efficient system, and there was minimal wastage and little science duplication. In the early 2000s it stopped working. FRST and MORST were merged and ultimately ceased to exist when they became part of MBIE in 2012. The PBRF was introduced in 2002. Government departments increasingly became silos and started doing their own things and a plethora of alternative funds for science emerged. The whole system became uncoordinated and hyper-competitive.

The major crown investment funds for research (excluding health) are:

1. **Endeavour Fund:** "The Fund encourages researchers to sample a diverse range of ideas and conduct excellent research, with transformational potential. It will provide the highest potential impacts across a range of economic, environmental and societal objectives, and give effect to Vision Mātauranga"

   https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/

2. **Marsden Fund:** "Supports the excellence in science, engineering, maths, social sciences and humanities in NZ by providing grants for investigator-initiated research"

   https://www.royalsociety.org.nz/what-we-do/funds-and-opportunities/marsden/

3. **Infrastructure funded through the Strategic Science Investment Fund.** The Strategic Science Investment Fund (SSIF) supports infrastructure and programmes that are deemed to have national benefits that won't be developed through the mainstream science system. Things funded here are typically large scale, complex, have long duration and have multiple sources of funding. This fund also manages the relationship between the government and research organisations to help deliver science priorities. This fund ensures a minimum level of funding for CRIs.

   https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/funded-infrastructure/

4. **MPIs Sustainable Food and Fibre Futures (SFFF).** SFFF is a $40m investment fund that supports innovation in New Zealand's food and fibre sectors. The fund coinvests in projects so depending on the scale of the research, the applicant may need substantial resources.

   Sustainable Food and Fibre Futures: https://www.mpi.govt.nz/funding-rural-support/sustainable-food-fibre-futures/

The Marsden fund has a 12% success rate (Table Nine Below). This means 88% of applications, consuming 100s of hours of researcher's time is wasted. Why the low success rate? It is partly because the government has contributed little extra funding since 2018 and is also an indication of how short of funding the science sector is: everyone is chasing money (Author's Note)

Table Nine: Successful Outcomes from Funding Rounds 2017-2021

Endeavour Fund	2021	2020	2019	2018	2017
Applications	544	128	414	399	408
Approved	69	17	71	69	68
Success	13%	13%	17%	17%	17%

Marsden Fund	2021	2020	2019	2018	2017
Funding Success	10%	12%	12%	12%	12%

Table data adapted from: https://www.royalsociety.org.nz/what-we-do/funds-and-opportunities/marsden/ and https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/

Competition for research money is a feature of science in NZ because research money is limited. There will always be priorities, and contestable science funding will remain one of the core pillars of our science system. There are perhaps as many as 120 different funds that provide science grants (Author's Count), and this is not including venture capital or late stage seed-funding from investors. The funds allocate money to research that is judged to meet their research criteria. The contestable nature of the funding rounds is meant to drive the efficient use of research money, to ensure value to the government and taxpayers. Funding science in this manner requires convincing someone to give you money. The funds are oversubscribed, so there are always winners and losers, and competition for research money is intense. Most money is allocated towards big projects, so the success or failure of bids for research organisations that depend on grant money for their survival, makes winning 'mission critical'.

5.11 'THE FUNDER GAMES'

Writing submissions for funding has become a whole industry in itself and is known colloquially as 'Grantsmanship', which means being good at writing proposals for funding. If the project team is big enough (15+ people), then there will often be one person entirely designated to proposal writing. The interpretation of the language of different agencies and their funds is a skill, a lot of time is spent by senior scientist writing very good bids, often tailored to meet the fund's criteria, rather than from the science perspective. Scientists play it safe, as securing the funding is the all critical outcome. Ultimately the success of the project is intrinsically linked to the career success of the scientist as funded projects need to be successful. The system seldom creates true science in the Thomas Kuhn sense or enduring science programmes. All this drives a 'management intensive' science environment: Bid process (Grantsmanship) > Funds > Project > Budgets > People > Reports. Truly creative thinkers are hard to manage and they do not thrive in a management-focused environment (Henry Kressel, 2015), this was one of Kuhns major ideas, paradigm shifts are spontaneous and require 'space' for this to happen (Kuhn, 1962).

Table Ten: Bid Observations– John Foley

- A common criticism from interviewees was that there was no feedback as to why the bid was rejected.
- There is a belief the bid process is inconsistent; it all depends who is on the panel
- Young people seem disadvantaged in the bid process, experience in submitting bids is critical (Grantsmanship), senior researchers as a lead and experienced staff on the project bid are necessary
- Mātauranga principles are widely supported, however incorporating them is making the bid process more difficult because there is a shortage of expert advisors.
- Assuming your bid is successful, a team is built, the project runs to its completion, the funding finishes and the team breaks apart. The funding model makes it difficult to build enduring capability
- Once the bid expires, no more funding is available so the project halts. From the perspective of the scientists involved this is frustrating as all the effort put into the project ends without a satisfactory conclusion such as commercialisation or the generation of IP

One of the impact categories for the Endeavour Fund is to 'preserve and protect and transform' (Endeavour Fund Roadshow, 2020). The preserve and protect aspects appear to be less important criteria in the science funding rounds. There seems to be a notable shift from business as usual to the transform criteria. Thanks to government support through Callaghan Innovation and MBIE, NZ has an emerging space sector that has had some world-leading successes such as Rocket Lab. Few people would argue that this is not an exciting development for NZ, with the potential to create both high-tech industries and jobs. The issue is that transformative sectors are viewed in MBIE as an either/or to other sectors. There is a risk of under investing in sectors that still have high growth or value creation potential. Pastoral agriculture is a prime example, in 2021 export receipts from this sector exceeded $31.1 billion (Situation and Outlook for Primary Industries, 2021) and yet there was only one successful project funded from the Endeavour fund for AgResearch, the CRI task with providing research support to this sector. Table Eleven below presents the issues. In the last five years the average success rate for applications for Endeavour funding has been 15% (Endeavour Fund successful proposals, 2021), so like the Marsden fund (2021 13% success), there is a tremendous waste of resources putting forward unsuccessful bids (Smol, 2020). The universities are more successful than other research organisations accounting for 55% of successful bids. As mentioned earlier, the impact from the science is measured in publishing and the h indices, so the science output is academic orientated, favouring universities. Secondly, the universities are much larger entities than the other research institutes so can devote more resources towards the grant's application process. The CRIs on average, represent 30% of successful bids and looking at AgResearch by itself, just 12% success from its bids to the Endeavour fund. Table Eleven below presents this situation:

Table Eleven: Who got Funded? Endeavour Funding Rounds 2017-2021

Organisation	2021 Success rate (%)	2020 Success rate (%)	2019 Success rate (%)	2018 Success rate (%)	2017 Success rate (%)	Average 5yr Success rate (%)
Total Success	13%	13%	17%	17%	17%	15%
University share of successful bids	57%	65%	59%	36%	59%	55%
CRIs share of successful bids	25%	29%	30%	36%	32%	30%
Others	19%	0%	11%	28%	9%	13%
AgResearch success of its bids	8.30%	0%	18.20%	19%	16%	12%

Source: Endeavour Fund successful proposals:https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/success-stories/

Despite strong growth in export earnings from pastoral agriculture, between 2012 and 2020 agriculture was the only industry to record a decrease in R&D expenditure – by about 19% (The Government and Science: The Research, Science and Innovation Report, 2021). This argues a strong case for more government support for the CRIs, particularly AgResearch. AgResearch, like all the CRIs, relies on grant money for its survival (Smol, 2020). It receives some bulk funding, about $40 million/year from the Strategic Science Investment Fund, this is about 1/3 of its total budget. The rest comes from commercial investment, funding applications, and royalties. In its current form it is struggling to secure funding, and restructurings are a constant feature. AgResearch responded to the signals from MBIE by moving into food research and then won a successful bid in 2021 for a 3 year $1m project on novel infant formula emulsions. This is the misalignment of incentives in the NZ science sector in action. AgResearch is now competing for grant money for food research that other research institutes have specialist capabilities in, such as Plant and Food Research. AgResearch is only following the signals from an outsourced decision-making process. It is as though MBIE no longer supports the funding of pastoral agricultural science or funding bids from AgResearch. However, this is an oversimplification, the underlying issue is a lack of deep technical competence in the MBIE and government departments in general.

Over the decades there has been a decline in expert capability inside government (Cook, 2004) – people who had depth and breadth of experience in their roles. Cost efficiencies and productivity became guiding principles (Cook, 2004) and a 'slimmed' down state sector still resonates with the electorate. At the same time government dependence on outsourcing and the use of consultants has skyrocketed. In 2018/19 the state services commission reported that 12.8%, or $914m, of expenditure in the state sector was for consultants or contractors (Use of contractors and consultants starts to level off, 2021). As an example, the Hon Megan Woods recently quoted PWC modelling work around recession plane changes to the Town House Bill aimed at increasing infill housing in urban areas (Coughlan, 2021). There is also plenty of evidence that outsourcing to consultants is poor value for money to the taxpayer. A UK report suggested that consultants' costs were 40% higher than had the expertise been retained in-house (Mazzucato, 2021). In an earlier time, government expertise across a wide variety of disciplines was both expected and the norm. During the Apollo space programme, the government did not rely on consultants to project manage the missions, nor did it rely on experts to advise them on what technology was required. They had this capability in-house through NASA. Having in-house capability proved to be one of the cornerstones of the successful lunar missions. NASA's decision making was streamlined, efficient, and quick, and they could work with whoever had proven experience and capabilities (Mazzucato, 2021).

NZ is not alone in this phenomenon, across the western world governments have restructured down their internal capabilities and ramped up their reliance on outsourcing and consultants. This in turn, has lowered the ambition of governments and reduced the experience held internally (Mazzucato, 2021). It is the loss of internal capability that is most concerning from the NZ perspective. Government departments are staffed by people spread thinly across areas of specialty. Furthermore the nature of career advancement in the state service sector is based on broad based skills meaning short tenure and secondments are common, and people don't have time to develop deep experience. All this makes policy change, at any level, difficult and executing substantial reorganisation or visionary change to the status quo, very complex as consultants need to be engaged at every step. Science delivery and leadership is greatly impacted, and this has contributed to the misalignment of incentives that drive the sector. For example, government research funds are governed by external appointees rather than by internal government staff, the decision-making process has been outsourced.

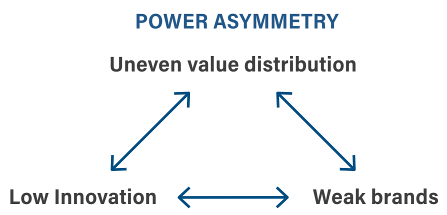
6. Discussions – Collectively creating our future

6.1 THE VALUE DILEMMA

This report has built a case for change to the way research and development is conducted in this country. What we have today is the result of a massive reform agenda in the 1980's and 1990's, where market forces were introduced to areas of the economy that had traditionally be protected. In the 30 years since, there has been a series of efforts and polices to 'fix' our science system, to roll back the unintended consequences of the reforms. These efforts have mostly been 'small', and at the edges of the big problems. It is almost as if the appetite or desire of government for reform has evaporated. The upheavals of the earlier era has left little appetite for fundamental changes. So we have a science system that is fragmented, siloed and characterised by fruitless competition. The structures and funding drive perverse incentives such as, doing science to get published, to get funding, to get published.... The government has retreated from applied research, expecting the private sector to fill this gap when they don't or can't take the risks involved meaning incremental applied research is normalised. We need a science system built on collaboration, with a new mandate to create value for NZ. For agriculture, the research and development has to create value for farmers, for agribusinesses, for exporters, and wealth for NZ, beyond the production/efficiency status quo.

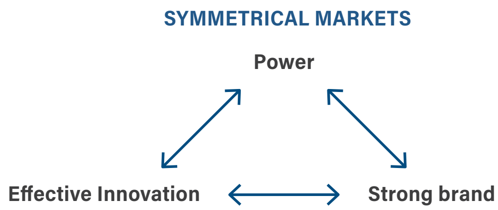
Figure Nine: The Value Dilemma

Brand not strong	**-**	**price is an issue**
Low Innovation	**-**	**price is an issue**
Power Asymmetry	**-**	**price is an issue**



FLIP

Strong brand	**-**	**power**
Power	**-**	**innovation**
Innovation & Brand	**=**	**Symmetrical Market** (more even value distribution)



Value is broadly created in two ways: through innovation and through branding. There is a strong correlation between the two; good innovation usually leads to strong branding and a strong brand position allows for sustained investment in innovation. Brand building is difficult and requires commitment over long horizons, particularly with products that lose their provenance by being an ingredient, and /or part of long supply chains that have multiple changes of ownership. These market conditions make it very difficult for the owner of the branded product to capture the value. Furthermore, we largely supply homogenous products into mass markets with relatively few buyers and many competing sellers. These sellers are either other NZ companies or other countries such as, Uruguay, Ireland, Australia, and others. Competition is on price. These factors combine to create asymmetrical markets where other value chain parties extract proportionally more value. The value dilemma diagram above (Figure Nine), illustrates the point. If the competition is centred on price, the products will have low brand equity, the business involved will be investing less in innovation and more value will be captured by other value chain participants (asymmetry). The three factors are sides of the same triangle. If you flip the model and consider a situation where the brand position of a business is strong, then power in the value chain is more evenly distributed, and the additional value captured can fund greater levels of R&D - the market is symmetrical.

Table Twelve: The Meat Industry: Value creation for someone else

Despite 25 years of efforts by food exporting companies, levy paying organisations, and farmers to capture more value for NZ, the asymmetric, competitive dynamic continues to skew value away from farmers, processors and exporters. To illustrate this point consider the grass-fed meat story that resonates with consumers on the west coast of the USA (Wilkes, 2020). NZ ground beef is in demand and commands a premium price in the retail network. Grass-fed ground Angus beef sells $NZ42/kg. The FOB price is $NZ15.0/kg, the margin for the in-market participants is a 65%, the farmer receives just $NZ8.50/kg or 20% of the value (Wilkes, 2020). So a premium product, sold with high value in a market that recognises its qualities doesn't translate to higher farm gate returns in NZ. To highlight the point further at an economy scale, the FOB value of all NZ agricultural exports in 2012 was $NZ25billion, yet the final value was calculated at $NZ140 to 200 billion, Riddet Institute report 2012 (Wilkes, 2020), using the lower end of this range NZs share was just 16% of this. NZ farmers and exporters are doing an incredible job creating value through its value-add strategies – however other value chain participants are capturing the premium. For all the outstanding efforts from our levy paying organisations and exporters – NZ products enjoy a high level of brand awareness and trust, the reality is NZ is selling premium commodities into commodity markets where the main point of difference is on price. Commodities are the raw ingredients of the value chain and so are typically traded in high volumes with low margins. Participants higher up the value chain extract more value through secondary processing, branding and value-added activities and is the case of our exporters, the higher value is from being 'in-market'.

Source: Discussions with Dr Jim Wilkes Value Chain expert,

6.2 THE PROGRESSION ON ECONOMIC VALUE

Pine and Gilmore proposed a progression of economic value in a model developed in the 1990's (Gilmore, 1998). They argue that as economies evolve, an increasing share of the value is captured at higher positions in the value chain and as these value chains evolve, the next iterations become the place of maximum value (Figure Ten Below). They see the development of economic value as being defined in four evolutions: Extract Commodities, Make Goods, Deliver Services and Stage Experiences (Gilmore, 1998). Their proposition was that the next evolution of the value chain was occurring- the emerging "experience economy" where consumer are getting other attributes (the experience) as well as the good or service they are consuming. In the context of NZ meat exports and the example of the ground beef referenced in Table Eleven above, the experience is the branding and story telling that gives the meat providence - the intangibles that sway consumer choices. NZ exporters are already doing this, right? In a sense they are, but it is through proxies (distributors, wholesalers and retailers) who are 'in market'. This is a fundamental point as envisaged by Pine and Gilmore, the closer to the experience, the greater the value. For most of our agricultural exports, as shown in the Progression of Economic Value model below, this is in offshore markets where most NZ businesses aren't represented on the ground in a meaningful way. Wakatū Incorporation based in the Nelson region is a good example of a New Zealand enterprise having success doing this with a range of innovative products in the Japanese market (Andy Elliot).

Figure Ten: The Progression of Economic Value

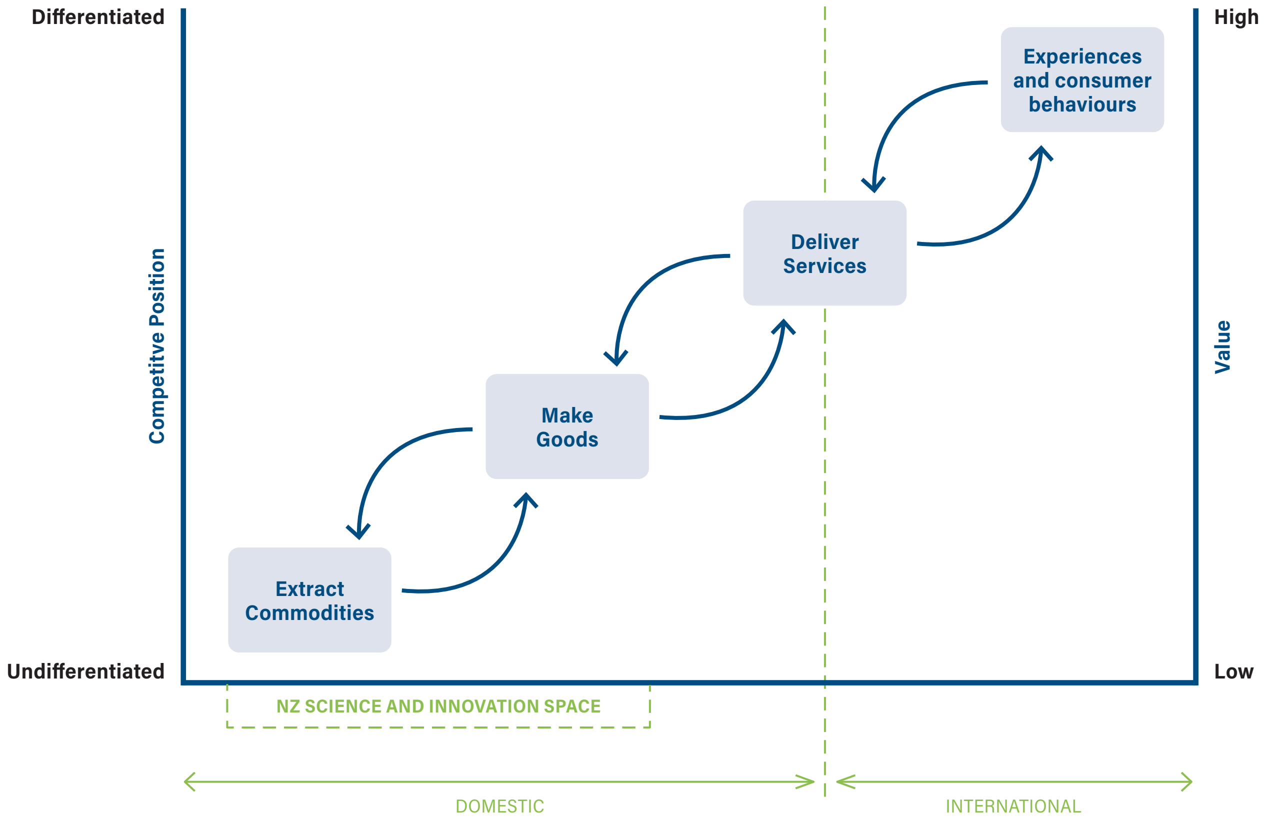


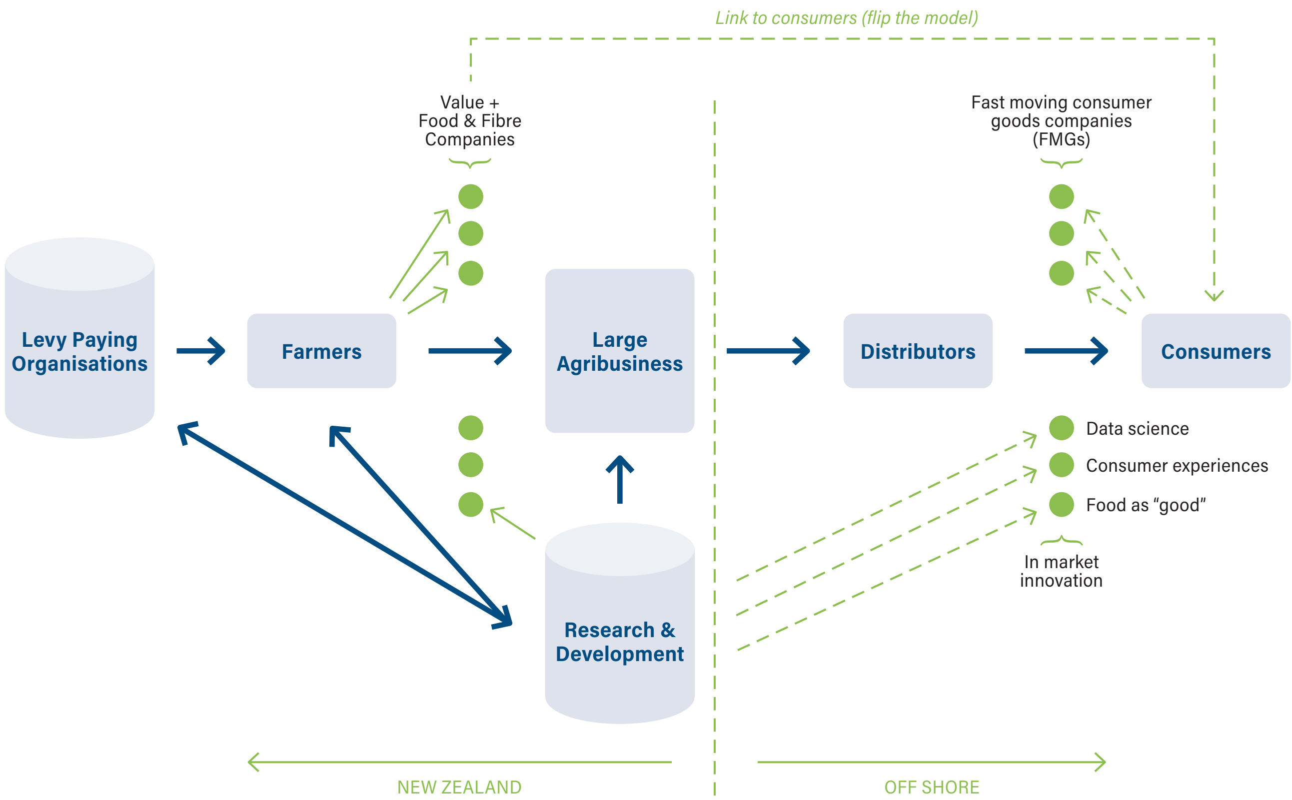
Chart Adapted from Prof Hamish Gow and Pine and Gilmore (1998)

6.3 VALUE CREATORS, INNOVATORS, AND THE OFF-SHORE PLAY

NZ exporters have other value chain players undertake the higher boxes in the diagram above. To move higher up the model requires innovation – food for health and wellness, providence stories, customer service and control over 'in market' distribution. The innovation for value, and the wealth Sir Paul Callaghan discussed, in his 2011 speech is out on the end of the diagram's continuum. However, as this report has discussed our economic system has created a paradox for NZ agriculture and its innovation mindset, we localised into an efficiency and production model. We need to rebuild our offshore capabilities.

The emerging value chain diagram below (Figure Eleven), highlights this point. Domestically our levy paying organisations and agribusiness including the COOPs, support the farming community with representation, processing, farm inputs, marketing and distribution to overseas markets (the left-hand side of the diagram). In offshore markets, distributors and retailers link through to customers, selling premium products that resonate with customers and capturing the value (the right-hand side of the diagram). Fast moving consumer goods (FMCGs), those that have novel attributes, wellness or health claims and providence as traits, are an emerging premium category. The challenge for NZ food exporters is to link to those companies directly, i.e. hold the customer relationship (dotted lines). For NZ food and fibre producers this is the innovation play – creating the products with novel attributes and linking providence stories directly to consumers. Data sciences will be crucial in picking emerging trends.

Figure Eleven: The Emerging Value Chain



Amongst our success stories for NZ agriculture is a group of businesses that have successfully scaled in their offshore markets and, as a consequence, are highly profitable and innovative. Zespri, First Light Farms, Atkins Ranch, Apple and Pear, and PGG Wrightson Seeds are such transformational businesses. They are highly differentiated from their competitors and have defendable market positions that give them some protection of the value that they have created. Atkins Ranch does final processing 'in-market' tailored to its customer requirements. First Light Foods has its steak club that helps 'lock' its customers in. Zespri invests heavily in understanding consumer trends and has a strong IP story. Apple and Pear have leading genetics protected by IP, and PGG Wrightson Seeds does local innovation to get close to its customers. These businesses have changed the nature of competition and in the process, have made it harder for competitors to exploit the second mover advantage. From the outside, these types of successes always look shiny. However, the reality is, these businesses had vision, took risks, and invested in people and businesses to create long term success. The strategy becomes the 'lock-in' for these businesses, not the sales. Opportunity, vision, and indeed good timing plays a part.

We don't build businesses that have economic value but build averaged value in assets such as land.
– Prof Hamish Gow

Table Thirteen: Zespri: New Zealand's International Food Company

Zespri is an example of a NZ exporter capturing genuine value for its growers. However, the road to industry leading value creation has been long. In the 1980's the kiwi fruit industry was incredibly volatile and went through cycles of booms and busts. Eventually growers came together and with the support of legislation, Zespri was formed. Zespri has statutory rights that give it exclusivity to market NZ Kiwi fruit beyond Australasia, this right allows Zespiri to constrain supply of its leading varieties, this helps maintain value. Zespri is a sales, marketing, and IP company. It owns the IP created from its joint venture Kiwi fruit breeding programme with Plant and Food Research.

Sales and Marketing is where Zespri excels, it has 10 overseas offices located in key markets. Being close to the market and understanding their consumers is fundamental to Zespri success. These insights drive both the product development in the JV and give clear signals to growers. Being in market for sales and distribution allows Zespri to get a head of change and react quickly, for example compostable labels for fruit are becoming mandatory in France and Zespri has a strategy to comply with this new requirement ahead of it coming into effect. If you are in NZ and exporting without these beach heads, others will get these signals and therefore capture the value.

Cloning the Zespri model with statutory powers in other sectors is virtually impossible because our trading partners, trade agreements and WTO rules would not support this. The concept of single-desk national sellers is looked upon as a form of protectionism and therefore not aligned with trade liberalisation. However, it doesn't mean that key aspects of the model can't be replicated in other sectors. These include being co-located in key markets, being close to the consumers, being responsive to consumer trends, and having a strong IP position. The latter is part of Apple and Pear's strategy to develop its presence in key offshore markets. It is using its strength in IP as a way of dealing with seasonal supply and market access issues, and competitors in offshore markets.

Table Fourteen: Apple and Pear – Using IP Innovatively Offshore

Apple and Pear use IP to overcome market access challenges. For example South Korea require the fumigation of fruit products, this biosecurity requirement effectively limits the opportunity to sell NZ produced apples in their market – an effective non-tariff barrier. Apple and Pears strength in IP allows them to create value beyond the phytosanitary restriction where they enter licensing agreements with Korean apple producers. South Korea now produce NZ apple varieties under licence and potentially they could even export these to other markets so it's a win for their apple producers and as a consequence are less likely to oppose future NZ apple imports. Licensing apple varieties to Korean producers also strengthens apples position in the Korean fruit market – high quality local production helps reduce the seasonality of apple supply, so the consumers have year-round choice. In return for this Apple and Pear enjoy an enhanced reputation and receive royalty income back to help fun their R&D activities.

Another successful variation to the Pine and Gilmore model is how PGG Wrightson Seeds used its IP and technical know-how to establish its South American operations: build an integrated business model that is aligned to its customer base.

Table Fifteen: PGWS Seeds - Fully Integrated Offshore Businesses

PGG Wrightson seeds used its elite pasture genetics and seed production know how to develop its beach head in Uruguay. Their genetic technologies were incorporated into a joint venture with INIA, the Uruguayan governments agricultural research entity. The JV has gone on to create breeding programmes that produce locally adapted, high performing proprietary pasture cultivars resulting in greatly improved pasture production and quality. PGWS has a strong reputation in Uruguay for supporting local research activities. The JV returns royalties back to the NZ PGWS entity that helps funds R&D and further investment. Local seed production capability was critical to develop scale in the company's business activities and produce seed for retail channels at a price point that was competitive. Proprietary seed production commands a grower price above commodity production and combined with NZ seed production knowledge has helped create more value in the Uruguayan arable sector.

These examples have common principles. Their IP is based on plant genetics where programmes run over long horizons and therefore require committed managers and shareholders willing to invest. These organisations have cultures that are shaped by the long-term commitment to R&D. They all have leadership willing to invest and wait for the rewards. With this approach, returns are amortised for the future. Companies such as these have different mindset. Their respective IP stories are strong and resonate. They all have built off-shore 'people capability' who are responsible for sales, marketing, and logistics 'in-market'. These case studies show that when combinations of the producer, the scientist, the farmer, the marketer and the distributor are located in the same market, the value chain is less asymmetric, and a greater share of the value captured. Short term projects and time horizons will never be able to deliver success on this scale.

The challenge for New Zealand is linking the domestic value chain to the international part. Entrepreneurs and science has become focused on the local – our domestic base, this explains why we can do efficiency very well because it is 'in-market', however, the innovation is localised, as well difficult to scale to other markets. Our Fast-Moving Consumer Goods Companies (FMCGs) and start-ups, that are locally successful, run into the same issues as our food exporters, when they attempt to internationalise.

NZ needs to "find the niches and own it globally" (Dr Christian Walsh). This was Sir Paul Callaghan's point as well, when he was referencing our most successful wealth creating enterprises. These were niche manufacturing companies working in areas that were too small for the major manufacturers to focus on (Callaghan, 2011). The nature of the products they produce are highly specialised and high value. NZ however, instead of finding niche opportunities, has a history of jumping onto the 'next big thing'. In science it was biotechnology, then smart packaging. In trade, it was the UK in the 1970's, in the 1980's it was the USA and Japan, in the 1990's it was the 'Asian Tigers', and more recently China. At each juncture, the focus for NZ was on these markets, every exporter went in, and the outcome was more often than not just a trading relationship. Did we strategically align ourselves with the customers in these markets? In most cases no, we didn't do the science to understand the consumers and their problems. The strategy has to be more than just sales to capture the value. We need a strategy to re-internalise NZ in the global world.

7. Recommendations: "A place where talent wants to Live"

The era of trade liberalisation and reform in the 1980's and 1990's left NZ focusing on what it was good at: efficient commodity production with a domestic focus for our innovators - NZ exploited its comparative advantage. The offshore part of the value chain, with a few exceptions, was left to others and whilst productivity increased, NZ was able to sustain its first-world living standards.

As discussed in this report, we are moving into a new economic era and we need to adapt to the new paradigms, particularly within environmental limits for our farming systems. People who become leaders in a system focusing on efficiencies and production maximisation with a domestic focus, tweak the model rather than shift the paradigm - disruption seldom comes from within. We need to build an internationalised NZ. This is different from the likes of NZ Trade and Enterprise, it is a much broader vision that encompasses government workers, education, science and innovation, our exporters and farmers – a "mission for NZ inc.". The key outcome is to develop people with international experience, networked into research organisations, who have relationships 'in-market', and with deep understanding of consumer trends. To reference Sir Paul Callaghan, he believed that if New Zealand could create 100 business with 100 entrepreneurs, NZ would be a wealthier country.

7.1 MISSION ORIENTATED INNOVATION

Mariana Mazzucato states "we get the kind of government we think is possible" (Mazzucato, 2021). If the ambitions for government are low, the result is outsourced expertise, fragmented services, and poor policy interventions. In this scenario, the government can't create value and therefore has no need to invest in its own capabilities, such as strategic management, organisational behaviour, and direct science and innovation (Mazzucato, 2021). This view is underpinned by the belief that outsourcing 'always' saves the taxpayer money and it shouldn't 'pick winners'. The orthodoxy that pervades public policy that limits the aspirations of government, is based on New Public Management Theory (Triola, 2021). The theory states that governments need to be run like a business, only fixing markets when required, and then moving out of the way to let the private sector do the innovating. This ideology created the science sector we currently have. When we try and 'fix' the issues, we enter into what is known as the 'complexity' paradox (Mazzucato, 2021), where layers of policies drive the creation of silos that begin competing with each other. Rather than 'fixing,' the problems, they are exacerbated. We need to do much better. Whilst innovation happens close to consumers, in value chains, science institutions, and in private enterprises all across the economy, the government does have a role in creating the framework and policies to encourage it. This report has discussed many of the challenges in our science sector and stated that we are entering a period of change.

Table Sixteen: Mission Orientated Innovation:

Missions are based on clear challenges and identifiable concrete problems, and are directed by strong centralised agencies e.g. MPI or MBIE.

Missions aren't siloed endeavours or 'pet projects' of governments or ministers.

Missions are determined by consensus i.e. sector and government input.

Goals are built and solved through collaboration, on a large scale, between public and private sectors.

Success of Missions is only possible through resilient systems, especially government capability and the right infrastructure.

Having the vision is not enough, industry and citizens must be on-board.

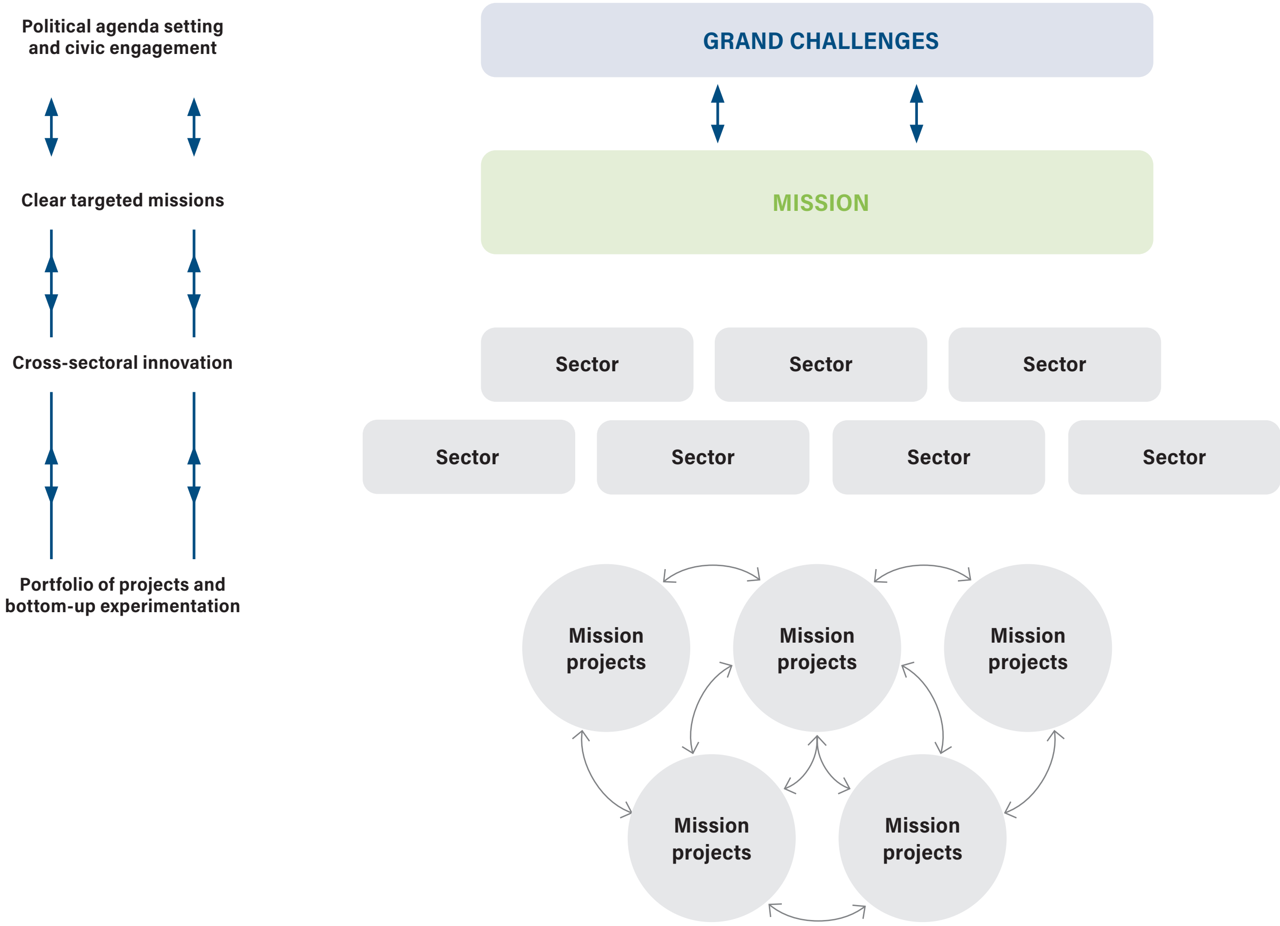
Sourced and Adapted from Mission Economy, a Moon-shot Guide to Changing capitalism, Mariana Mazzucato 2021

The starting point for a 'Mission' orientated approach is identifying the grand challenges, from this, the missions are defined i.e., what problems need to be solved? These problems are framed as goals that focus the investment and innovation across all sectors. This framing of goals drives collaboration at the mission project level (Mazzucato, 2021). Figure 12 shows in diagrammatic form, the workflow for a Mission oriented approach. Mariana Mazzucato identifies seven key pillars required for mission success, many of which require reimagining our economic system.

1. **Value and the collective process through which it is created:** This is proposed in the notion of public purpose, through this, the value is created, owned, and shared.
2. **Markets:** Governments no longer 'fix markets,' instead become they co-creators and co-shapers of markets.
3. **Organisations:** With a common purpose, competition is reframed as cooperation, capability building, and risk taking – together.
4. **Finance:** Long-term funding and long-time horizons for projects/missions/organisations, incorporating Te Ao Māori , – shifting from the 'short term.' The approach is to 'flip' the mindset from society working for the economy, to the economy working for society.
5. **Distribution:** Missions emphasise collective value creation and market shaping, that is, broad distribution of value that creates good jobs and ensures the collective ownership of public utilities. The mindset is 'replenishment' rather than 'extractive'.
6. **Partnership:** Missions are collaborative by nature; collective value creation redefines how organisations and governments work together. In the current paradigm, partnerships are often where one organisation grows at the expense of the other. For example, consultancies, compared to internal capabilities in government departments. This is a parasitic relationship rather than symbiotic – in Missions, both parties prosper.
7. **Participation:** Bringing different experiences and voices into consensus building processes. This includes businesses, workers, local and central government, sector groups, iwi and societal groups, who all have important voices for collective value creation.

Adapted from Mission Economy Mission Economy, a Moonshot guide to changing capitalism Mazzucato, M. (2021). Dublin: Penguin pgs 165- 203.

Figure Twelve: A Mission Innovation Example



Adapted from Mission Economy Mission Economy, a Moonshot guide to changing capitalism Mazzucato, M. (2021). Dublin: Penguin pg112

Mission Orientated Innovation is an approach to solving complex challenges within sectors and across societies. This report has suggested three missions for agricultural science and innovation for this country:

There are three layers to this vision for NZ:

1. Creating Internationalised researchers and businesspeople
2. Creating the opportunities for technological convergence
3. Creating a world leading agricultural institute

7.2 MISSION ONE: CREATING INTERNATIONAL RESEARCHERS AND BUSINESSPEOPLE

An insight gained from the interviews for this report, was the high number of late stage career people who had international experience early in their careers. These people worked in the export offices of NZ companies offshore, or studied abroad as part of government programmes. Unlike the 'O.E' that many of us did, this was strategic for the country and the exporting organisations. The people who had these experiences were 'internationalised' and 'networked' into offshore markets and these have served them well throughout their careers. To move higher up Pine and Gilmores model, NZ needs 'in-market' innovation and expert people. New Zealand has a history of doing this, for itself pre reforms, and as part of international organisations, notably the Colombo plan where people from the Asia-Pacific region were given the opportunity to study and learn professions in countries such as NZ, Australia, the United States and Great Britain. For NZ, experts were able to work on projects in participating countries and the universities were able to build international networks. NZ needs to create a 'reverse' Colombo plan where we send people out to the world.

Table Seventeen: The Colombo Plan:

The Colombo plan was established in 1951 with the stated aim of strengthening economic and social development in the Asia – Pacific region (Colombo Plan, 1950). There are 27 member countries and New Zealand is a founding member. The Colombo plan has six permanent programmes, one of which is the Long -Term Scholarships programme (LTSP) that allowed students from participating countries to study abroad. From the 1950's through to the 1980's, hundreds of people from South Asian countries have studied at NZ's tertiary institutions. These students returned to their home countries with new knowledge and expertise (Clark, 2001). For NZ, experts visited and worked in Colombo plan nations gaining valuable experience. NZ's educational institutions gained international insights and became more diverse. From the 1980's onwards, these educational opportunities were incorporated into bilateral relationships (Clark, 2001)

New Zealand produces world-class researchers. Our universities have strong PhD programmes that attract both domestic and foreign students. However we need to attract both talented people to NZ and we need to send talented people out into the world. According to the Ministry of Education's Moving Places Research report, 77 percent of New Zealand researchers spend a portion of their career overseas (Berquist, 2017). Given this statistic, is there a way to keep them 'networked' into NZ whilst they are overseas, instead of being lost all together? In an earlier era, funding PhD students through overseas studies was common: The NRAC (National Research Advisory Council) gave a small number of scholarships per year. The recipients had to work for a government research Department (e.g. the DSIR) of their choice, for 18 months before leaving on their studies and were bonded for one year, on return. The recipient could choose any university, and many chose to study in the USA. They had their fees paid, a living allowance, and travel paid for (Dr Phil Rolston). MAF Tech also had a scheme to fund students through offshore PhD programmes (Prof John Hampton). These we long-lived programmes. Many of NZ's leading scientists benefited from the experience and NZ science was undoubtedly a beneficiary with a cohort of 'internationalised' researchers with extensive networks. These programmes didn't survive the reforms of the 1990s and the scientists who went through these programmes are now late-stage career. Looking back it seems incredible that such programmes were discontinued.

'The Reverse Colombo' plan would aim to recreate this initiative – sending high quality students to overseas universities to study. The guiding objective is to develop NZ's links into key markets. Therefore, we must be strategic by building knowledge, facilitating technology transfer back to NZ and out to the world, building understanding of markets and societies, creating student exchanges for cultural understanding and professional networks. We need to be building capability at multiple layers. The target countries would have markets that have genuine opportunities for value creation. These placements could be across a range of disciplines, even being directed into areas of need for NZ. A scheme for student placements into overseas universities and faculties could be developed, funded by government and even through private sector sponsorship. There are good examples overseas to replicate, for example, Michigan State University runs a programme of student placements into leading research universities across the USA and globally (Students and Placements, 2021). Closer to home, Prof Hamish Gow ran a pilot programme with Lincoln University in the early 2000's. Six B. Com Ag students over four years, completed a Master's degrees at top American universities. All came back to NZ with strong networks and all have successfully used these in business (Prof Hamish Gow). The government could also consider directly investing in research being undertaken by NZ scientists overseas. "We need to make islands of people overseas and keep them linked into NZ" (Prof Hamish Gow). This would make them part of NZs' offshore network'. An internship programme could be developed for young businesspeople and government staff. As discussed earlier, our government lacks a depth of expertise, in contrast to earlier times, when government departments had deep expertise. This idea is strategic development of people in a broad coordinated sense, developing programmes for researchers, food innovators, consumer trends, policy areas, and offshore capabilities.

There is a modern precedent for the Reverse Colombo Plan. The European Union has recognised a similar issue with its SMEs that make up 99% of all businesses within the economic union. To create wealth for its citizens they need their SMEs to be more ambitious and take growth opportunities. They have identified skills gaps such as a lack of international experience and have come up with a novel solution: an EU wide industry secondment scheme. The ultimate goal is for SMEs in Europe to develop extensive networks with local contacts and develop the skills, knowledge and competencies of businesspeople to find business partners across the EU (EU launches new programme to support European SMEs, 2021).

Table Eighteen: The European Union's Small, Medium Enterprise Businesspeople Secondment Scheme

This scheme launched in March 2021 is a dedicated programme to encourage and support employees to work in other SMEs across the EU. The idea is that exchanging skills and knowledge will help the internationalisation of Europe's SMEs that make up 99% of all Europe businesses (EU launches new programme to support European SMEs, 2021). Increasing the knowledge and experience base of their SMEs will help create more business opportunities and wealth for the EU. Key Features:

1. The scheme involves the exchange of staff from a SME in one EU country to another SME in a different county.
2. The programme allows the use of the scheme to boost collaborations already in place,
3. There are no deadlines to participate. The SME programme works on an ongoing basis,
4. Mobilise SME programme consists of a temporary exchange with a minimum of 1 month to a maximum of 6 months period
5. Staff remain employed by the sending company during the period of the secondment. The sending employer still pays his/her salary and expenses incurred.

The European Union pays up to 1100 euros/month per participant to help fund the secondment.

Source: Mobilise SME, Mobility exchange programme for SME staff: https://mobilise-sme.eu/about-mobilise-sme/

New Zealand has 530,000 SMEs which includes most of our farms and orchards. The research suggests that most of these don't undertake innovation or invest in R&D. If a programme could be designed along the lines of the EU example, it could create a huge opportunity for NZ. If people in SMEs had the opportunity to spend short periods of time in other SMEs overseas, there would be a huge transference of knowledge. If farmers could be linked to FMCGs (Fast Moving Consumer Goods), then the direct relationship would be established as suggested in Figure Eleven, the Emerging Value Chain - the farmer is brought much closer to the value. This concept is the way farmers can move higher up Pine and Gilmores model.

7.3 MISSION TWO: CREATING THE OPPORTUNITIES FOR CONVERGENCE

"Structure follows strategy. Strategy is always the starting point"
– The Hon Ruth Richardson

The 'Reverse Colombo' plan is about sending people out into the world. This mission is about making agriculture "a place where talent wants to live" (Sir Paul Callaghan). There are accelerating forces for change. Science is on the cusp of a revolution (see text box below), society is changing rapidly through urbanisation and digitalisation, and humanity is facing existential threats through climate change and biodiversity loss. Likewise, in agriculture there are forces that will make change necessary i.e. climate breakdown, digital working, consumer preferences (e.g. natural, sustainable, localised), the disruption of global supply chains, and the social licence to farm, will all require big responses. The government's review of our science system in its Te Ara Paerangi Future Pathways green paper is extremely timely and signals that the incumbent system is broken. However, the new system needs to be more than reactive to change, it needs to be able to meet the challenges of our time -it needs to be H2+ in Sharpe's Three Horizons model and not the H2- that reinforces the status quo.

Table Nineteen: The Technological Revolution in Science

In 2008, the editor of 'Wired' magazine, Chris Anderson, predicted the demise of theory-based science. He reasoned that so much data had been accumulated and, when combined with the emerging field of artificial intelligence, we would no longer use the traditional approach to scientific reasoning i.e. Hypothesis > Predict > Test > Results (Spinney, 2022). In the 13 years since his prediction, traditional science has continued to thrive globally, meaning that the prediction has not been particularly accurate. However, science is under-going a revolution - Artificial Intelligence, particularly machine learning that uses neural networks, has advanced exponentially and is now used successfully in most fields of scientific research (Spinney, 2022). These neural networks learn from the data without specific instructions being given. The technology is creating new insights and directing scientist towards new discoveries, and has huge potential to reshape science (Spinney, 2022). Science is undergoing profound transformation and many traditional ways of structuring sciences may face redundancy. It's time to re-imagine the future.

The convergence of ideas is the basis of innovation and often these ideas are completely unrelated. Aerial top-dressing of fertiliser on hill country farms is an excellent example. Soil and plant science knowledge had been advancing (knowledge creation) for decades, up until the 1940's. The development of aircraft happened in parallel but was completely unrelated to the former. Then, following WW2, innovative NZ farmers, ex-air force pilots and mercantile companies saw the opportunity to apply fertiliser to hill country pastures with aircraft. This was a paradigm shift created from the convergence of technologies and knowledge advancement through science and innovative thinking. The convergence of technologies requires collaboration and this report has discussed the many impediments to this in our current science system. Collaboration takes many forms and is much used and often misunderstood. Collaboration as inferred here, uses a definition suggested by Rebecca Hyde in her Nuffield report in 2017, "Collaboration brings previously separate organisations into a new structure with full commitment to a common Mission" (Hyde, 2017).

Translators: Thomas Kuhn's theory suggests that paradigm shifts are spontaneous and the people who create these, are working on the margins of the current paradigm. For those in the current paradigm, the new knowledge or innovation is a potential threat to their belief systems. This makes the 'translators' special people that are often resilient as well as visionary. To shift the paradigm the system needs to be open to new ideas. Translators are not cheap people to have in businesses – they are generally very skilled and very expensive. Low margin industries such as agriculture, have the challenge of not being able to afford these types of people at an enterprise level. NZ needs to invest ahead of the curve and develop or acquire these people and bring them into our global food strategy. Zespri for example, has recruited good people because they can now afford to – the pay-off from their strategy previously described, giving them the resourcing to invest (the flip in the value dilemma diagram figure nine). It is the "long game" to develop these types of people. New Zealand does have highly talented people operating this space, they are the 'thought leaders' for NZ agriculture – we need more of them.

Table Twenty One: The Translator – Craige Mackenzie and Precision Agriculture

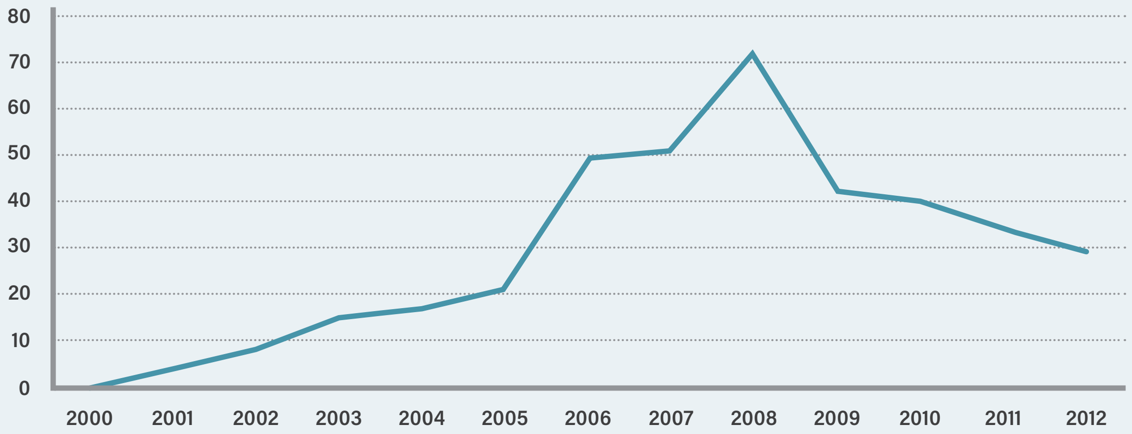
Precision agriculture is an umbrella term that encompasses the deployment of a range of technologies into a farming system. These technologies include artificial intelligence, machine learning, quantum computing, satellites and sensor technologies, soil maps and geospatial data and information from equipment. The farmer uses the data collected from the technologies as decision support tools to optimise farm inputs and improve the profitability and sustainability of the farming operation. At the heart of precision agriculture is geospatial field information so inputs and field operations can be accurately applied and tracked. All these technologies were developed in parallel to each other and their convergence created precision agriculture. To bring these ideas into real world practical use requires innovation – the translator, the person who can see the opportunity before anyone else and is prepared to take the risk of creating the paradigm shift. Craige Mckenzie, an arable farmer from Methven, is a good example of someone who has deployed these technologies at scale and demonstrated the value proposition to other farmers. Craige has been a translator in New Zealand agriculture's precision ag adoption.

Absorptive capacity (Absorption of technology) – NZ farming systems have been good at this post- 1985 (when subsidies removed). The absorption of new ideas has kept agriculture as the dominant sector in our economy. Many of the innovations through this era have been 'on farm', practical and often 'easy' to see or to measure the benefits. Table Twenty-Two below, showing the adoption of the AR1 novel endophyte is a good example of this concept in practice. The benefits of the technology were obvious and the adoption of the technology straightforward, so the uptake was rapid. The new economic era will mean innovations will be less practical and more complex, and increasingly at a farm systems level. The Diffusion of Innovation (DOI) Theory is a good model to think about farmers' adoption of ideas. NZ farmers over the last 40 years can be characterised as being early adopters and in the early majority of the model. The economic advantages of adopting the innovation have been broad, often sector wide. If future innovations become increasingly complex, then the absorptive capacity will drop and the future of farming in NZ could look like a landscape of winners (understand and adopt innovation) and losers (those that don't). For the sector to stay profitable, let alone be capable of capturing the value described in this report, it is going to need ways to develop its absorptive capacity.

Table Twenty-Two: Absorptive capacity – Novel Endophytes

AR1 endophyte was the second novel endophyte released into the NZ market. It was commercialised in 2001 and by 2007 when AR37 endophyte was released, 75% of the perennial ryegrass sold in NZ had the AR1 endophyte (Caradus J L. S., 2013). After 2007 the decline in the graph is because AR37 became the dominant endophyte int the market. The adoption of this technology was rapid and was the result of extensive animal testing and on farm trials that demonstrated the benefits of the technology. Once this had been clearly demonstrated the industry quickly adopted the technology.

Uptake of AR1 by New Zealand Farmers



Adapted from Adoption of forage technologies (J. Caradus, S. Lovatt and B. Belgrave), 2013

How does NZ agriculture improve its absorptive capacity and attract and retain the translators necessary for transformation i.e. on the H2+ trajectory in Sharpe's model? Too much of what currently happens is viewed through the lens of rivalry and patch protection, and this lowers ambitions for what is possible. New ideas brought to market face headwinds because they conflict with funded projects or established orthodoxy. The applied research NZ agriculture needs must be pan-sector, pan-CRI, and include farmers and agribusiness. The challenges involved are complex and at multiple layers across the sector - in other words, it is well suited to using a mission-orientated approach.

Innovation needs to be linked with value creation – Pine and Gilmore's model shows this clearly. Commodity production is grounded in the principle of being as efficient as possible and adding costs tilts farmers competitiveness away from success. Much of the compliance requirements around improved environmental outcomes are costs that farmers and growers have little ability to pass on to other value chain participants. Can applied research find ways for farmers to monetise the attributes created from good environmental practices, such as, providence stories and improvements to the natural environment? The flip is the potential to turn these into royalty streams that go back to farmers rather than being passed on to processors in the hope that they can capture more value.

Farmers have 30 'harvests' so investing in changes that take 3 -5 years to add value to their enterprises, represent 10-15% of 'their' time, and limits how much change is possible. This further builds the argument for a new approach to applied research. System changes need to be based on sound economics. How much analysis currently identifies the marginal costs and marginal revenues of producing that extra unit of output? Understanding this at a farm system level will be critical to farming within environmental limits. In the USA, the co-location of the extension and farm economic services provided by the US department of agriculture (USDA) creates the economic modelling for supporting innovation (Prof Hamish Gow). Companies that create value invest more in innovation and, as a consequence, are more absorptive of new ideas. Value is intrinsically linked to innovation and the over aching mission, to improve the absorption of innovation and develop the translators, needs to have a focus on value.

The new model for applied research, using a mission orientated approach needs to have broad terms of reference including considering the points made in the paragraphs above. The mission projects will be 'bottom up' rather than a top down, as has been the case for the last 30 years, in other words coordinated nationally, owned locally. There are existing models to guide a mission-orientated approach to building a new applied research model for NZ agriculture. Thriving Southland, a catchment group initiative, is an excellent example that reflects such a model.

Table Twenty: Thriving Southland

"Thriving Southland is a community-led group with a vision to create a prosperous Southland, healthy people, healthy environment from the mountains to the sea" (About Thriving Southland, 2021)

Thriving Southland is an umbrella organisation that represents 32 catchment groups, located in four geographic regions across Southland. The heart of Thriving Southland is the catchments, these contain diverse landscapes, diverse farming operations, urban areas, and local Iwi. By their nature a broad cross section of people in these regions are represented. Thriving Southland has expert coordinators whose purpose is to guide the catchment groups into activities that align with the overall goal. They are the enablers of projects where they link groups with the people and organisations who can help and are the promoters of the good work being undertaken. The projects themselves are developed by the individual catchments and they must pass through an expert panel before funding and resources are allocated. The projects must align with the overall goals; however the nature of the projects can be very broad in terms of their objectives and scope. The key aspect to any projects is the ground up approach, that is community 'ownership'.

Thriving Southland uses a fundamentally different approach to achieve its goals compared to top down approaches of centralised projects. The catchment groups are genuinely representative of local communities and coordinate projects that solve local issues, and collaboration is a fundamental part. Contrast this to more usual centralised decision making with solutions developed in silos i.e. (research & levy paying organisations). due to misaligned incentives and competition for funding they are often short on collaboration and poorly aligned to the community's needs.

Table adapted from interview with Richard Kyte & https://www.thrivingsouthland.co.nz/about-us/)

7.4 MISSION THREE: CREATING A WORLD LEADING AGRICULTURAL INSTITUTE

New Zealand has a very good university system, all eight are highly ranked internationally. The incentives created, when the sector was restructured and the 'market' brought in, resulted in many unintended consequences i.e. competition for students and competition between each other, the duplication of academic programmes, and competition for research projects. Over the years, the universities themselves, have taken steps to reduce competition and the government has tweaked polices to encourage collaboration. The NSCs helped return joint programmes to the sector, for example the A Better Start, E Tipu e Rea is led out of the University of Auckland, but has a research cohort based at the University of Canterbury.

Applied research was the biggest casualty of the reform period as discussed earlier. The PBRF is responsible for much of the disincentives towards applied research in the science sector. A new model would need to change the incentives, to make publishing for impact a consequence of good science, not the driver. How should change happen here in NZ? The Te Ara Paerangi Future Pathways green paper has signalled that the CRIs and Callaghan innovation are up for review. The outcome of this review should be a bold reorganisation of our science landscapes. The CRIs associated with the land-based industries i.e. Plant and Food Research, Ag Research, Manaaki Whenua - Landcare Research, and Scion should be rolled into a new entity, with Lincoln University at its centre. This would create a concentration for applied agricultural research and excellence. Each entity would keep their independence, but the cluster would be marketed as Lincoln University. Lincoln is largely still an applied university – the legacy of having an agricultural focus since its founding. Because of this, the commercialisation success of its research, compared to other universities, is outstanding (Prof Bruce McKenzie).

The mission is to become the leading food and agricultural university, creating the reputation that NZ agricultural science is world leading. International businesses, universities and researchers will want to partner with NZ scientists and businesses, with the scientific 'horsepower,' such an entity would create. It would attract world class researchers to NZ leading to world class research. This would be a 20-year project, that would need bi-partisan support to ensure the strategy is delivered. Lincoln University is the only place such a centre could be located as it has a singular focus i.e. land-based science. Massey University is too complex, it has multiple campuses, and extramural schools, likewise the big universities of Auckland, Otago and Canterbury are multi-focused, and this would create tensions from the outset. However, the new entity could include Massey's Palmerston North Campus creating a dual campus model.

The concept is to bring together, co-host, and co-locate, government research entities, agri businesses involved in R&D, levy paying organisations, and incubation hubs such as Lincoln Ventures, into a singularly focused agricultural educational entity. Creating New Zealand's version of Wageningen University and Research (see Table Twenty-Two Below). Co-location is fundamental for the fostering of the convergence of ideas and technologies. To understand consumer trends and emerging ideas, the entity would need to build applied engagement spaces – 'in market'. For instance, being based in the USA will build understanding of their consumers. If the new entity is just limited to NZ, who does it co-design for? NZers. Co-designing in NZ meets the need for no one apart from NZ and so the sales of the innovation overseas is another just transaction. There is precedent for NZ universities being in off shore markets, for example, the University of Otago runs a Doctor of Business Administration degree programme in China through the Shanghai Jiao Tong University (Supplementary information for Shanghai-based Doctor of Business Administration (DBA), 2021).

Wageningen University WUR – How did the smallest university in Holland becomes the No1 ranked agricultural university in the world? Where the best researchers in agriculture science want to work? By being the host to all the government research entities involved in primary sector and environmental science, all co located - under one umbrella with private sector research companies and business incubators. The institutes and entities remain separate; however, they are marketed to the world as Wageningen University WUR.

Table Twenty-Three: Wageningen University WUR

Wageningen University and Research, in Holland, has become a world-renowned centre of excellence for agricultural and natural sciences. In 2021, it was ranked the number one agricultural university and the 123rd best ranked university in the world (QS World University Rankings, 2021) & (The Academic Ranking of World Universities , 2021). The university has several research institutes collocated on its campuses and these carry out applied research commissioned by the government, by commercial businesses and with non-profit organisations. Collaboration between research institutes is common and actively encouraged with the university itself, and with other domestic and international partners. This co-location under the university umbrella has created a highly effective and collaborative applied research institution.

All modern organisations are going to have to keep innovating. How can the private sector gain access to new pools of knowledge that helps them fulfil their mission? E.g. synthetic milk. The deployment of innovation is through private enterprises into the market. The solutions are often coming from private enterprises through the application of applied research. The focus is not just the growers and the farmers – we need the whole supply chain involved to get the idea going. New Zealand has models for this, The Science for Technological Innovation Kia kotahi mai - Te Ao Pūtaiao me Te Ao Hangarau (SiFTI) does this very well, co-developing and deploying robotic technologies into the horticulture sector (see Table Seven). The Lincoln University cluster concept is a bolder, more ambitious version of this.

Bringing in private sector companies who commercialise technology is key. Having these companies on campus, creates the pathway for innovation to be commercialised. This enhances the opportunity to improve the absorptive capacity of NZ agribusinesses through linking them to the innovators and creating the opportunity for them to develop the 'translation skills. Private sector co-location would be the third component (the University, CRIs being the others). This would open a range of possibilities, from staff secondments, between institutes and the private sector, student internships, co-funding of science, and sponsorship of postgraduate studies. The commercialisation pathway for the science would be greatly enhanced. Research part-funded by businesses in universities has substantially higher economic impact (The Government and Science: The Research, Science and Innovation Report, 2021)

7.5 LIMITATIONS OF MISSION ORIENTATED INNOVATION

One of the guiding principles is Missions is to tilt the playing field in the direction of the common good. Who decides what the common good is? Many of the issues in the current science sector that have been highlighted in this report could easily emerge in Mission innovation. For example: lobbyists, pet projects, siloes and grantsmanship. If the government is to engage with citizens to determine the missions and their scope, what happens if what the citizens want, are different to the government? Citizens engaged in the process all have different risk profiles depending on their age, stage of life and economic background (Borone, 2020). These factors could potentially translate into conservative, low aspirational missions that could be achieved with the incremental science that we are already getting within the current system.

Top talent requires top renumeration, as well as autonomy. Is society prepared to pay for the talent? State service salaries are already a political 'hot potato'. Autonomy is a complex issue, it requires the ministers to step back from the mission and let it run its course, a great deal of discipline from the government is required. The money is the people's, not the government's and if it is spent on a mission that fails, then the government will be held to account - even though the government isn't responsible because it has given the mission autonomy. Is it unreasonable to expect a minister to bear responsibility and not have the ability to intervene? If they have the power, then this subverts the missions autonomy.

8. Conclusions

This report has looked at NZ's science system through the lens of agriculture. I wanted to know what the challenges were to improving innovation for our sector. Many of the challenges discussed in the pages above have been covered in countless reports and successive governments have tried to 'fix' the issues.

The current government has commissioned a review into the sector through its Te Ara Paerangi Future Pathways green paper and has signalled that the CRIs and Callaghan Innovation are likely to be reformed. This to me highlights the key issue – the report's terms of reference have been narrowed to just the CRIs and Callaghan Innovation, and excludes other research entities, the funds, the universities, and the government departments that run the sector- these are 'out of scope'. This will once again result in a piece-meal approach to solving the sector's issues and further reinforce the complexity trap – the unintended consequences. A potential outcome of the review is merging the land based CRIs in to one entity and, from everything I have heard and read in researching this project, I believe this would be a mistake. The outcome would be a huge organisation, top heavy with management and wracked with internal politics. The 'funder games' would be internalised, but no less brutal. For example, pastoral agriculture versus horticulture - pastoral agriculture already loses in the current system, imagine its chances when it is up against kiwi fruit and apples? Secondly, if it is already difficult for the private sector to engage with the CRIs, then how is it going to be improved in an even bigger organisation? How will businesses engage, and at what level -with the scientists or the managers, and what level of management would the relationships be held? This report proposed an alternative model, based on Wageningen University WUR, where the CRIs retain their independence, but are represented by the over-arching umbrella of Lincoln University. Under this scenario there is no need to compete with each other – there is a greater good. This is what the whakatauki "Nāu te rourou, nāku te rourou, ka ora ai te iwi" means in the context of this report: With your food basket and my food basket the people will thrive - it speaks to community, and a collaborative and strengths-based approach. It acknowledges that everybody has something to offer, and by working together, we can all flourish (Whakatauki Information sheet, n.d.).

Reforming the science system with narrow terms of reference will likely disappoint. The problems it is attempting to solve are from issues created outside the sector and stem from the fundamental building blocks of our modern market driven economic system. They are the result of bringing market forces into areas that should have been protected from them, and they are also the consequence of New Public Management Theory being applied in the operation of government. The NZ science sector reflects these factors, it is in the funding models, the un-productive competition, the publish or perish pressure on scientists, the 'light touch' of government in terms of direction, and the outsourcing of core competences to special interest groups whose incentives are to reinforce the status quo. Nothing will change until there is a shift from this paradigm towards a more collaborative form of government.

This report has suggested the Mission Economics framework as a way of transforming the sector. Missions are collaborative at their core and have been suggested as a framework that could help solve the big challenges of our time, such as, the climate crisis. Missions are the perfect merging of Western and indigenous perspectives and values, for example, Te Ao Māori , the Māori worldview. The EU Green Deal – a series of policy initiates aimed at improving societal and environmental outcomes uses a mission economics approach. The debate NZ needs to be having when tackling its big issues, i.e., climate change, child poverty, farming within limits, and biodiversity losses, is as much about the 'how' as to the 'why'.

8.1 FURTHER QUESTIONS FROM RESEARCH

1. How can agriculture give better direction/signals to the science institutions? Is there a place for sector governance to direct funding priorities in a pan sector sense?
2. Could there be a model for business to collectively fund science and innovation especially new technologies, but have different channels to market?
3. Long term projects should be the domain of the CRIs, shorter term projects better suit the universities as they align with PhD & Master's programmes. How could this be structured into the science system?
4. The funding system is broken, the MBIE and MPI funds need to be better coordinated and there need for a more supportive environment for the CRIs. What are alternative ways these funds could be structured?
5. Many NZ scientists experience job insecurity, this was a theme highlighted time and again. If science is to continue to be contestable, should it just be for the projects, and not staff involved?
6. What is the impact on foreign ownership on agriculture's ability to bring value back to New Zealand? Is there any analysis into what happens to value created through NZ originated value chains?
7. Does domestic innovation suffer through foreign ownership? Some industries have significant offshore ownership, for example the wine industry and the seed industry. Both these sectors have large multinationals from the same industry holding significant NZ investments. The logic would suggest that economies of scale would be exploited in the global parent, including in R&D. Investment and innovation is often concentrated near the headquarters of the global parent so is allowing the ownership of NZ companies to pass to off shore competitors really in this country's best interests

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10. Appendix One: Interviewee List

Richie Legge
Gretchen McFadden
Dr Gemma Payne
Dr Richard Sim
Amy Adams
Dr Christian Walsh
Blair Murdoch
Thomas Chin
Ian Lawry
Vanessa O'Neil
Rebecca Hyde
Alison Stewart
Craige Mackenzie
Craig Osborne
Lynda Cooper-Smith
Rob Lindores
Chris Denham
Leith Pemberton
Professor Eric Lyons
Nick Fitzpatrick
Collier Issacs
Tim Cutfield
Brendon O'Conner
Dr Phil Rolston
Malcolm Nitschke
Turi McFarlane
Professor Stephen Goldson
Steven Carden
Dr John Caradus
Elizabeth Hopkins

Dougal Fergusson
Professor Derrick Moot
Hon Ruth Richardson
Phil Weir
Hon Nathan Guy
Nick Pyke
Professor Bruce McKenzie
Mark Patton
Linda Cooper
Helen Celia
Angela Traill
Professor Sally Davenport
Professor Bruce McDonald
Mike Taitoko
Andrew Cameron
Kenneth Allen
Lloyd Mander
Dr Max Kennedy
Professor John Hampton
Professor Keith Woodward
Caroline Lambert
Hon Stephen Joyce
John McKenzie
Dr James Hutchinson
Professor Garth Barnaby
Richard Green
Dr Arthur Morley-Bunker,
Hon Pete Hodgson
Nicola Grigg
Dr Jim Wilkes

Andy McFarlane
Professor Gail Gillum
Ian Proudfoot
Matt Morrison
Hugh McDonald
Andy Elliot
Kate Scott
Richard Kyte
Brendan Brown
Michael Taylor
Chris Parsons
Damian Lynch
Professor Hamish Gow
Dr Derek Bartlem
James Parsons
Ben Anderson
Lynsey Stratford
Dave Eade
Daniel Ebb
Ben Mclauchlan
Shannon Harnett
Loshni Manikam
Nick Murney
Dr Geoff Smith