THE UNIVERSITY
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How co-innovation anticipates scaling: the modulating function of a co-innovation space

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PhD in Science and Technology Studies

The University of Edinburgh

2020

Abstract

Characterised as a mindset rather than method, co-innovation is a systems-inspired approach to agricultural innovation activity. The application of co-innovation is underpinned by guiding principles of collaboration, co-ordination and complementarity that together give rise to a so-called 'co-innovation space'. Building on this interpretation to address an identified knowledge gap, I explore the question of how co-innovation anticipates scaling. This consists of increased uptake over time of a novel product or process (outscaling) and creation of an enabling institutional environment (upscaling).

Consistent with an agro-industrial emphasis on productivity, early interpretations of agricultural innovation activity tended to describe a linear process of technology transfer, from researcher to farmer. In recent decades, however, increased emphasis on accommodating agricultural, environmental and social aspects has contributed to innovation activity resulting from complex interactions between diverse participants. Taking into account interactions between a novel technology or practice, supporting network of actors and prevailing institutions, Agricultural Innovation Systems (AIS) is among these more holistic interpretations.

Through a case study approach of the Primary Innovation Programme in the context of New Zealand's agri-food sector, I follow the in-field application of co-innovation. Despite this sector's history of fast-paced change, the combined challenge of improving environmental and social outcomes while increasing export-earnings from agriculture is unprecedented in its complexity and is prompting a search for alternatives to business-as-usual. Guided by AIS thinking and using the concept of anchoring as a proxy to understand dynamic scaling processes – the making and breaking of fragile technological, network and institutional connections – I argue that co-innovation anticipates scaling by holding space to allow for modulation of diverse temporal (from short-term to long-term), spatial (local to global) and institutional (conforming or reforming) perspectives. By facilitating their join-up in this way, co-innovation alleviates potential disconnects or mismatches associated with movement along and between scales that may otherwise hinder or block scaling processes.

Lay summary

The agri-food sector has become increasingly industrialised over the last one hundred years. The pursuit of higher outputs and lower costs being largely justified on the basis of producing sufficient affordable food to meet the needs of a growing world population. While providing a clear sense of direction to policy-makers, researchers and producers, this claim has, however, been increasingly undermined by persistent food inequalities within and between countries. At the same time, rising levels of concern about social, animal welfare and environmental impacts of more intensive farming activities have prompted questions about the sustainability of this approach.

The challenge for the sector is to not only address these concerns but also increase output to meet rising worldwide demand. Innovation activity is expected to play a vital role in helping the sector respond but it too is having to change. For example, by adopting a more joined-up approach that better accommodates diverse points of view. Co-innovation has been proposed as one way of meeting this requirement. Rather than a blueprint for action, it is based on guiding principles of collaboration and co-ordination. This framework allows sufficient flexibility to adapt to different contexts and to respond to changing circumstances and learnings as they emerge.

In this study, I explore how a co-innovation approach was received in a New Zealand context. With an agri-food sector that accounts for a relatively high proportion of economic activity, New Zealand is somewhat unusual among developed countries. Nevertheless, it faces the same issues as elsewhere. If anything, the sector's local, regional and national importance giving an added sense of urgency. In applying the principles of co-innovation in a New Zealand context for the first time, both barriers and opportunities were encountered. These contributed to learnings that usefully informed the project and, with the support of a wider network, the co-innovation process began to both yield results and gain acceptance. I argue, by creating and holding a dynamic space that encouraged interactions between diverse stakeholders around a shared concern, co-innovation helped to make these outcomes possible. Bringing stakeholders together in this way helped, on the one hand, to build a more rounded interpretation of the problem from multiple perspectives; and, on the other hand, to provide a catalyst for change by harnessing the energy of the group.

Acknowledgements

I wish to acknowledge the support of my supervisors. It is thanks to their time, energy and commitment that this research journey was possible, at times challenging, but always inspiring. In particular, Professor Laurens Klerkx, in the Knowledge, Technology and Innovation Group at Wageningen University for providing expert guidance with respect to the conceptual approach and, through constructive criticism, encouraging me to clarify my thinking through the written word. Dr Ann Bruce, Associate Director of Research in Science, Technology and Innovation Studies at the University of Edinburgh, for bringing challenge and support when they were needed and, by timely questioning, helping me to keep an open mind to new and emerging perspectives. Dr Neels Botha, Senior Scientist (retired) at AgResearch for sharing with me his local knowledge and contacts, providing an introduction to New Zealand that was of great value. Professor Andrew Barnes, Head of Department of Rural Economy, Environment and Society at SRUC, and Dr Chrysa Lamprinopoulou, Postdoctoral Research Fellow at the University of Edinburgh for providing me with the opportunity to undertake this project and for their ongoing encouragement.

Co-funded by SRUC in the United Kingdom and AgResearch in New Zealand, and with input from the Universities of Edinburgh and Wageningen, the project itself was an exercise in collaboration between institutes and across borders. For me, the support of colleagues, the spirit of co-operation and the warm welcome extended by the various departments was a source of inspiration throughout.

This work would not have been possible without the support of all the participants in New Zealand that so willingly shared their time. Specifically, Dr James Turner at AgResearch and the wider Primary Innovation team. Dr MS Srinivasan and colleagues at the National Institute of Water and Atmospheric Research (NIWA) for their expert assistance with the Water Use Efficiency project; and Rob Brazendale and colleagues at Dairy NZ for their generous help with the Heifer Rearing project.

This thesis is dedicated to the memory of my parents: to my father, Andrew, for his courage in the face of adversity; and my mother, Joyce, for her unwavering support.

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List of Abbreviations

AIS	Agricultural Innovation Systems
AKIS	Agricultural Knowledge and Information (latterly: Innovation) Systems
B+LNZ	Beef and Lamb New Zealand
CfC	Community for Change
CRI	Crown Research Institute
CWMS	Canterbury Water Management Strategy
Dairy NZ	Dairy New Zealand
ECan	Environment Canterbury
ESR	Environmental Science and Research
EU	European Union
FEP	Farm Environment Plan
FWB	Farm Weather Briefing
HR	Heifer Rearing project
II	Irrigation Insight
LEP	Land and Environment Planning Toolkit
MBIE	Ministry for Business, Innovation and Employment
MfE	Ministry for the Environment
MLP	Multi-level Perspective
MPI	Ministry of Primary Industries
NIWA	National Institute of Water and Atmospheric Research
NL	(The) Netherlands
NM	Nutrient Management project
NSC	National Science Challenges
NSSI	National Statement of Science Investment
NZ	New Zealand
PIP	Primary Innovation Programme
P+F	Plant and Food
R&D	Research and Development
RMA	Resource Management Act (1991)
SME	Small and Medium-sized Enterprises
TPP	Tomato Potato Psyllid project
TS	Timber Segregation project
TT	Technology Transfer
UK	The United Kingdom of Great Britain and Northern Ireland
WIL	Waimakariri Irrigation Limited
WUE	Water Use Efficiency project

Chapter 1: Introduction

Through case study of the early stages of a five-year project in New Zealand's agri-food sector, I explore how co-innovation anticipates scaling, with the former broadly interpreted as a collaborative response to a complex problem and the latter consisting of upscaling, creating an enabling institutional environment, and outscaling, increased take-up of a novel product or process. By better understanding how co-innovation is operationalised, my investigations lead me to focus on the functions of the so-called co-innovation space in facilitating movement along and between scales.

I begin this introductory chapter with a brief, personal reflection on my interest in researching agricultural innovation activities and this then sets the scene to consider how understandings have evolved over recent decades to accommodate a more joined-up, systems perspective. Against this background, I present my research objectives and an overview of my approach before mapping-out the thesis structure.

1.1 Research interest

My father, grandfather and great-grandfather all farmed and under their stewardship the family farm variously expanded and contracted. In common with many other farms, their decisions reflected the context of the time as well as being shaped, for much of the last one-hundred years, by a system predicated on the agro-industrial promise that the key to producing plentiful supplies of affordable food lies in harnessing technology. This gave them the confidence to invest, for example, in the farm's first steam engines and later, the first combine-harvester. It also gave licence to challenge the underlying relationship between farming and nature and, in order to best utilise the new machines, this saw hedges removed and a more open landscape replace the traditional patchwork of meadows. More recently, however, persistent food inequalities and adverse environmental impacts have prompted questions about the sustainability of the agro-industrial approach and triggered calls for a rethink. While innovation activities continue to have a vital role to play in enabling the sector to evolve, they too are having to adapt to new ways of operating that reflect the challenge of delivering multiple outcomes in response to complex problems. My research interest lies in contributing to a better understanding of their application.

1.2 Background to the research

The agri-food sector has a rich history of innovation activity. Guided for much of the last century by a dominant agro-industrial paradigm, the emphasis has been on the application of science and technology to increase output and improve efficiency. More recently, however, concerns stemming from a better understanding and rising awareness of the environmental consequences of industrial farming are prompting change in favour of increased outputs with improved social and environmental outcomes. Established interpretations of agricultural innovation activity as a linear process of technology transfer from researchers to producers have, at the same time, been reappraised in light of growing recognition of the value of a wider, systems perspective that better accommodates complex and sometimes contested interactions.

1.2.1 Shifting paradigms

Coming to prominence after the Second World War, the agro-industrial paradigm has been the defining narrative of agricultural development in the second half of the twentieth century, informing the direction of travel and guiding the behaviour of actors (Bonney et al., 2007). At a time when food was in short supply and distribution networks were in disarray, the original premise of harnessing technology to deliver science-driven improvements in productivity resonated with policy-makers and crucially, sent a clear signal to producers (Lang and Heasman, 2000). Over time, associated practices became embedded as the accepted rules-of-the-game, further cementing the dominant position of agro-industrialism (Marsden, 2013).

This dominance drowned-out early concerns that industrial farming was out of step with the natural environment (for example, Rachel Carson's Silent Spring, 1963). More recently, however, as the consequences of an agro-industrial approach have become more widely understood and appreciated so policy-makers, producers and consumers alike have been prompted to question the logic of an ongoing pursuit of industrial farming (Gaitán-Cremaschi et al. 2019; Pant, 2016; Duru et al., 2015). The response has been described in terms of "weak ecological modernisation" of the agro-industrial approach (Horlings and Marsden, 2011, Page 444) although it remains to be seen whether or not this is sufficient or if a paradigm-shift in favour of

an agro-ecological alternative[1], for example, better meets the need for increased production and improved environmental outcomes (Lang and Heasman, 2015).

1.2.2 Context of agricultural innovation

Farmers have long been accustomed to adapting in response to and in anticipation of change (Hoffmann et al. 2007; Roep and Wiskerke in Wiskerke (ed.), 2004) with evidence of novel or innovative agricultural practices stretching back to some of the world's earliest civilisations (van der Veen, 2010).

Farming is distinct from other sectors, given the large number of small producers; each farm's unique mix of climate, soil, topography, latitude, altitude and distance from market; the influence of external variables such as weather; and, the change-ability of pests and diseases (Pardey et al, in Hall and Rosenberg (eds.), 2010). At the same time, the sector is confronted by diverse issues[2] that together give rise to an over-arching challenge of such complexity (Foresight Report, 2011) that it has been described as having all the characteristics of a so-called wicked problem[3] (Struik and Kuyper, 2017; Waddock, 2013). That is, a problem that cannot be resolved but must instead be "re-solved – over and over again" (Rittel and Webber, 1973, Page 160).

These factors shape innovation activities in an agricultural context. For the context-specific requirements of fields, farms and regions to inform wider agricultural innovation activity and to avoid the risk of potential "knowledge gaps" (Douthwaite et al., 2001, Page 835) between researchers and stakeholders, requires that the global

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[1] From its roots in agronomy and ecology, the agro-ecological paradigm has broadened to encompass "interactions between plants, animals, humans and the environment" (Dalgaard et al., 2003, Page 48). Variously understood as discipline, movement and practice (Wezel et al., 2009), it has been argued (Levidow et al., 2014) that for the transformative potential of agro-ecology to be realised these strands need to be linked via knowledge sharing, interdisciplinary working and social pressure for change.

[2] The Foresight Report (2011) identifies six key challenges: i) feeding an increasing world population; ii) changing tastes and demand; iii) evolving governance of food systems; iv) climate change impacts; v) depletion of finite natural resources; and vi) a changing ethical stance among consumers.

[3] Waddock (2013) defines wicked problems: as ill-defined and subject to multiple interpretations; with various possible responses but no definitive solution; actions liable to trigger unforeseen reactions; unique, thereby limiting the usefulness of previous experience; and requiring wider systems change.

and local are joined-up and collaborating in what Hall (2009; Page 224) has described as an "interconnectedness of scales" – not only to stimulate innovation activity but also to catalyse wider, systems change (Dentoni et al., 2012).

1.2.3 Evolving agricultural innovation thinking

In recent decades, as shown in Figure 1, below, agricultural innovation thinking has evolved to accommodate this interconnectedness (Douthwaite and Hoffecker, 2017; Lamprinopoulou et al., 2014; Klerkx et al., 2012; Röling, 2009; Biggs, 1990).

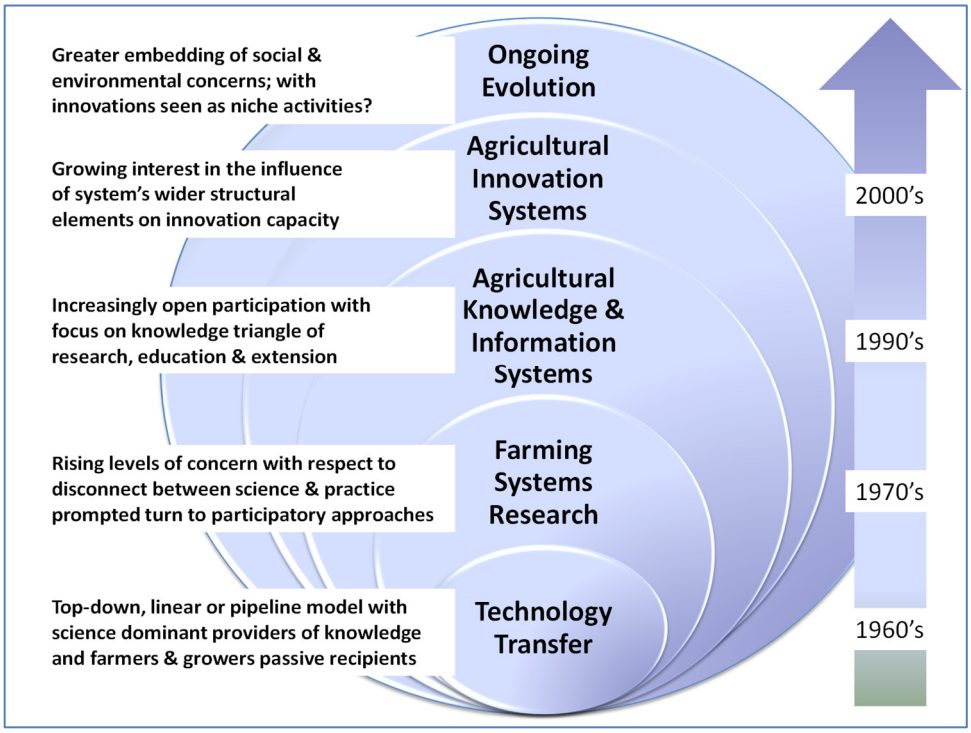

Figure 1 Shifting perspectives of agricultural innovation (adapted from Klerkx et al., 2012)

The Technology Transfer (TT) approach of the 1960s, the Farming Systems Research (FSR) work of the 1970-80s, the development of Agricultural Knowledge and Information Systems[4] (AKIS) and, later, Agricultural Innovation Systems (AIS) have all contributed to an evolution in agricultural innovation thinking (Klerkx et al., 2012). This process is ongoing with social and environmental concerns becoming

[4] Latterly Agricultural Knowledge and *Innovation* Systems (Hermans et al., in SOLINSA, 2013)

more embedded (Hall, 2017; Meynard et al., 2017) and increased interest in understanding innovation activities as a so-called niche (Knickel et al., 2009).

In the 1960s, agricultural innovation thinking was dominated by the TT perspective, its promise of technology-driven solutions resonating with the prevailing, and relatively uncontested, agro-industrial paradigm of the time (Darnhofer et al., 2012). The diffusion of innovations tended to be understood in terms of a linear progression, or pipeline, from invention to innovation to implementation (Crivits et al., 2014) with little allowance for feedback. Although it still has its advocates and its applications, TT has increasingly been eclipsed by recognition that agricultural innovation is an altogether messier process of mutual learnings, false-starts and occasional breakthroughs (Moors et al. in Wiskerke (ed.), 2004). A point of view that reflects a wider interpretation of innovation activities as systemic processes (Lundvall et al., 2013; Lee et al., 2012; Chesbrough, 2003; Rogers, 1995) involving complex interplay between technology and society (Rip and Kemp, 1998).

Despite the appeal of central source models, such as TT, for their relative simplicity, a limited capacity to accommodate interactions between users and researchers was giving rise to growing unease (Biggs, 1990). To address this disconnect (Collinson (ed.), 2000), in the early 1970s, FSR effectively recast producers as active participants in the innovation process rather than passive recipients of its outcomes (Koutsouris, 2012). New avenues of research and practice were opened-up, to such an extent that by the mid-1980s, the number of different interpretations of FSR along national and disciplinary lines[5] was prompting calls for a new terminology on the basis that "research with a Farming Systems Perspective" would better reflect the diversity of the field (Merrill Sands, 1986, Page 100).

By the 1990s, increased interest in the so-called 'knowledge triangle' of research, education and extension (Esposti, 2013; Hermans et al., in SOLINSA, 2013) was

[5] Merrill Sands (1986) six types of FSR: Farming System Analysis; Farming Systems Adaptive Research; Farming System Component Research; Farming Systems Baseline Data Analysis; New Farming Systems Development; Farming Systems Research & Agricultural Development.

informing work on AKIS. Elsewhere, however, the focus was starting to shift in response to increased levels of interest in understanding a system's underlying innovation capacity. This highlighted the constraints of AKIS (van der Heiden et al. in Langeveld and Röling (eds), 2006) and contributed to development of AIS. The latter, by extending the boundaries to better encompass the structural elements of the innovation system – policy, infrastructure and institutions – providing the more holistic perspective required (Klerkx et al., 2012; Spielman and Birner, 2008).

In moving towards a systems perspective, the focus shifts from the decision-making of individuals to wider interactions between diverse stakeholders with a shared interest in "making innovation work" (Basu and Leeuwis, 2012, Page 35). This more rounded interpretation better accommodating "social and organisational arrangements, such as new rules, perceptions, agreements, identities and social relationships" (Leeuwis and Aarts, 2011, Page 23). In particular, AIS thinking understands innovation as emerging from complex interactions, or co-innovation processes (Klerkx and Nettle, 2013), between technological, social and institutional dimensions. Embedded in this interpretation, and echoing Rip and Kemp's concept of finding a "configuration that works" (1998, page 330), is scaling where this refers to the search for alignment between the evolving technology, developing knowledge and institutional environment (Wigboldus et al., 2016). However, whereas a linear, TT perspective is transparent with respect to scaling, in terms of the diffusion of innovations (for example, Rogers, 1995; Ryan and Gross, 1943), an AIS perspective is more opaque (Crivits et al., 2014). How an AIS-inspired approach, such as co-innovation, anticipates scaling is, therefore, not well understood (Botha et al., 2017).

1.3 Research aims

My objective is to address this knowledge gap by better understanding the interactions between co-innovation and the dynamic processes of scaling. In particular, by asking:

1. What is understood by co-innovation?
    a. how are the principles and practice of co-innovation understood?
    b. what is the evidence that co-innovation anticipates scaling?
2. How is co-innovation operationalised?
    a. what are the associated challenges and opportunities?
3. How does applying a co-innovation inspired approach anticipate scaling?
    a. of the co-innovation approach?
    b. of emerging innovations?

1.4 Outline approach

I explore the application of co-innovation through case study of the Primary Innovation Programme (PIP) in New Zealand (NZ). Data is primarily based on 47 semi-structured qualitative interviews, mainly conducted in the 12 months between October 2014 and October 2015 – but extending to September 2017 to allow for inclusion of the project's closing workshop. Informed by Agricultural Innovation Systems (AIS) thinking, I investigate co-innovation processes, associated challenges and opportunities, and interactions with the dynamics of scaling.

New Zealand is a country with a proud agricultural heritage that informs national identity (Gluckman, 2015). It has a vibrant agri-food exporting sector built on a commitment to quality and promoted around the world on the image of 'clean and green New Zealand' (Saunders et al., 2016). Market reforms implemented in the 1980s that largely dismantled farming subsidies prompted root-and-branch restructuring of the sector (Smith and Montgomery, 2004). Many sought to farm their way through, intensifying their practices and converting to higher profitability enterprises, often dairy (Haggerty et al., 2009). NZ's primary sector now faces a dual-challenge; delivering increased export earnings and addressing the social and environmental consequences of these changes (Duncan, 2017).

Although innovation activity is expected to play a vital role in enabling NZ's agri-food sector to respond to this challenge, the capacity of the prevailing innovation system to support the process has been questioned (Turner et al., 2015). This is not to doubt NZ's track-record of successfully developing new products and markets but rather in recognition of the urgency and complexity of the combined challenge of increasing outputs and improving social and environmental outcomes that has all the

characteristics of a so-called wicked-problem (Doole and Romera, 2015). Among developed nations, NZ is unusual for the relative importance of agriculture to the national economy and, in the absence of producer subsidies, the exposure of farmers to global market forces (Vitalis, 2007). In other respects, however, the challenge faced by NZ's agri-food sector mirrors that faced in other developed economies, making NZ's experience of co-innovation of potentially wider interest.

1.5 Thesis overview

This thesis proceeds as outlined in Figure 2, below. In the main body of the report, a short intermezzo provides a 'breathing-space' between chapters.

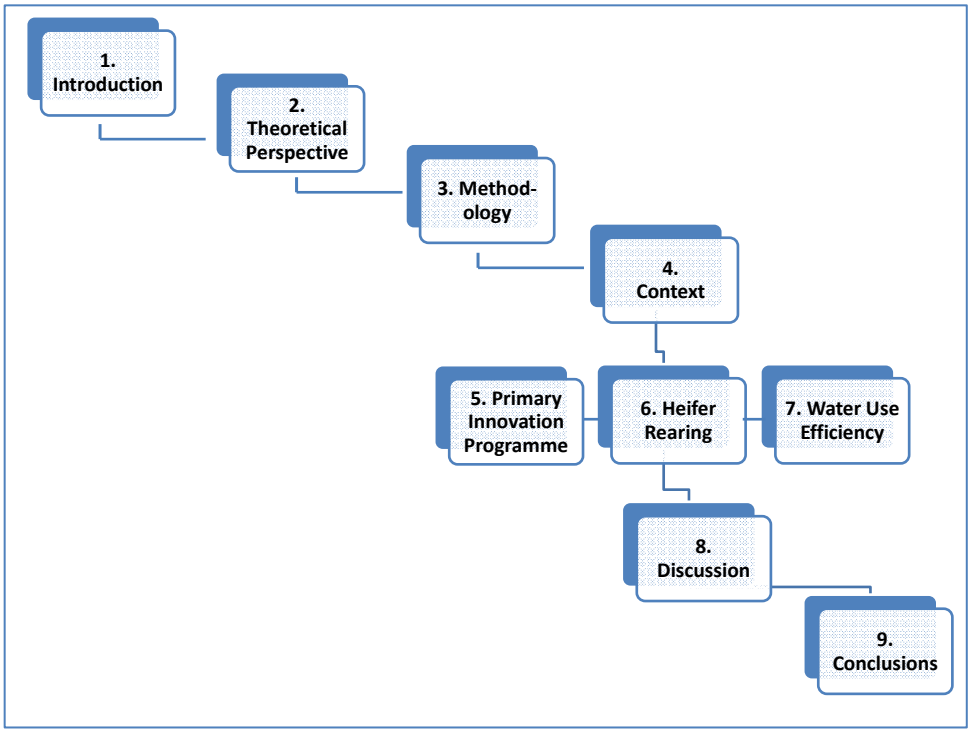

Figure 2 Overview of thesis chapters

Theoretical discussion in Chapter 2 outlines the evolution of AIS thinking and the development of the co-innovation approach. Scaling is introduced as a dynamic process of upscaling and outscaling where the former describes activities to create conditions conducive to change and the latter refers to the increased take-up of a novel product or process across regions, communities or sectors. In the absence of a theory of scaling, the concept of anchoring is presented as a proxy to help frame

understanding of these complex dynamics and to guide my enquiry. This leads in to Chapter 3 and detailed discussion of methods. In this chapter, I reflect on the rationale for a case study approach and provide details of data collection and analysis. Since the fieldwork was conducted in NZ, Chapter 4 provides an overview of the country's agri-food sector, its rapid development over the last one-hundred years and, in particular, the transformative changes of the 1980s. In all of this, I aim to convey New Zealanders' 'can-do' attitude and spirit of self-reliance that reflect, in part, the country's remote location, keen sense of history and proud farming heritage that, in turn, shape their interpretation of the principles and practice of co-innovation.

Analysis of empirical data provides the basis for Chapters 5, 6 and 7. The Primary Innovation Programme (PIP) is the focus of Chapter 5 and, in particular, upscaling of the co-innovation approach as it is applied in a NZ context for the first time. In Chapter 6, Dairy Heifer Rearing, the focus shifts to outscaling of the co-innovation approach as I trace its in-field application. While in Chapter 7, scaling of the approach meets scaling of an emerging innovation in the Water Use Efficiency study.

The discussion in Chapter 8 draws together the cross-case findings from the empirical chapters to inform my conclusions, Chapter 9, and consideration of their practical implications with recommendations for future investigation.

1.6 Closing remarks

Over recent decades, the case for more industrialised and globalised agriculture has been undermined by persistent food inequality and occasional price volatility. At the same time, an improving understanding of how farming practices are impacting on the natural environment has added weight to calls for a more equitable balance to be struck between agricultural activities and the natural environment. In response, the sector has tilted away from the agro-industrial and towards the agro-environmental. With the certainties attached to the former, productivist approach being replaced by the uncertainties of the latter, new ways of operating are being explored. In the process, the prevailing logics of business-as-usual are being challenged to adjust.

In agricultural innovation activity, accommodating the often messy and multi-faceted challenges of post-productivism is outwith the capacity of established, linear models of technology transfer, prompting growing interest in systems thinking. This has contributed to increased application of participatory approaches, bringing together different disciplines and connecting researchers with diverse stakeholders in novel, and sometimes uneasy, combinations. Definitions have been sharpened[6] to more clearly distinguish between different levels of collaboration while work is ongoing to better understand the practicalities of collaboration[7]. More specifically, others have studied the influence exerted by the fluid dynamics of power and trust between actors (for example, Wittmayer et al., 2017; and Avelino and Wittmayer, 2016).

Various forums exist to provide support to practitioners working in this area, such as Integration and Implementation Insights (i2insights[8]), a community resource run by the Australian National University. Among contributing authors, Katrin Prager (2016) has commented on the rising popularity of "co-creation and related terms like co-design, co-production, co-construction and co-innovation" leading her to argue that effective participation is a pre-condition for each and all of these activities. Sometimes these terms are applied with respect to specific sectors, such as co-design in the health sector; and sometimes they are used interchangeably (Voorberg et al., 2015). Given its particular use and application in the agri-food sector, my focus is on co-innovation and by exploring how operationalising a co-innovation inspired approach anticipates scaling, I am contributing new knowledge to the discussion in this area. In the next chapter, I elaborate on my theoretical perspective.

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[6] For example, informed by an extensive literature review, Bernard Choi and Anita Pak (2006) argue that multidisciplinarity combines knowledge and expertise from various disciplines, boundaries between disciplines are, however, observed and maintained; interdisciplinarity bridges these boundaries to encourage interaction between disciplines; while transdisciplinarity seeks to transcend differences in pursuit of a more holistic approach. In this way, the terms "multidisciplinary, interdisciplinary and transdisciplinary are additive, interactive and holistic, respectively" (Page 351).

[7] Including, for example, Lyall et al.'s Interdisciplinary research journeys: practical strategies for capturing creativity (2011).

[8] i2insights: https://i2insights.org/ - building research resources for action-oriented team science.

Chapter 2: Theoretical perspective

This chapter, informed by Agricultural Innovation Systems (AIS) thinking as outlined in the introduction, begins by describing innovation activities as a coming together of the concepts of hardware (technology or practice), software (supporting network) and orgware (institutional context). Co-innovation is then introduced as a means of facilitating this interaction, not least by providing the space necessary to bring together diverse actors around a common interest in addressing a complex, or wicked-problem. The focus then turns to the search for alignment between an emerging technology, supporting network and prevailing institutions that drives its evolution, or scaling. The chapter ends by outlining the concept of anchoring as a guiding framework to assist with interpreting the dynamics of scaling, setting the scene for the methodological discussion in the chapter that follows.

2.1 Innovation through interaction

An AIS perspective understands innovation processes as open and opportunistic. At its core are interactions between actors brought together[9] by a shared interest in a common problem, informed by a wider context of history, culture and politics (Pant et al., 2012). In this way, different perspectives and logics become connected across multiple levels (Hermans et al., 2013). Subsequent interactions are sustained by the flow of knowledge, skills and resources (Klerkx et al., 2012; Spielman and Birner, 2009; Spielman et al., 2008), enabled or inhibited by relevant institutions (Foran, 2014; Kilelu et al., 2013) and guided by intermediaries (Kivimaa et al., 2019).

2.1.1 Institutional awareness

An institutional awareness informs AIS-thinking. Understood as comprising hard institutions, in the form of formal laws, governance and regulations; and soft, such as accepted norms, logics and behaviours (Smink et al., 2015) and sometimes described collectively as ‘orgware’ (Smits, 2002). Institutions are responsive to context with

[9] Sometimes brought together through the activities of intermediaries such as ‘innovation brokers’ with the ability to make connections between otherwise diverse actors (Hermans et al., 2013)

Cleaver (2002) using the concept of 'institutional bricolage' to describe how institutions respond to influences at the local level. For van Mierlo and Totin (2014) the relationship between institutions and context is similar to that between a live performance of a play and its audience wherein, despite the same cast, lines and props, no two performances are ever quite the same. From an AIS perspective, innovation activity extends to working for the reform[10] of prevailing institutions (Klerkx et al. 2010; Röling, 2009; Spielman et al., 2008; World Bank, 2006) with a view to facilitating an "enabling environment of change" (Douthwaite et al, 2003, page 247) or "institutional readiness" (Webster and Gardner, 2019, page 1).

2.1.2 Search for alignment

Hardware and software – as distinct from the hard and soft institutions making up orgware – refer, respectively, to a novel technology or practice; and to the mutual learnings and diverse knowledge of relevant actors (Kilelu et al., 2013). From an AIS perspective, innovation activities involve an ongoing search for alignment or balance between orgware, hardware and software driven by interaction between diverse actors (Hermans et al., 2016; Leeuwis and Aarts, 2011). This diversity gives rise to difficulties, not least in bridging scientific and practitioner knowledge (Koutsouris, 2012), that makes collaboration between multiple actors with different perspectives of a problem and sometimes contrasting views on how best to respond, a messy process of negotiation and compromise (Elia and Margherita, 2018, Campbell et al., 2015). Co-innovation offers a way of facilitating this process.

2.2 Interaction through co-innovation

Inspired by systems thinking, co-innovation describes context-specific collaboration as an approach to tackling complex or wicked-problems. It seeks an alignment of mind-sets among diverse actors united by a shared interest in a common problem and working together towards a response (Klerkx and Nettle, 2013). The process is

[10] It has been argued that the pursuit of change in prevailing institutions may benefit from the lobbying activities of so-called 'institutional entrepreneurs' (Hermans et al., 2013; Battilana et al. 2009) that Westley et al (2014) identify as requiring a well-developed sense of political awareness as well as cultural, social and resource mobilisation skills.

iterative and not without tension, based on negotiation, informed by mutual learning, and alert to the wider, institutional setting (Turner et al. 2015; Dogliotti et al. 2014).

2.2.1 Interpretations of co-innovation

From an Innovation Systems perspective, Rossing et al (2010) described "the three cornerstones of co-innovation" (Page 406) as dynamic project monitoring, systems approaches and social learning. More specifically: i) dynamic monitoring refers to close to real time, as opposed to ex-post, monitoring and evaluations that enable findings to inform project development, in-line with van Mierlo et al.'s (2010) concept of "reflexive monitoring" (Page 333); ii) systems approaches describe the within-farm enterprise dynamics, and the dynamics between farms and the wider operating, or institutional context; and iii) social learning highlights interactions between relevant actors. From a value-chain perspective, Lee et al. (2012) saw co-innovation as an extension of open innovation[11] with an emphasis on "engagement, experience, and co-creation" (Page 824) to drive shared-value. Bringing together innovation systems and value-chain thinking, Bitzer and Bijman (2015) described co-innovation as activities "that combine technological, organisational and institutional changes and that encompass different actors in and around the value chain" (Page 2182). With changes at one level supported, as required, by changes at other levels, co-innovation becomes a multi-actor, multi-dimensional and multi-level process.

More widely, from their study of the implementation of a decision support system in the Italian viticulture sector, Rossi et al. (2014) described co-innovation as a process of "close collaboration with external consultants, end-users, and stakeholders in order to address their needs" (Page 98). In Borgen and Aarset's (2016) study of Norwegian pig-breeding co-operatives, co-innovation was used to reflect a sharing of benefits. While in the context of the Tasmanian salad sector, Bonney at al. (2007)

[11] Chesbrough (2003) described a "paradigm shift" (Page 33) from the linear, closed innovation approach with its clearly delineated boundaries between research and development functions; and the increasingly porous and subsequent breaking down of these boundaries in open innovation that allows organisations to tap-into "a landscape of abundant knowledge" (Page 38). In practice, organisations exist on a continuum from those operating under entirely closed to fully open conditions.

drew a distinction between product, process and service innovations within firms; and co-innovation between firms; and, for their study of family farming in Uruguay, Dogliotti et al. (2014) understood co-innovation as a process of interactions and collective learnings. In practice, co-innovation is all of these things; identification of common needs, creation of shared benefits, leveraging of competitive advantage, interactions and mutual learning – a guiding framework rather than off-the-shelf approach with the response tailored to the needs of the problem (Klerkx et al., 2017).

2.2.2 Principles of co-innovation

Boyce et al. (2016) have described co-innovation as a live process that evolves and adapts over the lifetime of a project from early stage co-design activities (problem scoping), through mid-stage co-development (monitoring and response development) and later-stage co-innovation (implementation and evaluation). They identify five core principles as being to: i) engage with stakeholders; ii) focus on the problem; iii) assemble the required team; iv) share emerging findings; and v) monitor and reflect.

The term "triple-co" was coined by Bitzer and Bijman (2015, Page 2194) to reflect their understanding of co-innovation as a collaborative, co-ordinated and complementary approach. More specifically: i) collaborative to describe the coming together, over time, of a diverse and evolving group of stakeholders variously contributing knowledge, skills and resources to the process and deriving learnings from their involvement; ii) co-ordinated across a range of levels, such as the farm and the wider problem-domain, with stakeholders working together towards not only a shared vision for change but also building trust and an equitable balance of power between an otherwise diverse group; and iii) complementary in terms of seeking to create favourable conditions for change by recognising that innovation in any one dimension, for example technical, may require change in other dimensions, for example organisational and/or institutional, mindful of the uncertainties that accompany any move away from the familiarity of a 'business as usual' approach. Given that co-innovation activities are informed by context (Klerkx et al., 2017), this might, arguably, be added as a fourth 'co', as illustrated in Figure 3, below.

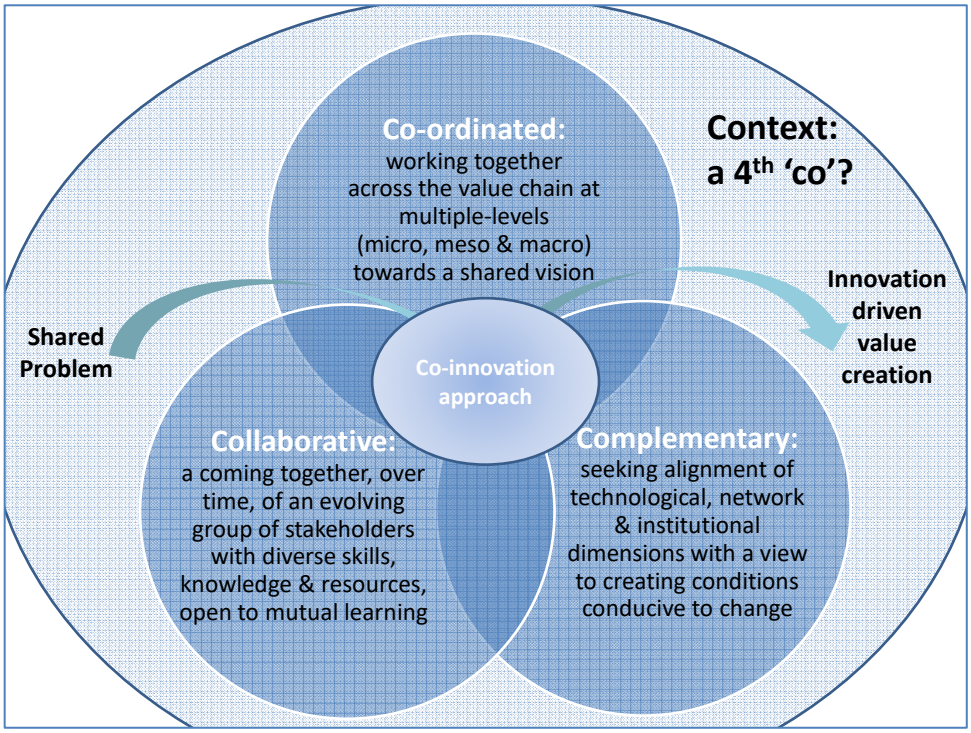

Figure 3 Co-innovation conceptualised as a 'triple-co' (adapted from Bitzer and Bijman, 2015)

Drawing on Nederlof et al's. (2011) nine principles for a collaborative approach to innovation[12] and loosely grouped around themes of group dynamics, self-reflection and a problem focus, Coutts et al. (2017) identified a so-called "co-innovation space" (Page 101), as shown in Figure 4, below. Group dynamics emphasises an inclusive approach that values knowledge in all forms and from multiple sources while recognising that relationships may take time to develop; self-reflection highlights the value in an open approach not only to encourage mutual learning and to develop trust between diverse participants but also acknowledging tensions as part of this process; while a problem focus allows time to reach a thorough understanding of the issue(s) and provides a reminder of the benefit of maintaining a shared vision, recognising that this is likely to evolve as the project progresses and external factors evolve. The more of these principles present and the stronger they are perceived to be by

[12] Nederlof et al. (2011) identified nine main principles of an agricultural innovation system as: i) the application of knowledge; ii) an interactive process; iii) sustained by relationships in various forms; iv) actors and roles evolve as the process unfolds; v) accepted norms exert a powerful influence on propensity to change; vi) policy/regulatory support a potential enabler of change; vii) demand-side influences need to be taken into account; viii) a willingness to change; ix) value in all knowledge.

participating actors then the greater the likelihood of realising a co-innovation space and delivering desired outcomes (Coutts et al., 2017).

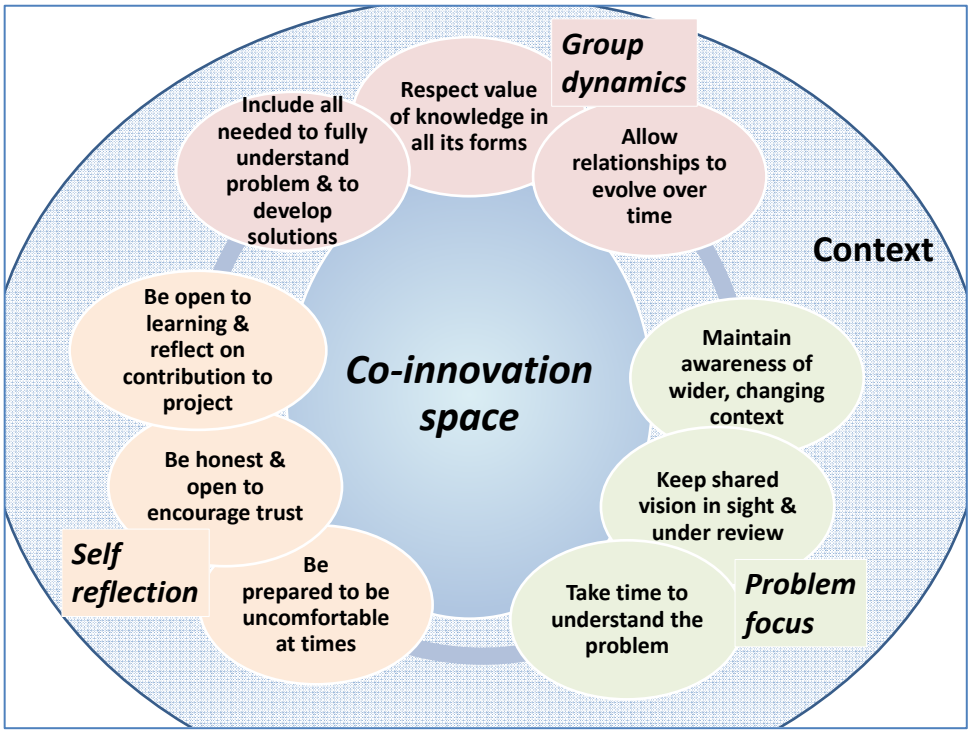

Figure 4 Co-innovation space (adapted from Coutts et al., 2017; and Bitzer and Bijman, 2015)

Coutts et al. (2017) drew on the concept of 'learning spaces' from education and software development but there are parallels too between their conceptualisation of 'co-innovation space' and the intersection of Bitzer and Bijman's (2015) 'triple-co' in that they are both providing a relatively protected forum for development activities as well as facilitating a boundary-bridging function. The latter entails a mix of "art and tension" (Betzold et al., 2018, Page 873) that, in recent decades, has prompted increased interest with a view to optimising the artistry and mitigating the tensions at the interface of science with policy and knowledge with action (Clark et al., 2011).

2.2.2.1 Boundary activities

Putting any collaboration into practice has potential to be problematic. Kuenkel (2015) has noted, for example, the tendency for collaborations to over-emphasise their function of resolving a problem with too little regard for their functioning as a

group[13]. Bringing together multiple stakeholders from different backgrounds with diverse priorities and varying perspectives is no less problematic and recognised as an "extremely difficult" task (Carr and Wilkinson, 2005, Page 256). The challenge of building a *lingua-franca* – a 'system for mutual understanding' (Concise Oxford Dictionary, 1995) – is exacerbated by boundaries that range from the impermeable, blocking exchange of knowledge, to the overly-permeable[14] and diluting the value of knowledge (Clark et al., 2011). Boundary work describes the various activities addressing this challenge, facilitating the exchange of knowledge via a "mediating space" (Kivimaa et al., 2019, Page 1062). This requires: i) the active engagement of participants from 'all sides' of the debate; ii) that participants' contributions are acknowledged and that they are accountable for their contributions; and iii) outputs that are sufficiently robust to withstand all-round scrutiny (Clark et al., 2011).

Boundary 'bridgers' – objects, organisations, or individuals – share an ability to "link disparate communities, facilitate communication among them and provide the mechanisms necessary for mediating disputes" (Bidwell et al., 2013, Page 610). They tend to be associated with a "mediating" (Cash, 2001, Page 432) or "stabilising" (Pohl et al., 2010; Guston, 1999, Page 88) function at the interface of research and policy, helping participants to "know policy issues differently" (Feldman et al., 2006, Page 96). By bridging different levels, such as the "local, state, and national" (Cash, 2001, Page 431), and extending to the wider "research-stakeholder interface" (Schut et al., 2013, Page 92) they may also reach more widely.

In their study of boundary activities in increasingly open innovation contexts, Fleming and Waguespack (2007, Page 166) contrasted the roles of 'innovation broker' and 'boundary spanner' noting that "brokers can span boundaries, but not all boundary spanners' broker." They furthermore contrast a perception of brokers as

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[13] Kuenkel (2015) identifies six, interlinked dimensions that contribute to effective collaborations: i) a shared vision; ii) step-by-step engagement to encourage trust; iii) innovation to maintain momentum; iv) mutual respect; v) recognition that tensions are a source of energy; and vi) a systems outlook.

[14] Parmentier and Mangematin's (2014) study of innovation activity in the music sector showed value in a managed exchange of knowledge across permeable boundaries between a firm and its wider users.

"calculating and politically savvy operators" with boundary spanners the "well respected guardians" that contributes to distrust of the former and engenders trust in the latter. With respect to boundary objects, Star and Griesemer (1989) have argued that they need to be "…plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites." (Page 393). If and when boundary objects stabilise they may be understood as 'standardised packages' providing "practical and operational details with sufficient clarity to allow all stakeholders to understand what each needs, and is allowed, to do" (Franks, 2016, Page 62). From Guston's (1999) original perception of boundary organisations[15], they are characterised by: i) provision of a space for "the creation and use of boundary objects or standardized packages"; ii) the active participation of "principals and agents, or scientists and non-scientists"; and iii) a "mooring to mutual interests and distinct lines of accountability" (Page 106).

Gustafsson and Lidskog (2018) noted that the approach has since been variously critiqued for its: i) overly static theoretical assumptions; ii) insufficient account of the continually changing nature of the organisations and the relationships between them; iii) lack of sensitivity to science and policy boundaries that are increasingly blurred; iv) insufficient account of potentially skewed and shifting power relationships; and v) over simplification of situations that more typically involve multiple boundaries across multiple scales. Nevertheless, in their study of boundary organisations in the context of environmental governance, they find that the term is of value not just as a label but 'performatively' (Page 8): informing an organisation's identity, conferring legitimacy and providing a foundation for interactions.

In the agri-food sector, Klerkx and Leeuwis (2008) have referred to "multiple goal boundary organizations" (Page 186) to reflect their interpretation of increasingly complex activities involving multiple stakeholders across multiple boundaries and Tisenkopfs et al. (2015) have characterised the role of boundary organisations in

[15] More recently, an increased level of interest in collaborative activities between boundary organisations has prompted investigation into so-called boundary chains (e.g. Kirchhoff et al., 2009).

"joint action formation or alignment in practices" (Page 14). For Carr and Wilkinson (2005), their core value lies in the potential to provide "an interrogative service, rather than an interpretive service" (Page 257) that functions against the increasingly blurred boundaries of the agri-food sector where levels are "neither completely global nor local" (Page 256) and the linear and participatory intersect.

2.2.3 Implementation of co-innovation

From their study[16] of natural resource management in a developing country context, Clark et al. (2011) found boundary activities with input from multiple communities that aimed to support decision-making outcomes gave rise to a level of complexity that made it difficult "to shape the boundary work needed to implement it successfully" (Page 4). Likewise, Klerkx and Nettle (2013) connected co-innovation to a range of "implementation challenges" (Page 75) including "different actors' diverging strategic and vested interests, inherent cultural differences between actors, different planning horizons, different incentives and accountability mechanisms" (Botha et al., 2014, Page 220). While Systems Analysis tools, such as models and simulations may be of value in helping diverse participants find common ground, the complexity of some problems is such that multiple tools and expert facilitation may be needed[17] (Ditzler et al., 2018).

The cast of participants is fluid rather than static as the collaboration forms and reforms over time, in response to an evolving understanding of the problem. This can give rise to uncertainty and unpredictability and may challenge existing perceptions of roles, blur established responsibilities and require new interactions, for example between producer and consumer, public and private sector. For Bremmers and Sabidussi (2009), co-innovation is largely defined by this

[16] Clark et al. (2011) proposed a matrix to distinguish between boundary activities where the source of knowledge is personal expertise, single or multiple communities (from less to more complex) and use of knowledge supports enlightenment, decision-making or negotiation (from less to more complex).

[17] In addition, Ditzler et al. (2018) recommended that: tools are designed to cater for a wide-range of users; incorporate user feedback in their development; and are considered more explicitly by researchers in order to build a more detailed understanding of their application in different contexts.

"cooperative effort between public sector/research institute and private organizations" (Page 29). Furthermore, given their flexibility and ability to mobilise a rapid response, they go on to argue that small and medium sized enterprises (SMEs) have an enabling role to play in the co-innovation process that, by virtue of its structure, should make the agri-food sector especially well-suited.

To operate effectively, listening, learning, negotiating and communication skills are needed (Daane, 2010, Page 78). At the same time, in order to maintain the engagement of and to prevent misalignment between multiple participants with diverse "needs and preferences" (Bitzer and Bijman, 2015, Page 2194) requires an absolute commitment to being open to knowledge from many sources and in many forms. Drawing on the in-field experience of a number of co-innovation projects, Botha et al. (2017) identified shared uncertainties accompanying the approach. For example, researchers and stakeholders are required to adapt to new and unfamiliar roles; adjustment of monitoring and evaluation processes to accommodate diverse impacts; an emergent research design that does not always conform to funders' established reporting and control structures. Nevertheless, where co-innovation has been applied to good effect, this is characterised by outscaling of an innovation across a target area and upscaling in terms of facilitating an institutional fit (Albicette et al., 2017; Dogliotti et al., 2014; Millar and Connell, 2010). How co-innovation anticipates scaling, however, is not well understood (Botha et al., 2017).

2.3 The scaling pathway

Scaling has been described as an integral part of, rather than following-on from, responsible innovation[18] processes, a multi-dimensional understanding of impact to

[18] Stilgoe et al (2013, Page 1570) proposed four dimensions of responsible innovation, recognising the potential for tension between them: i) anticipation refers to potential for positive and negative impacts of new technologies and the value of robust challenge to ensure impacts are given due consideration; ii) reflexivity brings to the fore potential for more than one framing of complex issues and the need for transparency in moving towards a shared understanding, a stretching of boundaries is encouraged such that roles are extended to encompass wider moral and ethical responsibilities; iii) inclusion refers to the potential value in processes of public engagement, recognising that this may take different forms; and iv) responsiveness highlights the need for engagement with new and emerging knowledge, not accepting the direction of travel as pre-ordained and willing to challenge the status-quo.

accommodate interactions "between biophysical, social, economic and institutional factors" (Wigboldus et al., 2016, Page 45). Context is critical and while there is scope for lessons to be learned from both more and less successful scaling activities, repeating the same approach in a different setting does not guarantee the same or similar outcomes (Smits et al. 2007; Meinzen-Dick, 2007). Opportunities for success do, however, appear to be optimised if scaling is factored-in to projects from an early stage (Wigboldus and Leeuwis, 2013; Linn, 2012), not as a template for success but to signpost the so-called scaling pathway (Westley et al., 2014; Linn, 2012). Described by Mars and Schau (2017) as part science and part art, negotiating this pathway provides the basis for ongoing "learning by scaling" (Sahal, 1985, Page 61).

2.3.1 Language of scaling

Scale, scales and scaling have multiple meanings that touch our lives in many different ways[19]. Drawing on concepts of scaling from various sectors and moving from the firm, to local and regional levels, some common themes nevertheless emerge in terms of learning, context and institutional alignment.

In a Dutch architect's studio, Yaneva (2005) observed the movement of actors back and forth along a scaling continuum that, over time, appeared to acquire a certain rhythm. There was a shared commitment to "knowing through scaling" (Page 870) and a curiosity to understand how changes in one parameter impact on others. Early scale models brought-together actors, captured the wider context, stimulated ideas

[19] According to The Chambers Dictionary (2006), scales include those that, as a sequence of interconnected plates, protect the skin of a fish or that describe the incremental build-up of lime-scale deposits inside a boiler or kettle; and to scale (or de-scale) describes the action of removing them. The expression, 'the scales fell from their eyes' describes a sudden insight or dawning realisation of the truth. In music, scale refers to a succession of notes, the range of a voice or instrument; and playing or practising scales is to progress up or down accordingly. The ratio between an object and its representation, for example in design and mapping applications is another form of scale and critical engineering or navigational decisions sometimes depend on having an accurate scale, clearly conveyed. A scale is also a device for weighing. In a sporting context, jockeys 'scale-in' and boxers 'tip the scale…' A weigh-scale has applications in industrial and retail settings, as well as in domestic kitchens and bathrooms – all with a shared requirement for accurate calibration and consistency. The weight of evidence presented by the prosecution, balanced with the counter-arguments of the defence is represented by 'the scales of justice' and associated with concepts of rights and fairness. Scaling may also be used to describe an ascent, for example, of walls or mountains or in some personal or professional capacity, to convey a sense of challenge overcome and a goal attained.

and revealed constraints, and supported the development of an enabling vision. Theirs was not a linear trajectory from scaled-down (model) to scaled-up (building), both existed in parallel so that the bigger picture and the finer detail were kept jointly in mind, each informing the other.

Gwin (2009) found it was only by learning through scaling that those stakeholders' promoting extensive grass-fed beef production systems in America came to fully appreciate the barriers and opportunities, and crucially the trade-offs between them. In a sector with prevailing institutions based on the mainstream of more intensive feed-lot beef production systems, scaling grass-fed systems raised a number of issues across the value chain; for consumers, retailers, processors and for the producers themselves. Gwin concluded that "the path to scale that the sector will take is far from settled" (Page 205) and not without the risk of grass-fed systems finding themselves shaped, if not compromised, by the weight of prevailing institutions[20].

Scaling regional healthcare initiatives can translate into lives saved and it was with this in mind that Paina and Peters (2012) argued for regional healthcare initiatives in developing countries to pay closer attention to local requirements. They emphasised the importance of the scaling process, describing it as being as critical to the success of an initiative as the concept of the innovation itself. At the same time, they saw evidence of a disconnect between the "detailed initial planning and inflexible design" associated with many healthcare initiatives and the "dynamic interactions, multiple perspectives and unique local conditions" (Page 371) that are the reality of scaling. They argued that a one-size-fits-all, blueprint approach does not sufficiently take into account "local context, incentives and institutions" (Page 365), calling instead for tailored plans, alert to local needs that give stakeholders' freedom to operate.

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[20] The less than uniform cuts and fuller flavour of grass-fed meat does not conform with mainstream consumer experience. For retailers, regular supplies of consistent quality are the norm and variability of grass-fed beef supply requires an adjustment of expectations. For processors, local plants lack capacity to handle increased volumes but larger plants with spare capacity may require stock to be trucked long distances, against the principles of extensive beef production. Increasing breeding stock numbers takes time; introducing new bloodlines would accelerate the process but raises questions with respect to the authenticity of a product founded on the use of traditional breeds (Gwin, 2009).

The scaling rhythm of the architect's practice in the Netherlands; the challenge of positioning with respect to prevailing institutions in the American beef sector and the need for sensitivity to local healthcare contexts in developing countries reflect the multi-faceted nature of scaling. As noted by Wigboldus and Leeuwis (2013), for scaling "Diffusion of technology, dissemination of knowledge, mainstreaming of practices, institutionalisation of change: they are all sides of the same cube" (Page 2).

2.3.2 Outscaling and upscaling

A certain ambiguity about scaling, prompted Uvin and Miller (1994) to suggest that, "like the Loch Ness monster … it has been sighted enough to make even the most sceptical give it a measure of respectability" with descriptions "as varied as the people who have written about it" (Page 3) while Keshkamat et al. (2012) noted of scale that it is "one of the most overworked and yet, continuingly ambiguous terms" in science (Page 15). On the one hand, this brings a richness and diversity that allows the phenomenon of scaling to be explored in a variety of ways; on the other hand, concerns have been expressed that the interchangeable and inconsistent use of language with respect to scaling, gives rise to confusion (Wigboldus and Leeuwis, 2013; Millar and Connell, 2010; The World Bank, 2003; Gundel et al.; 2001).

To provide some clarity with respect to innovation activities, distinctions have been drawn between scaling as a "kind of replication" and scaling that targets the "institutional roots of a problem" (Westley et al., 2014, Page 237). With echoes of Smith and Raven's (2012, Page 1025) depiction of the path-following or "fit-and-conform" characteristics of some innovation activities and the trail-blazing or "stretch-and-transform" nature of others, Westley et al. (2014) distinguish between more-evolutionary outscaling and more-revolutionary upscaling. The former, out-scaling (scaling-out or horizontal-scaling) describing an innovation being taken-up by more users across a wider area; the latter, upscaling (scaling-up or vertical scaling) describing engagement with a broad spectrum of stakeholders, for example from growers to policy-makers in pursuit of wider, systems change and requiring the support of diverse actors at multiple levels (Hermans et al., 2016; Douthwaite et al., 2003). Some projects have a dual-ambition for outscaling and upscaling, others are

supported by, and lend their support to prevailing institutions and focus mostly on outscaling. Although, as noted by Westley et al. (2014), those prioritising outscaling may "come to realize that without deeper system change, their ideas and initiatives will never have the desired impact" (Page 238) and of the cases examined in their study, all were required to turn from outscaling to upscaling, as outscaling activities brought fresh institutional challenges into focus that demanded an upscaling response in order for progress to be made. The balance between outscaling and upscaling being determined, to a large extent, by the degree of alignment between the emerging innovation and prevailing institutional environment.

A reluctance among practitioners to address upscaling may be a reflection that it is complex and time-consuming and requires a systems perspective to provide the necessary appreciation of associated challenges and opportunities (Westley et al., 2014). Moreover, upscaling is likely to highlight a need not only for new or additional resources but also for stakeholders to let go of something(s) previously considered integral. Westley et al. (2014) go on to argue that navigating this complexity requires cultural/social, political and resource mobilisation skills[21] and, as shown in Appendix I, they propose that organisations tend to fit one or more of five broad typologies with respect to scaling, the: i) volcano, characterised by high levels of energy and excitement; ii) beanstalk, strong leadership motivated by frustration with the status-quo; iii) umbrella, protected development space funded by the initiating body; iv) lego, an incremental build-up from the grass roots; and v) gemstone polisher, seeking to use successful outscaling to catalyse wider change.

[21] Westley et al. (2014) identified: cultural/social skills as cognitive, knowledge management, sense making, convening; political skills as networking, advocacy, lobbying and coalition formation; and resource mobilization skills as financial, social, intellectual, cultural, and political capital (Page 257).

2.3.3 Scaling considerations

Complex interconnections within and across scales means that a change to any one dimension may have consequences in one or more other dimensions (Kampelmann et al., 2018) and, in an agri-food context where the "social, technological and ecological" intersect (Olsson et al., 2014), these impacts may extend to the wider environment (Wigboldus et al., 2016). Keshkamat et al. (2012) caution that participatory processes may surface "differences and anomalies" (Page 16) between scales with Christ et al. (2018) noting, for example, practical difficulties arising from "…differences in time horizons with academics electing to take a long-term view, whereas practitioners prefer more immediate payoffs…" (Page 554). Drawing on the concept of the tragedy of the commons and the risk of "that which belongs to all is cared for by none" Lee (1993, Page 561) describes potential spatial, temporal and institutional mismatches of scale[22] that Jagustović et al. (2019) argue risk giving rise to "trade-offs" (Page 74) whereby short-term (temporal) gains are 'banked' at the expense of negative, longer-term (spatial) impacts. As shown in Table 1, below, Lovell et al. (2002) proposed mitigating measures to address the risks associated with spatial, temporal and institutional mismatches and, by so doing, draw our attention to the complexities of moving along and between scales.

[22] From Lee (1993), spatial mismatches reflect a perceived absence of responsibility as witnessed by dumping "of waste products into waterways or air or land because the dumper has no responsibility to care for these commons to which there is unrestrained access" (Page 561). Temporal mismatches reflect discord between "biological time and human time" (Page 562) as demonstrated by depletion of natural resources, such as fish stocks, harvested more rapidly in pursuit of personal gain than they can hope to be replaced; and functional or institutional mismatches describe a disconnect between prevailing regulations and everyday practice, as one fails to keep pace with change(s) in the other.

Consideration	Risk(s)	Mitigating measure(s)
Spatial	Response rates vary across the natural environment and may vary between the local and wider scale; risk that some processes dominate, obscuring others	Make observations at the appropriate scale and seek to explore cross-scale interactions wherever possible
Temporal	Natural processes tend to unfold over different, and often extended, timeframes	Explore between faster and slower occurring events, ensuring that observations reflect the scale of the processes of interest
Institutional	Boundaries of relevant jurisdictions may not align with boundaries of natural resources with resulting overlaps/gaps	Take time to understand: where overlaps/gaps exist; where decision-making powers lie; and the relationships between individual decision-makers and the wider community

Table 1 Scaling considerations (adapted from Lovell et al., 2002)

Together: the need to accommodate a variety of measures from the finer to coarser grained; the challenge of working across timeframes that range from slower to faster; and the difficulties in maintaining an alignment of borders and boundaries as the focus zooms in and out, serve to highlight the complexities of moving across scales. Although it may be tempting to avoid cross-scale complexity by concentrating on one level, this risks impeding progress (Ramiller and Schmidt, 2018) and missing-out on potential interactions and contextualisation between levels (Jolly et al., 2012). Koehrsen (2018) speaks of 'going to scale' or 'scaling' as multi-dimensional processes that unfold over time in an 'accommodation between levels' while Westley et al. (2014) have described it in terms of a "move into the mainstream" (Page, 235).

It has been argued (Holcombe, 2012) that key indicators may help to provide an early gauge of the likely complexity of this move. Suggesting, as shown in Appendix II, that: scientific credibility; a known, local and respected presence; evidence of observable impact; sufficient funding; engagement with stakeholders; and a clear and distinct proposition are all 'simplifying' factors with the converse of each acting as a potentially 'complicating' factor. Similar to Holcombe's 'simplifying' and 'complicating' factors, Muilerman et al (2018) have described "conducive" and "constraining" factors (Page 178), noting also the scope for interplay between them.

The focus of Holcombe (2012) and Muilerman et al. (2018) was on the preliminary stages of scaling while, as shown in Appendix III, Hermans et al. (2016) sought to

provide a framework to assist in monitoring impact. From their study of grass-roots innovation activity in the Dutch dairy sector, they identified three scaling dimensions: i) spreading and diffusion; ii) politics and power; and, iii) adaptation and transformation[23]; each with relevant scales and measures attached.

In terms of evaluating agricultural research and innovation activity, Wigboldus et al (2016) highlight the increased interest among funding bodies and sponsors to take into account not only the immediate impacts and outcomes but also the "wider benefits" (Page 46) in an endeavour to gain a more holistic appreciation of "impact at scale" (Page 46). To this end, in their study of the photo-voltaic energy sector in India, Jolly et al. (2012) explored seven scaling dimensions: i) quantitative, the number of users/beneficiaries; ii) organisational, capacity to support innovation activity; iii) geographical, coverage in terms of villages, towns, cities, states, countries; iv) depth, reach across sectors of society; v) functionality, breadth of offer; vi) replication, extent of support, e.g. affiliates, franchisees; and vii) institutional, ambition for regulatory change. Recognising the benefits of shared-learnings between otherwise diverse projects, the World Bank (2003) has proposed a framework, summarised in Appendix IV, to assist in timely and structured collection of data. With the aim, in particular, of reducing the risk of unforeseen or undesirable outcomes; accommodating the time-lag involved in some processes; and allowing for inconsistent measures, for example of cost, given the diversity of actors involved.

2.4 Anchoring: a proxy for scaling

Guston (1999, Page 106) spoke of boundary activities in terms of a "mooring" of mutual interests and Sluiter (2017) evoked Wilson's concept of 'consilience' as a unifying of knowledge to portray connections between the new and the familiar "…'horizontally', between different contemporary domains and 'vertically', when creative constructions of the past are used as an anchoring device" (Page 23). The concept of anchoring as proposed by Elzen et al. (2012) offers a way to understand

[23] Wigboldus et al (2016) noted that users' in-field adaptation(s) of emerging technologies may further complicate consistent measures of impact.

the unfolding technological, network and institutional connections that constitute the innovation journey. By way of introducing more detailed consideration of this interpretation and its potential to provide a proxy for scaling (Wieczorek, 2018), this section outlines parallels between AIS thinking and system innovation thinking to frame discussion about the niche and regime as understood and applied in the multi-level perspective (MLP) and informing the concept of anchoring.

2.4.1 Context of the innovation journey

The essence of AIS thinking lies in understanding the interactions between orgware, hardware and software (Smits, 2002), there are, nevertheless, various interpretations that have developed along broadly: infrastructural, functional and process dimensions (Klerkx et al., 2012) that may be described as follows.

An infrastructural perspective, similar to hard systems thinking, emphasises the role of a system in supporting innovation activity within the constraints of clear boundaries, for example as represented by a national innovation system. A functional perspective, meanwhile, derives its understanding of system performance through analysis of its component parts. Work by Wieczorek and Hekkert (2012)[24] on structures and functions sought to bridge these two strands of thinking with the aim of better supporting the needs of policy-makers. A process perspective understands a system as being in a state of flux, evolving in response to the flow of knowledge and resources between diverse actors and, in this way, aligns with complex adaptive systems (CAS) thinking (Spielman et al., 2009). From this perspective, "innovation comprises a series of small technical and non-technical changes that take place as a response to a changing environment…" although this "…is not a new finding …it illustrates neatly what the process looks like — a complex adaptive system in action" (Hall and Clark, 2010, Page 310).

[24] Wieczorek and Hekkert (2012) combined structures and functions to analyse system performance using: 4xStructures; i) actors, ii) infrastructure, iii) institutions, and iv) interactions; and 7xFunctions: i) entrepreneurial activities, ii) knowledge development, iii) knowledge diffusion, iv) guidance of the search, v) market formation, vi) mobilisation of resources, and vii) creation of legitimacy.

Parallels between a process view of AIS as a CAS and a system innovation approach (Klerkx et al., 2012), as well as potential complementarities between innovation systems thinking, such as AIS, and system innovation thinking have been described (Weber and Rohracher, 2012; Markard and Truffer, 2008). Distinguishing between system optimisation, partial redesign of systems, and system innovation, Geels (2005) suggested that while optimisation of existing systems may be expected to lead to incremental improvement; and partial redesign will have a more marked impact; only system innovation, involving "changes on the technical side *and* the user side" (Page 6, italics in original) has the potential to achieve more radical, transformative socio-technical change. As reflected by Hoes et al. (2012), transformation of this nature entails "changes in artefacts, infrastructure and even more importantly in behaviour" (Page 41) that, barring critical events such as accidents, warfare or natural disasters, unfold across an extended period of time.

Over this timeframe, four phases of development have been conceptualised by Rotmans et al. (2001) as: predevelopment; take-off; breakthrough; and stabilisation. In the predevelopment phase there is an outward impression of business as usual as the emerging novelty consolidates its position vis-à-vis the prevailing system. At take-off, the reforms of the wider system necessary to support the innovation start to come into effect. In the wake of these changes, the innovation may break through, accumulated learnings and experience shaping its ongoing development until, eventually, a new state of equilibrium is attained and the system stabilises. The time period over which any change takes place, the pace of change and the extent of change eventually realised are all subject to variation and there is potential too for the process to break-down at any stage, in the face of resistance from the prevailing system, changing market needs or a more compelling alternative vision. The process is non-linear, similar to Rip and Kemp's (1998) depiction of the innovation journey as the way "yeast cells grow with developments branching off in different directions, and cross-connections and interactions complicating the picture further" (Page 357).

The Strategic Niche Management (SNM) approach has developed over recent decades to provide support and direction for radical innovations as they emerge from predevelopment and are confronted with the challenge of "bridging the 'valley of

death' between R&D and market introduction" (Schot and Geels, 2008, Page 538). A niche represents an intermediate step between development and the open market with a further distinction sometimes made between local (project-level) and global (programme-level) niches, the former coming together to give critical mass to the latter (Geels and Raven, 2006). Early SNM work concentrated on niche-internal processes – articulation of expectations; development of social networks; and a commitment to learning (Geels and Raven, 2006). Latterly, there has been increased interest in niche-external processes and this has seen the multi-level perspective (MLP) applied to provide a wider context (Schot and Geels, 2008).

Combining aspects of sociology of technology with evolutionary economics theory, the MLP is a process-based theory (Geels and Schot, in Grin et al. (eds), 2010) that builds on the concepts of niche, regime and landscape to assist with analysis of complex socio-technical change. It has been widely applied to the study of radical change, for example, the shift from sail to steam-powered shipping (Geels, 2002), the mechanisation of Rotterdam harbour (van Driel and Schot, 2005), Boeing's use of composite materials in the construction of passenger aircraft (Slayton and Spinardi, 2016), the shift from mixed-farming to intensive arable (Roberts and Geels, 2019) and to frame discussions with respect to the sustainability of agri-food systems (Marsden, 2013). It has also been applied to assist with analysis of change at a more local level, for example farming practices in Brittany (Diaz et al., 2013).

Markard and Truffer (2008, Page 597) noted commonalities between innovation systems thinking and the concept of system innovation as expressed by the MLP, highlighting in particular the importance attached by both to "networks and learning processes together with the crucial role of institutions for successful innovation processes." More recently, Weber and Rohracher (2012) have identified potential complementarities between the more "structurally oriented innovation systems approaches and the transformation-oriented multi-level perspective" (Page 1038).

In the context of the MLP, the niche and regime exhibit varying levels of structuration[25] (Fünfschilling and Truffer, 2013; Geels, in Elzen et al. (eds), 2004) and the landscape describes the sustaining "technical, physical and material" backdrop that makes some actions more straightforward than others (Geels and Schot, 2007, Page 403). As both the niche and landscape are said to be "defined in relation to the regime" (Geels, 2011, Page 26), this makes the regime of central interest. It offers relative stability through guiding rules, established markets and supporting infrastructures, "oriented around the fulfilment of a single societal function" (Sutherland et al., 2015, Page 1544). To assist with specifying regimes, Holtz et al. (2008) proposed five core characteristics[26] of: purpose, coherence, stability, non-guidance and autonomy. The over-arching landscape comprises wider macro-economic, political and environmental elements, it is the most stable of the levels although this is not to say that it is immune to sudden shocks, for example in the form of unforeseen natural disasters or sudden political upheaval (Geels, 2004). A niche has the most flexibility of the levels and provides a relatively protected space for innovation. Hinrichs (2014, Page 147) emphasised the role of the niche in shielding, nurturing and empowering innovation activities where shielding refers to affording protection from competitive forces; nurturing to initiating and supporting learning; and empowering to building capacity and resilience in preparation for exposure to wider market forces. For a niche to compete in accordance with existing rules of the game, or subject to their reform have been described, respectively, as strategies of 'fit-and-conform' or 'stretch-and-transform' (Smith and Raven, 2012).

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[25] Drawing on Giddens (1984), structuration is understood as the degree of institutionalisation and its susceptibility to influence by the actions of actors; in the weak structuration of the niche there is a low degree of institutionalisation and actors exert considerable influence; the stronger structuration of the regime affords individual actors less influence (Fünfschilling and Truffer, 2013; Holtz et al. 2008).

[26] Holtz et al. (2008) described the regime as embodying i) the interactions of various technologies, institutions, power relationships, values and beliefs that relate in fulfilling a societal function give the regime a sense of *purpose;* ii) interdependencies between diverse actors provide a sense of *coherence*; iii) incremental, rather than radical, evolution in line with prevailing institutions produces *stability*; iv) the regime is self-organising and, in the absence of an actor with overall control, has *non-guidance*; and v) since the regime develops within the constraints of, rather than as prescribed by, its boundary conditions, it may be said to have *autonomy.*

In practice, the levels are rarely so clearly delineated (Morrissey et al., 2013) and over time all three levels interact and evolve. These interactions, in turn, influencing the likelihood, and the likely direction, of change[27] (Geels and Schot, 2007). The MLP continues to evolve, not only in response to learnings from its application but also prompted by critiques of the theory. These have drawn attention, in particular, to: perceived inconsistencies with respect to its application (Genus and Coles, 2008); an over-emphasis on vertical, niche to regime level selection processes at the expense of intra-regime dynamics (Shove and Walker, 2010), and a focus on novelty and innovation that tends to overshadow everyday practices (Seyfang et al., 2013).

Making sense of the "complex array of interactive processes … operating at multiple levels in the niche-regime space" (Ingram et al., 2015, Page 60) is problematic. To help sharpen the focus on "local practices and novelty creation" another reading of these interactions understands them as *layers* rather than *levels,* (Rip, 2012, Page 161). On this basis, ever-present layers are understood as constituting "the general context of innovation journeys" (Page 161), their relative influence, and the innovation's ability to influence them, varying over time and according to the stage in the innovation journey. As envisaged in Figure 5, below, Rip also suggests an "anticipatory co-ordination" (Page 163) layer to reflect processes of projection and visioning that may help to pave the way for an emerging innovation.

[27] Geels and Schot (2007, Page 399) identified four potential pathways that they described as: "transformation, reconfiguration, technological substitution, and de-alignment and re-alignment." Respectively describing: regime reorientation in response to moderate pressure from the landscape and in the absence of corresponding niche activity; symbiosis between niche innovations and local regime problems that gradually reshape the wider regime; intense landscape pressure that aligns with innovative niche activity makes the prevailing regime vulnerable to displacement; intense landscape pressure destabilises the regime but in the absence of sufficient niche activity there is no immediate replacement and multiple niches compete in the resulting vacuum until one eventually predominates.

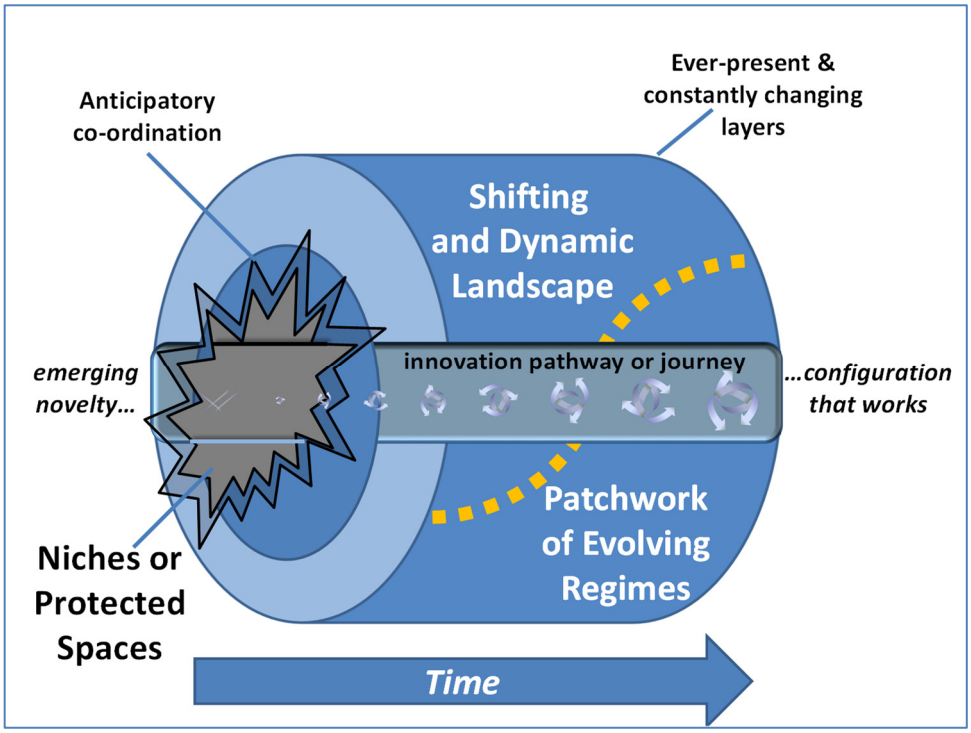

Figure 5 Contextual layers of the innovation journey (adapted from Rip, 2012)

On this basis, 'anticipatory co-ordination' provides the innovation journey with a sense of direction that is of value in steering an emerging novelty towards some 'configuration that works' of the technology, network and institutions, in the context of an overarching landscape, patchwork of regimes and multiple niches.

2.4.2 The concept of anchoring

The concept of anchoring (Elzen et al., 2012) understands the interactions between niche and regime as a "continuous process of probing new connections", sustained by "activities of individuals or individual organisations" (Page 4) with much activity driven by so-called "hybrid-actors" in a "hybrid forum" between niche and regime.

2.4.2.1 Elements of anchoring

Newly made connections are sensitive to their environment and if "forces go in one direction, an anchor digs in deeper and develops into a solid link. If forces go in the opposite direction, however, an anchor easily lets go" (Elzen et al., 2012, Page 3). As shown in Figure 6, below, there are three 'strategic': technological, network and institutional; and five 'tactical' elements of anchoring (Elzen and Bos, 2016).

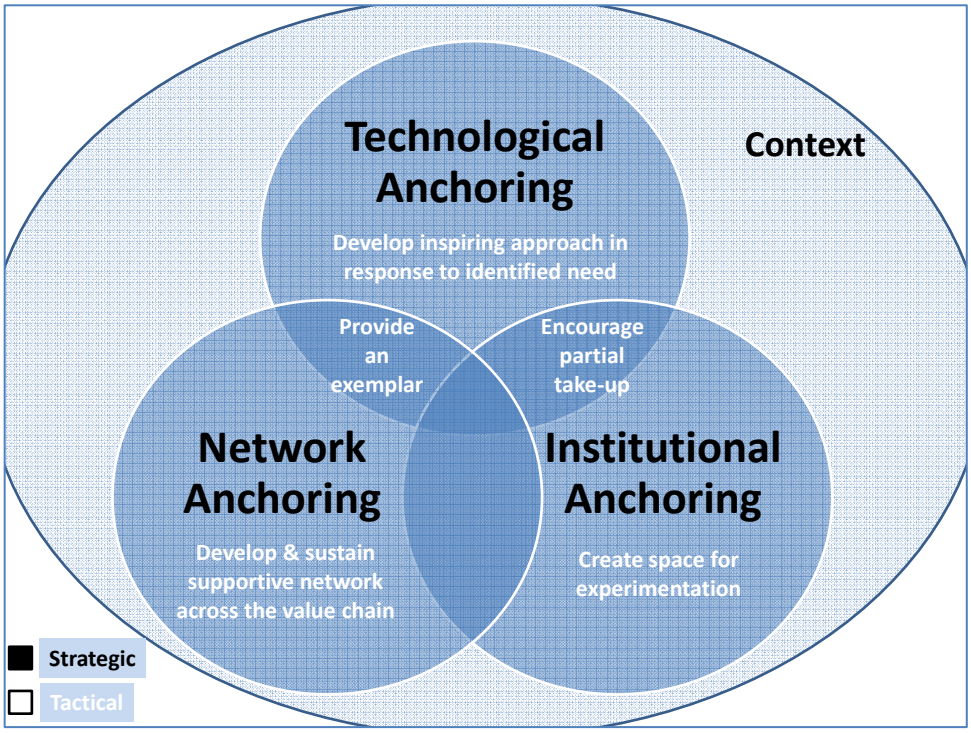

Figure 6 Overview of anchoring (adapted from Elzen et al., 2012; and Elzen and Bos, 2016)

Technological anchoring represents the relationships between actors and the novel technology or practice, reflecting the emerging sense of ownership that develops over time and through ongoing discussion, trial and adaptation. At a tactical level, it is associated with development of a clearly differentiated proposition that meets a distinct user need; and supporting materials that communicate these benefits in such a way as to create engagement and generate excitement are of particular value.

Network anchoring emphasises the inter-personal relationships between actors with respect to the innovation, taking into account the tensions and bonds between them. Initial connections are fragile and require continued support and it is only when this support can be withdrawn without the loss of the connection that more durable links can be said to have formed. Elzen et al. (2012) noted that new connections are especially vulnerable to individuals leaving the process although connections become more resilient to changes around them as they become more firmly embedded. Network anchoring is associated with tactical development activities that emphasise the importance not only of building links across the value chain but also sustaining these links in the longer-term through ongoing communications and engagement.

There is an overlap with 'technological' in the potential value of providing an exemplar that demonstrates early proof of principle as a way of sustaining interest.

Institutional anchoring captures the associated formal and informal rules that direct human behaviour, further broken down into three considerations of: i) interpretative (actors' sense of the world around them); ii) normative (wider societal values); and iii) economic (governance) aspects. It is associated with providing a protected space that enables and encourages experimentation and it has a tactical overlap with technological in recognising that since an innovation's development may be piecemeal, it is useful to trial and explore emerging components as they develop.

Connections are not restricted to niche-regime interactions and Sutherland et al. (2015) point to dynamics between the three types of anchoring, suggesting that further research will be of value in developing a better understanding of the role and impact of these interactions. A convergence of the three forms of anchoring, nevertheless, appears to be critical in forging enduring links (Elzen et al., 2012).

2.4.2.2 Hybrid forum

The concept of hybrid-forum is more typically associated with controversies as applied, for example, by: Lis and Stasik (2018) to explore shale gas extraction in Poland; Farías (2016) to chart the rebuilding of the city of Constitución in Chile after the devastating earthquake of 2010; and by Dusyk (2011) in his study of a large-scale hydroelectric project in Canada. Farías (2016) traces the term hybrid forum to an article by Callon and Rip (1992) and van den Hove (2004) offers her translation from the original French as referring to "interactions between actors of the scientific and technical sphere, the socio-political and economic sphere, and the regulatory sphere" (Page 10), a concept subsequently elaborated by Callon at al. (2009) to describe the "…collective learning, which simultaneously produces new knowledge and new social configurations … fabricating a close weave of micro-decisions, each of which is subject to discussion and linked to those that precede it as well as those that follow" (Page 10). Dusyk (2011) highlights that while this collective learning may take place in various formats, from the formal to the informal, and ranging from "advocacy councils to citizens' juries" (Page 874) there will be a shared emphasis on

longer-term transformation through processes of participation. For Farías (2016), the hybrid forum embodies three distinct tensions between: i) the concept and its realisation; ii) the role of the hybrid forum vis-à-vis other participatory approaches; and iii) maintaining a balance between a space for dialogue and a focus on building consensus. Lis and Stasik (2018), meanwhile, draw our attention to the potential for "cognitive and practical gains" (Page 30) to be derived from these tensions.

From their analysis, Elzen et al. (2012) argued that hybrid-actors differed from intermediaries, such as boundary spanners for example, in two key respects: i) they are inside, rather than outside, the relevant niche and regime; and ii) they are motivated by self-interest rather than a more altruistic desire to facilitate links. In this context, the hybrid-forum is understood by Elzen et al. (2012) as "…the location where translations take place" (Page 15) and although anchoring may occur in the niche and regime, the hybrid-forum serves an important function as an intermediate step – or an "adaptive zone" (Ingram, 2015, Page 72) – between the two.

2.5 Closing remarks

For much of the last century, the dominant agro-industrial approach has harnessed science and technology to promote increased production (Lang and Heasman, 2000). Its impacts are contested but it has provided a measure of certainty in the form of a clear and consistent direction of travel (Bonney et al., 2007). As the sector comes under pressure to find a new balance between increased production and improved social and environmental outcomes, it is not as yet clear if the agro-industrial approach has sufficient flexibility to adapt or if a more fundamental change, for example to an agro-environmental approach, is required (Lang and Heasman, 2015). In the meantime, established certainties are giving way to uncertainty and accepted rules-of-the-game are evolving, requiring innovation processes to adapt accordingly.

For some time, more holistic, systems perspectives have complemented established, linear interpretations of agricultural innovation activity and drawn attention to the complex interactions between emerging technologies (hardware), supporting actors (software) and the wider institutional context (orgware) (Hermans et al., 2016; Leeuwis and Aarts, 2011). Co-innovation has been proposed as a way of

operationalising this approach by bringing together multiple stakeholders with a common interest in reaching a better understanding of a complex problem with a view to developing an innovative response.

Characterised as a mindset rather than method (Klerkx and Nettle, 2013) and without a blueprint for action, co-innovation is actioned through the application of guiding principles to enable a so-called "co-innovation space" (Coutts et al., 2017). This space facilitates the exchange of knowledge and ideas, mutual learning and a sharing of resources (Bitzer and Bijman, 2015), a process that, as illustrated in Figure 7 below, is associated with a complex and dynamic web of interactions.

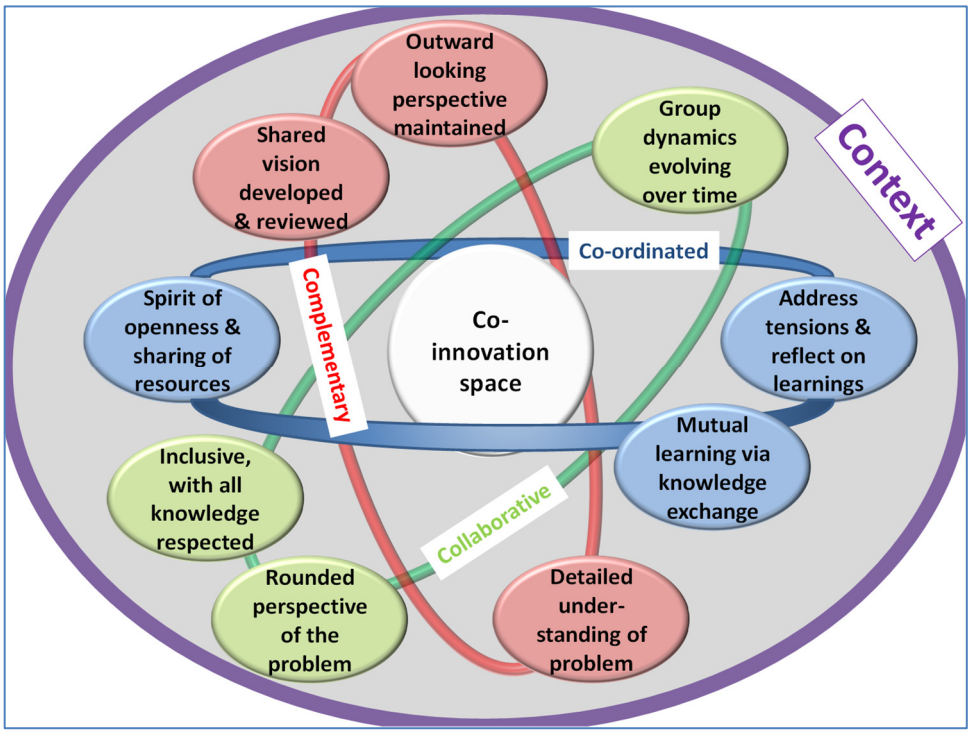

Figure 7 Schematic of co-innovation space and underlying principles (adapted from Coutts et al., 2017; Bitzer and Bijman, 2015; Nederlof et al., 2011)

Sometimes referred to in terms of outscaling, rolling-out more of the same, and up-scaling, creating conditions conducive to change (Hermans et al., 2016; Westley et al., 2014; Douthwaite et al., 2003), together, the context-specific evolution of the technology, development of the supporting network and institutional fit – or scaling – are complex and dynamic processes. In the absence of a theory of scaling, the concept of anchoring that describes processes of ongoing probing whereby fragile

technological, network and institutional connections seek to become more firmly embedded or anchored in their environment (Elzen et al., 2012), offers a guiding framework, or proxy, through which to explore scaling.

In searching for an alignment between the technology, network and institutions, there is a risk of 'mismatches' should these elements fall out of step with one another (Ingram et al., 2016; Olsson et al., 2014; Lovell et al., 2002). For example, reporting on a long-term (1996-2006) socio-ecological pilot study at Whatawhata in the Waikato region of NZ, Dodd et al. (2008) noted a tendency for two dominant feedback loops to operate at different rates, such that "the farmer – farm system – farm production loop is relatively fast, while the stakeholder – landscape – ecosystem loop is relatively slow" (Page 105). As shown in Figure 8, below, such disconnects between contrasting temporal (from short to long term), spatial (from local to global) and institutional (from conforming to reforming) dimensions of scale may give rise to tensions with associated challenges and opportunities.

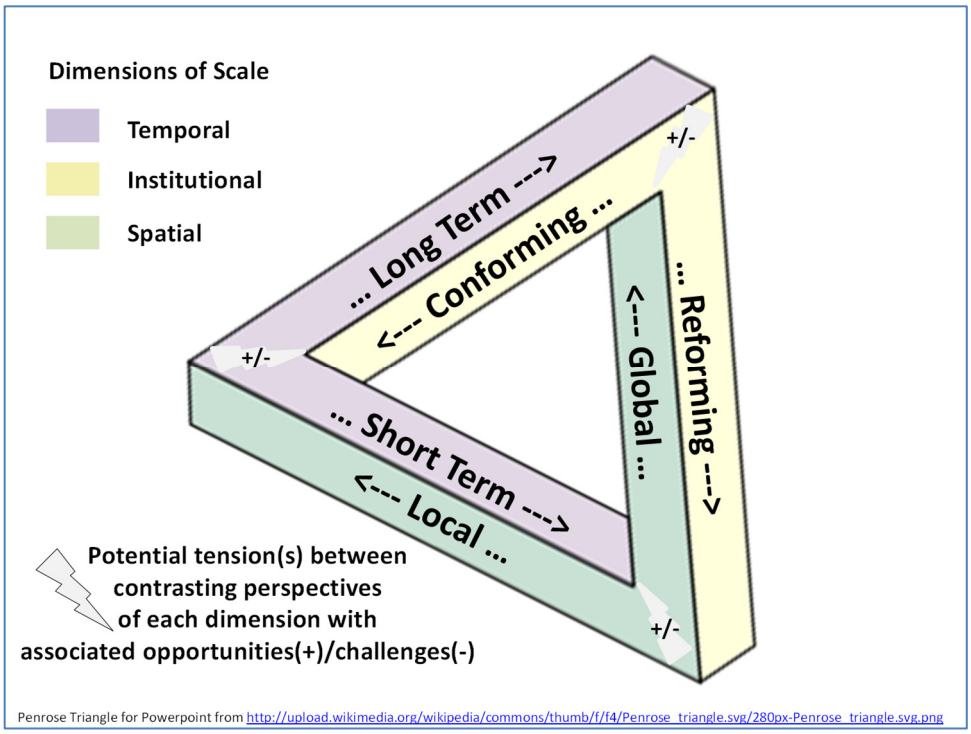

Figure 8 Dimensions, perspectives and tensions of scaling

Studies of scaling have considered factors impacting upon potential scalability (Muilerman et al., 2018; Holcombe, 2012); the dimensions and measures of scaling

outcomes (Hermans et al., 2016; Jolly et al., 2012); and frameworks to support the ex-post evaluation of scaling (World Bank, 2003). With respect to co-innovation, the in-field interactions and processes that anticipate Hall's "interconnectedness of scales" (2009; Page 224) are less well understood (Botha et al., 2017). To address this knowledge gap, I apply the concept of anchoring to explore how co-innovation anticipates scaling and my approach is described in the chapter that follows.

Chapter 3: Methodology

Through the research questions, the methodology connects the more general assumptions surrounding the problem of interest and wider theoretical perspective with the more specific protocols that guide the collection, analyses and interpretation of data. Following Creswell (2003), and as outlined in Figure 9, below, the overarching approach – be it qualitative, quantitative or mixed methods – is informed by consideration of three interconnected questions concerning: philosophical worldview, research design and research methods. In this chapter, I consider these questions and argue for a qualitative research approach as most appropriate to address my research questions. Informed by a pragmatic worldview and using case study as the strategy of inquiry, I set out how data were collected, analysed, interpreted and validated to provide a bridge between the theoretical perspective in the preceding chapter and discussion of empirical data in the chapters that follow.

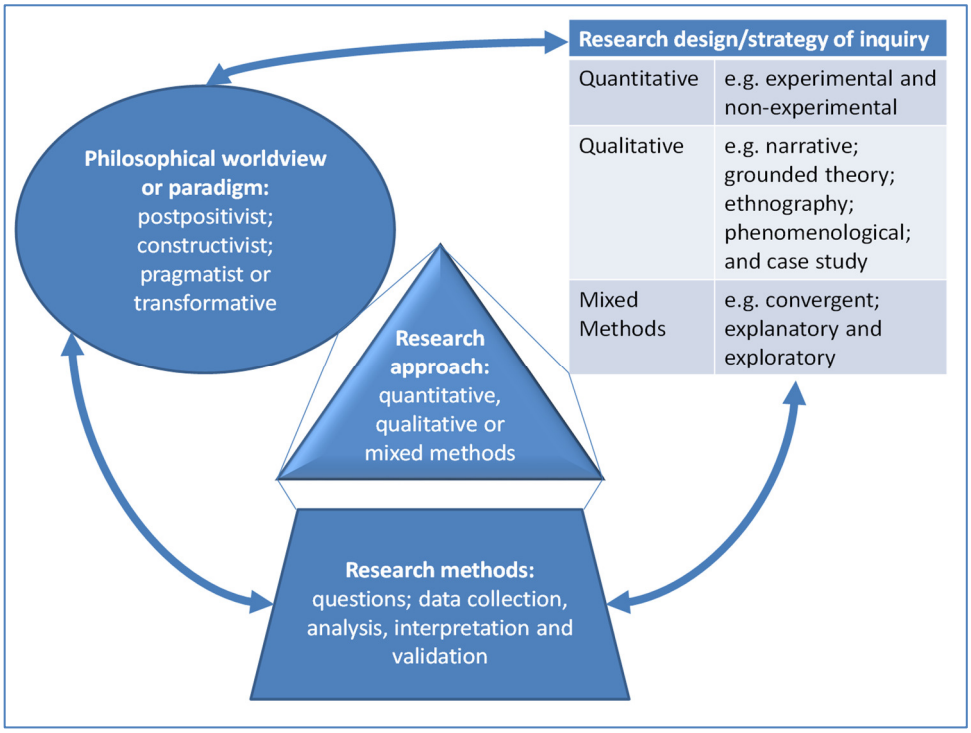

Figure 9 methodological considerations (adapted from Creswell and Creswell, 2018)

I begin this chapter, however, by first considering the features that broadly characterise quantitative, qualitative and mixed methods research approaches.

3.1 Research approach

Reflecting on the long-established orthodoxy of a quantitative approach, the increasing prominence in recent decades of qualitative thinking and the still more recent emergence of mixed methods, Blaikie (2010) sees some softening of the prevailing 'never the twain shall meet' characterisation. From Creswell and Creswell (2018), the three approaches are broadly differentiated around their use of numbers (quantitative) and words (qualitative) or both (mixed methods). More specifically, quantitative studies are associated with testing and measuring with a view to yielding, or converting to, numerical data for subsequent analyses. The relationship between survey results and the wider population of interest and the extent that findings may be generalised, requires consideration of sample structure and possible weighting of findings. Reporting tends to follow established conventions of "introduction, literature and theory, methods, results and discussion" (Page 4). In qualitative studies, the emphasis is on using words rather than numbers to explore and understand issues. Data collection allows for the individuality of participants and analysis tends to proceed iteratively, moving between the empirical and theoretical. While there is more flexibility in qualitative as compared with quantitative reports, value is attached to reflecting not only the wider context but also capturing the essence of individual meaning, for example through inclusion of selected quotations. Mixed Methods provides a structure for combining the benefits of quantitative and qualitative in the belief that the whole then becomes greater than the sum of its parts, facilitating the collection, analysis and integration of diverse data to provide a more holistic understanding than may otherwise be obtained.

With the aim of developing a better understanding of the complex interactions between a co-innovation inspired approach and the dynamic processes of scaling, the essence of my inquiry is both descriptive and exploratory. In order to achieve the required depth of insight and understanding, I believe that a qualitative approach, commensurate with a study of "things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them" (Denzin and Lincoln, 1994, page 2), provides the most appropriate approach.

3.1.1 Philosophical worldview

Philosophical worldviews – sometimes referred to, for example Blaikie (2010), as paradigms – inform the research approach with different worldviews reflecting different understandings of being (ontology) and knowledge (epistemology) (Moon and Blackman, 2014; Patterson and Williams, 2008). The relationship between worldview and research approach has particular resonance for the social sciences given their origins in the wider field of philosophy. Although, as noted by Hughes (1990), this relationship is at times awkward and, like the "parable of the prodigal son" (Page 1), sees the social sciences returning to their philosophical roots for support in times of doubt or crisis. Determined through a mix of personal, lived and worked experience and wider, environmental influences, there are multiple and varied worldviews. Creswell and Creswell (2018) draw our attention to four in particular: postpositivism, constructivism, pragmatism, and the transformative.

Evolving from the positivist approach and the traditions of the scientific method[28], *postpositivism* emphasises observation through numerical or quantitative measures. However, it allows for a less absolute conviction in coming to a true understanding of cause and effect, accepting instead the need to leave room for a measure of doubt in the study of human behaviours. *Constuctivism*, sometimes referred to as interpretivism, allows for the multiple and complex views of individuals rather than seeking a single or overarching truth. Understanding is developed via qualitative research and through wider interest in social interactions and context while acknowledging the potential influence of the researcher in the research process. *Pragmatism* is concerned with applying what works with an emphasis on finding practical solutions to problems. All approaches are on the table, quantitative, qualitative or some combination of the two in so-called mixed methods. Although pragmatism is not committed to any one philosophical tradition, there is no less emphasis on understanding the rationale for the decision-making process. The

[28] Blaikie (2010) describes Positivism as a Classical Research Paradigm, characterised by an emphasis on experience and observation as the basis of knowledge and understanding.

transformative approach collectively describes the worldview of researchers that while rejecting the postpositivist assumptions emerging towards the end of the twentieth century were, nevertheless, concerned that constructivism did not sufficiently support their agenda for reform[29]. With a shared ambition for change and well-developed awareness of the prevailing "issues of the day" (Creswell and Creswell, 2018, Page 9[30]), participants and researchers work together to mitigate the risk of further marginalisation, and research may become entwined with politics.

In the agri-food sector and in the context of the global challenge of building a more sustainable future, Olsson et al. (2014) emphasise the need for a deeper understanding of cross-scale dynamics and the implications of change at one scale on another. They welcome signs of convergence between different schools of thought, for example between socio-technological systems and social-ecological systems that, despite their different theoretical traditions[31], have a shared interest in this concern. Reflecting on the move towards increasingly participatory innovation and knowledge exchange systems in the farming sector, Douthwaite et al. (2003) note the need for an accompanying paradigm shift from (post)positivist to constructivist in order to better accommodate these more social processes. At the same time, however, they acknowledge that agricultural development activities often have their roots in basic or fundamental, scientific research, before moving on to more applied work, so requiring some accommodation between (post)positivist and constructivist worldviews in order for them to co-exist. In observing that "…people do odd things, in a way that potatoes don't" Thomas (2011, Page 8) highlights the crucial role of social sciences in bringing an understanding of human behaviours to this mix.

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[29] Among others, Creswell and Creswell (2018) identify: Critical Theorists; Action Researchers; Marxists; Feminists; Ethnic, Indigenous and Post-colonial People; and Minority Sexual Communities.

[30] For example: "…empowerment, inequality, oppression, domination, suppression and alienation."

[31] Olsson et al. (2014, Page 1) noted that the focus of resilience scholars has tended to be on understanding disruptive change through social-ecological systems while transition scholars have tended to focus on non-linear change from a socio-technical perspective.

My own pragmatic worldview allows for "different worldviews and different assumptions" (Creswell, 2003 page 12), accommodating the sometimes uneasy relationships between natural and social scientists (Lowe et al., 2014). This is of practical value in steering a course through a shifting environment by combining flexibility with the ability to adapt to emerging learnings (Rivera-Ferre et al, 2013).

3.1.2 Research design

Following Creswell and Creswell (2018), the various research designs or strategies of inquiry associated with different research approaches may be outlined as follows.

Quantitative studies typically collect data through either: i) formal, experimental designs; or ii) less formalised, non-experimental designs. The research may take a snap-shot, at a point in time or be conducted on a repeated or ongoing, longitudinal basis to allow shifts to be followed over time and trends to be identified. Data collection is structured with a view to informing the deductive testing of theories.

A qualitative approach opens the possibility of a variety of different designs, among them: narrative research; grounded theory; ethnography; phenomenological research; and case study have developed from different disciplines and traditions and with different applications. For example, narrative research developed in the humanities as a way of reaching a better understanding of the lives of one or more individuals by capturing experience through narrative descriptions then collated, for example chronologically, by the researcher. From sociology, grounded theory uses the views of participants collected and refined at various stages as the basis to develop an improved understanding of processes, actions or interactions. From anthropology, ethnography sees researchers' immersing themselves in the lives of a population of interest in their natural setting over an extended period of time for observation of language, actions and behaviours. From philosophy and psychology, phenomenological research involves a researcher interviewing participants with a view to building a detailed understanding of their lived experience with respect to a phenomenon of interest. Case studies are applied in various fields as a way of drawing on multiple and diverse sources of information over a sustained period with a view to better understanding a discrete, time-bound process, activity or event.

A mixed methods approach typically follows one of three broad strategies: i) a convergent design wherein quantitative and qualitative data are collected in parallel with one another with a view to integrating data from the two streams of inquiry to inform the analysis and interpretation of results; ii) in an explanatory sequential design, a quantitative phase precedes the qualitative phase, the latter being used to help explain and understand the results of the former; while in iii) an exploratory sequential design, a qualitative phase is the first step in building an early understanding that then provides the basis for subsequent quantification.

Collaboration is part-and-parcel of co-innovation and working in a collaborative setting raises the prospect that some target stakeholders will, as Moon and Blackman (2014) note, be more familiar with (post)positivist, tending towards quantitative, rather than constructivist, tending towards qualitative, approaches. This has potential to impact upon access to and engagement with target stakeholders. For example, in terms of gaining access to stakeholders in the early stages of the project and communicating findings at later stages, when, as Creswell (2003) advises, the experience of the intended target audience needs to be taken especially into account. By following a case study design, open to the inclusion of diverse data from multiple sources and providing insight from many angles (Thomas, 2011), opportunities for both access and engagement are maximised. My rationale for applying a case study design extends more widely, however, recognising it as something special (Stake, 1995), representing a "once in a lifetime opportunity" (Yin, 2004, Page 3) and, crucially, the opportunity of "getting close to reality" (Thomas, 2011, Page 6).

3.1.3 Research methods

With respect to methods, Blaikie (2010) describes them as comprising the "procedures and activities for selecting, collecting, organizing and analysing data" (Page 8). He also reflects that "methods can serve a number of masters" (Page 227), their application and interpretation informed by philosophical worldview and design, highlighting the interconnectedness of methodological considerations. I discuss my research methods below but I turn first to the question highlighted by Thomas (2011) that prompts researchers to consider – and re-consider – "what is this a case of?"

As an initiative putting the principles of co-innovation into practice, the Primary Innovation Programme (PIP) provides an opportunity to explore an unfolding process in the context of New Zealand's agri-food sector. The comprehensive structure of the programme that, as illustrated in Figure 10, below, includes three streams of activity – comprising ex-post analysis of three projects, ex-ante analysis of five more as well as stakeholder engagement – required decisions to be made with respect to the scope of the case study within the constraints[32] of my study.

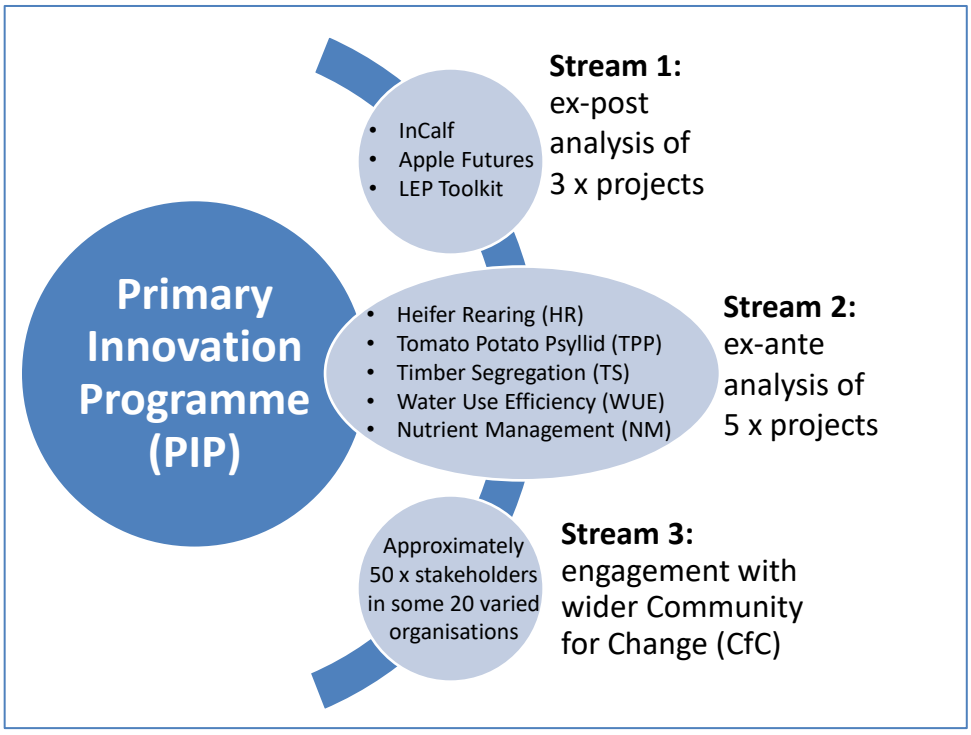

Figure 10 overview of the Primary Innovation Programme (PIP)

Yin (2004) cautions as to the importance of careful case selection, noting the rewards of an informative case and the dangers of an unrealistic or uninformative one. He advises that care is needed to select the "most significant case possible" (Page 3) and to take soundings from colleagues with a view to making the optimum choice. Accordingly, in discussion with colleagues and with a view to gaining the best possible all-round perspective of the co-innovation process, a "collective" case

[32] For example, constraints of time and budget.

approach[33] (Stake, 1995) was adopted. Two of the five in-field projects were selected, the Heifer Rearing (HR) and Water Use Efficiency (WUE) projects, with the overarching Primary Innovation Programme (PIP) providing the basis for a third. Both in-field projects originated in, and stayed in, the PIP[34] and the inclusion of the over-arching PIP allowed for a project-level overview. Practical considerations were also taken into account as regards access to the case while also being alert to the benefits of a case "hospitable to enquiries" (Stake, 1995, Page 4). Having made an initial selection, Stake (1995) nevertheless advises that not all cases work out well in practice and an early go/no go assessment should be made. Early contact with the respective Project Managers and discussion about the project and requested access gave me sufficient confidence that the selections would be suitable, and sustainable.

3.1.3.1 Questions

In addressing research questions through case study, Thomas (2011) speaks of the opportunity afforded to focus on a "line of inquiry" and to "weave together data" (Page 90) from a range of both primary and secondary sources. Among the latter, Gillham (2008, Page 21) identifies: journal articles; analysis of contemporary documents and records going back over time; 'detached' or 'fly-on-the-wall' and 'participant' or 'in-the-setting' observations; and physical artefacts, each with the potential to usefully contribute to developing an holistic perspective. Indeed, Yin (2004) points to the cross-bracing effect of drawing on different sources that "converge on the same findings" (Page 100). Gillham (2008) notes, however, that their inclusion will likely be determined by what is practical, available and relevant while Yin (2004) cautions that it must be borne in mind that they will have been produced for reasons other than "later serving as part of your case study (Page 156).

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[33] Stake (1995, Page 3) distinguishes between an *intrinsic* case, wherein the case is of highest importance, and an *instrumental* case, with the issues of interest of highest importance. Selection and study of more than one instrumental case on a 'collective' basis increases the opportunities to learn.

[34] Of the three other in-field projects: the Nutrient Management project, followed a twin-path with involvement in the PIP and a parallel, stand-alone project; the Timber Segregation and the Tomato Potato Psyllid projects both commenced outwith the PIP and were underway beforehand.

Providing structure in the form of issues to be covered with the freedom to follow emerging lines of enquiry, the semi-structured personal interview is perhaps the most powerful tool available to researchers in a case study (Thomas, 2011). They have the potential to yield not only an enhanced and particular insight but also to add a level of "richness" (Gillham, 2008, Page 62) that would not otherwise be obtainable.

White (2009) reminds us not to confuse data collection or interview questions with research questions. The former serving as part of the methodological bridge that links the latter with the findings, discussion and conclusions. Semi-structured interviews provide a mechanism to collect data from stakeholders and, for me, to explore in breadth and depth how co-innovation was understood and operationalised and how its application anticipated scaling. A Discussion Guide (Appendix V) provided an outline for interviews. Developed on the basis of Figure 11, below, it explored: general context; and more specifically hardware, software and orgware aspects of innovation activity with a read-across, respectively, to technological, network and institutional scaling. The guide was piloted and refined before being finalised, it was sufficiently flexible to provide a common basis for all interviews.

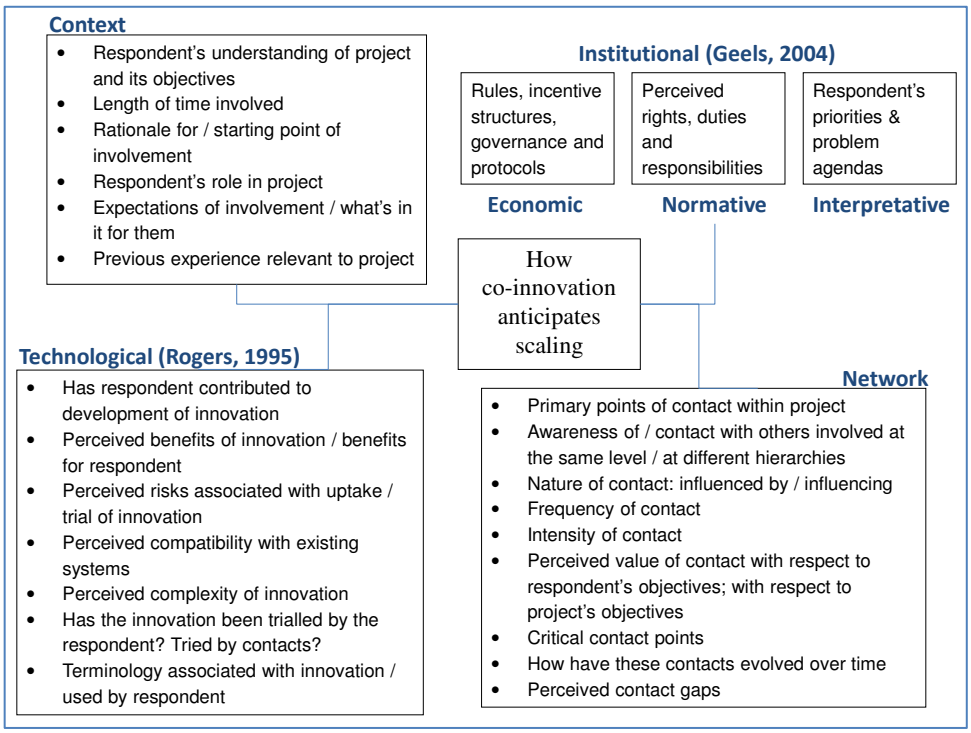

Figure 11 Genesis of semi-structured interview questions

3.1.3.2 Code of Practice and Research Ethics

Stake (1995) observes that the privilege of conducting a case study brings certain responsibilities[35] and he advocates "an ethic of caution" (Page 12). The University of Edinburgh has adopted the UK Research Integrity Office's (UKRIO) Code of Practice for Research[36] (Appendix VI). A one-page checklist (Appendix VII) offers a practical aid to researchers and this checklist was kept under review for the duration of the project. In addition, the University of Edinburgh's research ethics framework provides guiding principles that apply to all research and it is the frameworks of the College of Humanities and Social Science (CHSS) and the School of Social and Political Science (SSPS) that apply to this project. Additional checklists provided by the University assist in the identification of ethical issues with completed checklists requiring approval by the Head of School. All necessary clearances must be obtained before research work may begin. The Research Ethics Checklist (Appendix VIII) was completed and subsequently approved by the School's Research Group. A Self-Audit Checklist for Level 1 Ethical Review (Appendix IX) was also completed in line with the University's requirements. Responses confirmed the "Absence of Reasonably Foreseeable Ethical Risks" with respect to this project and the Ethical Review Form for Level 2 and Level 3 auditing did not, therefore, require completion.

3.1.3.3 Data collection

As shown in Table 2, below, fieldwork was mostly conducted in the 12 months from October 2014 to October 2015. During this time, I was based with AgResearch at Ruakura on the outskirts of Hamilton in the Waikato Region of NZ's North Island. A return visit in September 2017, enabled me to attend the PIP's closing ThinkTank, a two-day facilitated stakeholder workshop in Wellington, to observe discussions.

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[35] Thomas (2011, Page 69) suggests five questions re: ethics: i) who does the research benefit; ii) do you have the right to take up respondents' time and energy; iii) will participants be exposed to any discomfort; iv) is privacy being invaded; v) will participants' standing be compromised in any way?

[36] http://www.ukrio.org/publications/code-of-practice-for-research/

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Duration of PIP							
Period of Study							
47 x in-field interviews							
General n = 7 interviews + 3 seminars + 5 conferences			A B v	vii x	C D E		
PIP n = 6 interviews + 7 seminars			i ii iii iv	ix xi		xii	
HR n=16 interviews + 1 workshop			vi				
WUE n=18 interviews + 1 workshop				viii			
Indicative fieldwork stages			Research Design & Data Collection & Initial Analysis			Ongoing Analysis & Interpretation & Reporting	

Additional data collection opportunities	
i) Nov. 2014	Stream 1, x-case discussion meeting, Ruakura
ii) Nov. 2014	x-stream, innovation in NZ's primary sector, Pukekohe (with Auckland University)
iii) Dec. 2014	Stream 1, x-case discussion meeting, Ruakura
iv) Feb. 2015	Stream 3, Primary Innovation stakeholder workshop, Auckland University
v) Feb. 2015	General, Farm Demonstration Open-day, Matira, Ngaruwahia
vi) Feb. 2015	HR, Adoption of innovations in agriculture, David Pannell (UWA), Dairy NZ, Newstead
vii) May 2015	General, Farm Environment Planning on-farm workshop, Tirau, Waikato
viii) May 2015	WUE, annual stakeholder review, Oxford, Waimakariri
ix) June 2015	Stream 3, facilitated workshop with stakeholders, Wellington
x) June 2015	General, FieldDay, Joint Graduate School in Dairy Research and Innovation
xi) July 2015	x-stream, PIP 2-day workshop, Christchurch
xii) Sept. 2017	x-stream, Closing Seminar, 2-day ThinkTank, Wellington
External communication opportunities	
A, April 2014	International Farming Systems Association (IFSA) Conference, Berlin with follow-on visit to Wageningen University as part of AgResearch delegation
B, Feb. 2015	Dairy Business Forum, Centre for Innovation and Entrepreneurship, Auckland University, presentation and discussion
C, April 2016	Agricultural Economics Society (AES) Conference, University of Warwick presentation and discussion
D, July 2016	International Farming Systems Association (IFSA) Conference, Harper Adams with presentation as part of 'Scaling' workshop and completion of PhD systems training module
E, August 2016	Funded by the University of Edinburgh's Go Abroad scheme, a two-week study visit to Wageningen University with follow-on presentation and discussion at KIT, Amsterdam

Table 2 Overview of research activities and timelines

A combination of follow-up interviews with some (four) participants and several instances (seven) of one interview with two participants amounted to interactions with 48 interviewees across a total of 47 interviews, as outlined in Table 3, below.

Prefix	Identifier	Descriptor (to protect anonymity)	Interviews n = 47			Interviewees n = 48	
			1	2	3	1 : 1	1 : 2
General: comprising 7 x interviews with 9 respondents							
General	_AgResearch_1	PIP_Stakeholder					
General	_AgResearch_2	PIP_Stakeholder					
General	_Beef+Lamb_NZ	PIP_Stakeholder					
General	_Farmer	PIP_Stakeholder					
General	_Veterinarian	PIP_Stakeholder					
General	_Academic	PIP_ProjectTeam					
General	_Consultant	PIP_Stakeholder					
Stream 3: comprising 6 x interviews with 8 respondents							
Stream_3	_AgResearch_1	PIP_ProjectTeam					
Stream_3	_AgResearch_2	PIP_ProjectTeam					
Stream_3	_ESR	PIP_ProjectTeam					
Stream_3	_Ministry_PrimaryIndustries	PIP_Stakeholder					
Stream_3	_Scion	PIP_ProjectTeam					
Stream_3	_Plant+Food	PIP_ProjectTeam					
Heifer Rearing (HR): comprising 16 x interviews with 11 x respondents							
HR	_Consultant	HR_ProjectTeam	a	b	c		
HR	_DairyNZ_1	HR_ProjectTeam	a	b	c		
HR	_DairyNZ_2	HR_Stakeholder					
HR	_DairyNZ_3	HR_Stakeholder					
HR	_DairyNZ_4	HR_ProjectTeam	a	b			
HR	_DairyNZ_5	HR_Stakeholder					
HR	_Farmer_Beef	HR_Stakeholder					
HR	_Farmer_Dairy	HR_Stakeholder					
HR	_LIC	HR_Stakeholder					
HR	_AgResearch_1	HR_ProjectTeam					
HR	_AgResearch_2	HR_ProjectTeam					
Water Use Efficiency in the Waimakariri: comprising 18 x interviews with 20 respondents							
Waimakariri	_Farmer_Arable	WUE_Stakeholder					
Waimakariri	_Farmer_Dairy_1	WUE_Stakeholder					
Waimakariri	_Farmer_Dairy_2	WUE_Stakeholder					
Waimakariri	_Farmer_Dairy_3	WUE_Stakeholder					
Waimakariri	_Farmer_Mixed	WUE_Stakeholder					
Waimakariri	_DairyNZ	WUE_Stakeholder					
Waimakariri	_EnvironmentCanterbury_1	WUE_Stakeholder					
Waimakariri	_EnvironmentCanterbury_2	WUE_Stakeholder					
Waimakariri	_Environment_Officer	WUE_Stakeholder					
Waimakariri	_Irrigation_Support	WUE_Stakeholder					
Waimakariri	_Irrigation_Acceleration_Fund	WUE_Stakeholder					
Waimakariri	_Irrigation_NZ	WUE_Stakeholder					
Waimakariri	_AgResearch	WUE_ProjectTeam					
Waimakariri	_NIWA_1	WUE_ProjectTeam					
Waimakariri	_NIWA_2	WUE_Stakeholder					
Waimakariri	_Irrigation_Scheme	WUE_Stakeholder	a	b			
Waimakariri	_Zone_Committee	WUE_Stakeholder					

Table 3 profile of interviews and interviewees

Participants were purposively selected from the stakeholder networks associated with each case. Based on The World Bank's (2006, page 105) overview of the elements of an agricultural innovation system that describes various domains joined by a complex web of interactions, I anticipated my main points of contact would include farmers and their advisors (including veterinarians), extension services, trade associations and research providers as well as wider policy-makers. In practice, names and contacts tended to snowball as the project progressed. An additional source of reference was the Social Network Analysis led by Barbara King at the University of Melbourne. This portrayed the ongoing evolution of the PIP network, highlighting active individuals and organisations and potential influencers.

Care was taken, as advised by Stake (1995), to tread lightly and to respect the access afforded. Initial requests were submitted in writing (Appendix X), outlining the purpose of the study; identifying the sponsors; describing the intended activities and anticipated time span. A Consent Form provided a written record of all interviews (Appendix XI) while informal thank-you calls/e-mails followed. All interviews were conducted face-to-face, and mostly at participants' place of work or at a mutually convenient location. The former had the advantage of enabling participants to refer to relevant records or check information within the interview. Interviews lasted approximately 60 minutes. They were digitally recorded via 'Livescribe[37]' with verbatim transcripts prepared from the recordings for analysis.

As well as personal interviews, I also attended various webinars, seminars and workshops to observe co-innovation in practice, to collect additional data and to take soundings on my emerging thinking. I was involved in PIP-internal meetings with members of the project team as well as PIP-external meetings that drew on wider stakeholder involvement, such as the closing workshop or ThinkTank that took place in Wellington in September 2017, attracting some 60 delegates.

[37] Livescribe is the proprietary name of a digital recording system embedded in a pen that, if used in conjunction with associated notepaper, allows notes to be linked with recordings for ease of reference. As an aside, the novelty of the system was an effective ice-breaker, providing an early talking point.

3.1.3.4 Data analysis

Transcripts have potential to yield a wealth of data. So much so, Stake (1995) was prompted to observe that while audio recording and word-for-word transcribing is of value for catching respondents' actual turn of phrase, it may yield more material than can be coped with realistically. For example, as a guide Gillham (2008) suggests allowing at least ten times the time taken to complete the interview for the purposes of transcription and analysis. Almost thirty years ago, Dey (1993) saw a role for computers in assisting with the management of this process by speeding-up the recording and storing; filing and indexing; coding and retrieving of data (Page 57). Since that time, a number of specialist programmes have been developed. Of these, NVivo[38] provided me with a platform for managing, processing and analysing data.

While Thomas (2011) perceives as one of the joys of the case study the freedom it affords the researcher to roam through the data; with this freedom comes the danger of becoming lost or disorientated. To offset this risk, moving to and fro between the empirical and the theoretical helps to bring structure and maintain the focus of analysis. For me, this latter point was important since interviews were conducted over a twelve-month period, with follow-on data from the closing workshop at a later data still. Analysis was ongoing over this period, proceeding as described below.

The first step took the form of an initial read-through of each transcript, as it became available, while listening to the audio recording and cross-checking with any observations made during the interview (Gillham, 2008). Any necessary corrections were made before uploading finalised transcripts to NVivo. To structure subsequent investigations[39]. and ensure a consistent and methodical approach, a process of thematic analysis (Braun and Clarke, 2006) was then followed.

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[38] Proprietary qualitative data management and analysis software.

[39] Creswell and Creswell (2018, Page 198) describe a two-stage approach to qualitative analysis. Firstly, an initial analysis to familiarise the researcher with emerging data; a second stage, determined by the strategy of enquiry, involves, for example, application of: i) re-storying in narrative research; ii) analysis of significant statements in phenomenological research; iii) systematic steps of categorisation and coding in grounded theory; and iv) the contextualisation and analysis of themes in a case study.

In seeking to gain insight into how co-innovation was understood and operationalised and how its application anticipated scaling through a lens of Agricultural Innovation Systems (AIS) thinking, my analysis was informed by my theoretical perspective. Following Braun and Clarke's (2006) six steps, outlined in Figure 12, below, analysis was a recursive rather than linear process with writing an integral part of this process. In this way, my analysis and writing informed one-another and were, in turn, informed by an evolving understanding of my theoretical perspective.

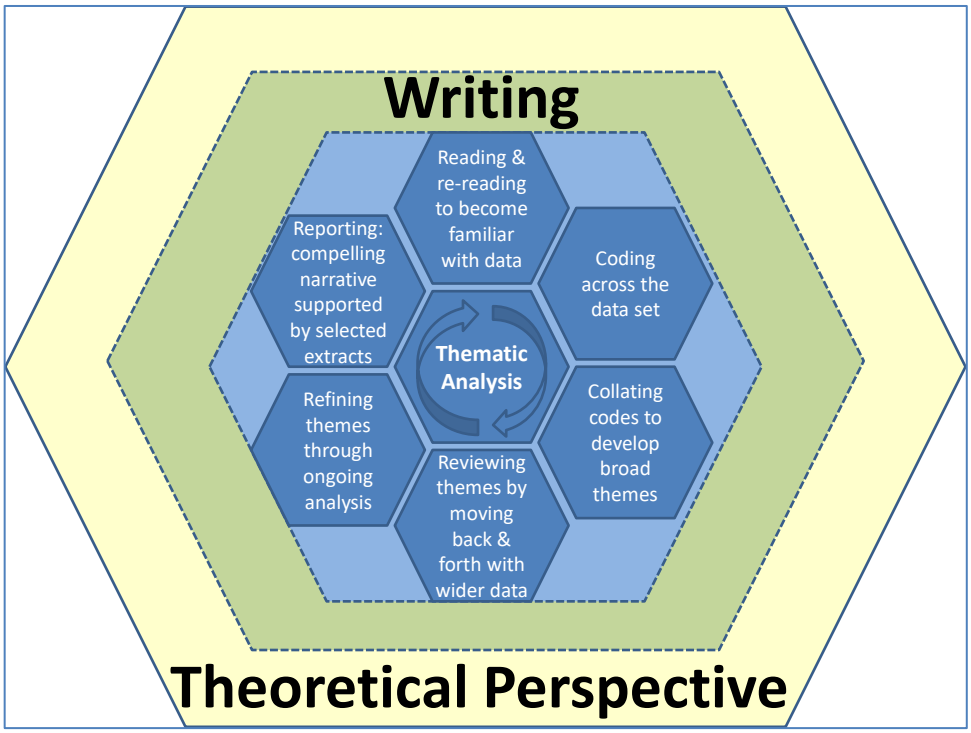

Figure 12 thematic analysis overview (adapted from Braun and Clarke, 2006)

An initial reading of the transcripts helped to inform the development and application of codes as a way of bringing some structure and consistency to the data. Over time, these codes were variously 'split' and 'spliced' (Dey, 1993) with some broken-down into component parts and others combined as broader themes emerged. In all of this, my aim was, as advised by Punch (2014), to make the data manageable without incurring the loss of either information or context. While coding provided a way of reducing the volume, the practice of memo-ing (Punch, 2014; Dey, 1993) provided a mechanism for capturing ideas as and when they emerged that may otherwise have become lost or subsumed. In this way, my analysis proceeded as an iterative process.

3.1.3.5 Interpretation

Commenting on the researcher's shifting roles[40] in the context of conducting a case study, Stake (1995) emphasises the value in developing sufficient self-awareness to recognise these different functions and the influence they exert. As well as reflecting on the researcher's role in the process, consideration is also required about the light cast on "something larger than the case itself" (Seawright and Gerring, 2008) and the question of generalising more widely from the findings. Unlike sampling research, the case is not intended to be representative of a wider whole (Thomas, 2011; Stake, 1995). It is, instead, something unique, deriving its strength from the breadth and depth of data supporting the conclusions (Yin, 2004) and generalisable "to theoretical propositions and not to populations or universes" (Yin, 2003, Page 10).

According to Thomas (2011, Page 192), the process of "tying it all together" represents the most enjoyable and rewarding part of the study while for Dey (1993) the process is akin to "making an omelette" whereby we end up with something quite different from our starting point (Page 30). In the process, Stake (1995) advises ruthlessly 'winnowing and sifting' in order to tell the reader only what needs to be told to address our research questions, leaving others to cover the remainder. This demands a careful balance to be struck between providing sufficient context to bring the case to life without allowing the background to overshadow the research findings. As Thomas (2011) indicates, this requires the researcher to adopt a discerning approach to the narrative, using the storyline to bring complex, and sometimes diverse, issues together in a coherent whole around the research questions.

3.1.3.6 Validation

On the one hand, the case study's flexibility is one of its strengths; on the other hand, this flexibility leaves it liable to criticism for being in something of a "curious

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[40] Stake (1995, Chapter 6) identifies the researcher as variously required to act as: i) teacher, with an obligation to their readers; ii) advocate, bringing a unique interpretation to the data but recognising their impact on the process; iii) evaluator, weighing-up diverse evidence to develop a rounded perspective; iv) biographer, allowing for the complexity of actors in the process; and v) interpreter, effectively communicating new understandings of complex scenarios to a diverse audience.

methodological limbo" (Gerring, 2004, Page 341). In addressing my research questions through a lens of Agricultural Innovation Systems thinking, for me, the appeal of the case study as a strategy of inquiry lies in its connection with systems thinking. As Thomas (2011, Page 173) notes, since the aim of the case study is "to try and avoid breaking-up a complex web of social activity, it fits naturally with the holistic emphasis" of systems thinking. To offset the criticisms and preserve the flexibility of the case study requires that "everything is weighed and sifted; and checked and corroborated" (Gillham, 2008, Page 32). Crucially, this includes asking the researcher to reflect on the possible influence they bring to bear on the process by considering "…what is the preferred picture as far as I am concerned?" (Page 27). All of this contributes to delivering and demonstrating the "trustworthiness" (Gillham, 2008, Page 25) of the case. This depends not on "intuition and good intentions" to identify findings in need of corroboration but on the application of "protocols and discipline", as outlined in Table 4, below (Stake, 1995, Page 112).

Data situation	**Need for triangulation**
Un-contestable description	Needs little additional confirmation
Dubious and contested description	Needs confirmation
Data critical to an assertion	Needs extra effort toward confirmation
Key interpretations	Needs extra effort toward confirmation
Author's interpretations, identified as such	Needs little confirmation

Table 4 Summary of data situation and the need for additional confirmation

A process of so-called member checking (Creswell, 2007) – whereby confirmation is sought from participants that emerging findings provide a true reflection in the light of their experience – provided me with a basis for triangulation, as indicated above. In practice, this involved a mix of more formal discussion of emerging ideas with stakeholders as part of the interview process as well as wider debate in project and programme meetings; and more informal exchanges with colleagues.

There are dangers in asking too much of a case and value in using the research questions to help maintain focus on specific aspects, leaving others to tell the wider story (Stake, 1995, Page 135). Reference to the research questions helps too in knowing when to bring a case to a conclusion. A challenge that, as highlighted by

Yin (2004), applies to all case studies and is made all the more complicated in the event that the 'case' of interest continues beyond the conclusion of the 'case study.' The closing ThinkTank that took place in Wellington in September 2017 marked the end-point of the Primary Innovation Programme, and a logical close for my own case study. The opportunity to attend this workshop was invaluable, to benefit from discussions among stakeholders and to take soundings on my own emerging ideas.

3.2 Closing remarks

The methodology is a reflective process requiring consideration of philosophical worldview, strategy of inquiry and research design (Patterson and Williams, 1998). In connecting the research questions and theoretical perspective with the findings and discussion, Punch (2014, Page 169) argues that the methodology provides the basis on which readers will judge how much confidence to place in the conclusions.

Reflecting on the opportunities afforded by a case study and the accompanying responsibilities for the researcher, Stake (1995) describes a nuanced, rather than formulaic approach. He emphasises the value in developing a "connoisseur's appetite" to distinguish between targets for interview that are not just available but informative and insightful while emphasising too the onus on the researcher to bring a well-informed and inquiring approach to the process. Stake (1995) also identifies practical considerations, noting the importance in respecting the "home grounds" of respondents (Page 57) and recognising the value in networking with other actors and perusing the press to gain a broader perspective. All of this, Stake argues, adds up to make the case something special that, as Gillham (2008) notes, has the potential to provide a window on "human activity" in the context of the "real world" (Page 1).

This combination of depth of insight and appreciation of broader context opened-up by a case study design, enabled me to address my research questions and to explore the in-field dynamics of co-innovation and scaling. To set the scene, I use the next chapter to outline New Zealand's agri-food sector before presenting and discussing the empirical data from my study of the case of the Primary Innovation Programme and the Heifer Rearing and Water Use Efficiency projects in the chapters that follow. I then draw together my collective findings in the Discussion and Conclusions.

Intermezzo, evolution of NZ's agri-food sector

In the spirit of 'Ka Mua, Ka Muri' – the Maori understanding of walking backwards into the future, unable to see what is to come but guided by what has gone before – this chapter reflects on the evolution of NZ's agri-food sector. A place that plays an important role in the sector's development is Ruakura Agricultural Centre. Now home of AgResearch, visitors[41] are met by a picture, Figure 13, commemorating the life and work of Dr Di Menna [1923-2014]. Her pioneering studies on Facial Eczema (FE), widely credited as establishing Ruakura's reputation for science excellence, came in response to a devastating outbreak in 1938 threatened the viability of NZ's ruminant sector (Di Menna et al., 2009). During the time I spent at Ruakura in 2014/15, work on FE was ongoing, reflecting the extended time-frames of agricultural research activities but highlighting too much that has changed. The work was part of a three-year project looking at on-farm measures to control FE in beef cattle, led by local farmers Steve and Sandra Parrott under a wider Beef & Lamb NZ initiative. It was supported by Franklin Vets and Gallagher Livestock Health with science input from AgResearch. As results emerged, interest among neighbouring farmers and advisors increased and each year's Open Day attracted a growing number of attendees, prompting a Senior Scientist from AgResearch to observe: "It was a good team of people to work with, no egos, everyone willing to listen to the viewpoints of everyone else." In many ways, an example in all but name, of co-innovation in practice. A sense of regret was, however, voiced that amidst the ongoing structural changes shaping NZ's science sector, the momentum of Dr Di Menna's early work had been lost to make the project, and others like it, necessary. This chapter considers these changes.

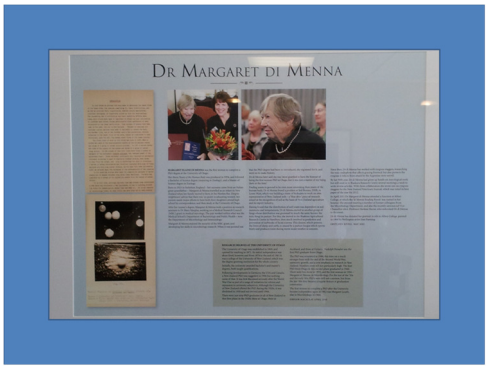

Figure 13 Tribute to Dr Di Menna (AgResearch, Ruakura 2015)

[41] For virtual visitors, AgResearch has an on-line archive at: https://agresearch.recollect.co.nz/.

Chapter 4: New Zealand, a context of change

Undiscovered until about one thousand years ago and the last large land mass to be settled, New Zealand's (NZ) agricultural sector has subsequently evolved at an accelerated pace, punctuated by a series of critical events that have informed development and, on occasion, prompted radical re-orientation. Implementation of sweeping reforms in the 1980s, for example, represent a watershed that continues to inform the sector to this day. At the time of their introduction they tested the sector's resilience and prompted a search for new opportunities to capitalise on NZ's relative competitive advantage, resulting in a particular focus on grass-fed milk production that has contributed to development of a diverse range of dairy products, exported around the world and widely promoted on the strength of the country's 'clean and green' image. More recently, however, growing levels of concern about the impact of farming activities on the natural environment have threatened to undermine NZ's clean and green credentials. How the country responds is expected to go a long way towards determining the next stage in the development of its agri-food sector.

4.1 Phased agricultural development

Lying on the so-called Ring of Fire[42] in the South-West Pacific, midway between Antarctica and the Equator, NZ was "the last large landmass found by human settlers" (Glasby, 1991, Page 63) with the arrival of Polynesian explorers around one thousand years ago marking the end of some 80 million years of isolation. NZ's subsequent evolution has been compressed into a relatively short timeframe[43] (Molloy, 1980), characterised by an accelerated pace of development (King, 2003).

Early settlers found a country rich in natural resources, much of it unique to NZ. Free from predatory mammals, native forests were, for example, alive with birdlife, including large populations of flightless Moa (Molloy, 1980). Rather than the benign

[42] Earning NZ the soubriquet of 'the shaky isles.'

[43] Compared, for example, with human activity that dates back over 200,000 years in the British Isles, and over one million years in China (Glasby, 1991).

presence sometimes portrayed, with their survival dependent upon these unfamiliar surroundings and on the adaptability of the resources they brought with them[44], early settlers soon began to impact on the environment (Glasby, 1991; Molloy, 1980). Trees were cleared to make way for settlements and to enable land to be cultivated; through a combination of hunting for meat and harvesting of eggs, Moa were driven to extinction; and the dogs and rats that accompanied the incomers further disrupted native wildlife. By the time Maori descendants of early settlers came to a better-developed understanding of the inter-dependence of their lives with the natural world[45], the environment had been irrevocably altered. In the years that followed, just as early settlers' hunted Moa to extinction so, King (2003) argued, those that followed would repeat a similar "pattern of behaviour many times over" (Page 128).

Indeed, it would be repeated as early as the mid-nineteenth century[46] when a second wave of settlers, this time from Europe, heralded the start of a so-called "frontier era" (King, 2003, Page 127). New arrivals brought fresh resources to clear land in order to make way for farming activities that aligned with their European ideals and, in the process, all but drowned-out emerging Maori concepts of stewardship, ushering-in a century of agricultural development. This ongoing evolution, unfolding alongside the development of NZ itself, has been characterised, as shown in Table 5, below, by phases of exploitation, expansion, early intensification, diversification and later intensification (MacLeod and Moller, 2006; Glasby, 1991; Molloy, 1980).

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[44] Huambachano (2018), for example, describes a lasting reverence among Maori for the kumara on the basis of its ability to flourish in NZ while other crops brought-in from Polynesia failed to thrive.

[45] As understood, for example, by Te Mana o te Wai that describes the relationship between the health and life-force of water, environment and people (Gluckman in New Zealand's Fresh Waters, 2017).

[46] King (2003) relates how Abel Tasman of the Dutch East India Company led two of the company's trading vessels on an expedition from Mauritius in search of commercial opportunities in Southern Australia. The ship's journal records that the party arrived instead in New Zealand, weighing anchor off the North Island on 18 December, 1642. An encounter with local Maori resulted in casualties on both sides and, under orders not to engage in warfare with natives, the Dutch vessels withdrew. They continued their exploration of the coast but not having identified a suitable harbour and concerned by the perceived hostility of the native population, sailed away on 6 January 1643. More than 100 years later, in 1769, Cook's arrival on behalf of the British Royal Navy marked the next encounter between New Zealand and the outside world, representing the start of a new period in the country's history.

Phase of development…	Characteristics	Context	Wider background
Exploitation: c. 1840-70	* native grassland burnt-off to carry increased sheep; * insufficient inputs result in depletion of grazing value	Early European settlers, drawn by plentiful seal and whale resources, turn attention to the land, triggering land-wars with Maori population for next 20 years, Maori belief in collective ownership at odds with incomers' ideals of private ownership. By 1860, believed that Maori population is outnumbered by 'pakeha[47] ' (settlers).	Treaty of Waitangi signed transferring sovereignty to the British Crown[48] (1840)
Expansion: c. 1880s	* native forest cleared for grassland; * refrigerated shipping enables exports of meat and dairy; * booming wheat price triggers increased planting causing soil depletion	Resolution of land wars brings further land clearance for farming. Infra- structure develops e.g. telephone and railway networks; refrigerated shipping sees first shipment of NZ lamb reach London in 1882. A growing sense of national identity develops as evidenced, for example, by first All Blacks rugby team, 1905.	New Zealand the first sovereign state to give women the vote (1893)
Early intensification: from early 1900s	* soil science better understood; * advances in genetics of livestock, crops and grass; * stocking density increases with corresponding increase in production	NZ fights alongside Allies in both World Wars contributing troops & maintaining shipments of food. Great Depression (1920-1930's) encourages spirit of self-sufficiency. Increasing pressure on natural resources prompts emphasis on science-driven agricultural improvement with emergence of farm advisory service.	Gallipoli landings (April, 1915) commemorated each year thereafter as ANZAC Day
Diversification: from mid 1900s	* improving control of pests and diseases; * horticultural, deer, goat, and forestry sectors established; * aerial top-dressing, electric fencing and plastic water pipes increase use of marginal hill country	'Save Manapouri' (1969), regarded as first national conservation project, prompts debate on relationship between people and the country's natural resources. NZ has to develop new markets when UK joins EEC (1973). Waitangi Tribunal established in 1975 to adjudicate over alleged breaches of the original Treaty	New Zealander Sir Edmund Hillary's ascent of Everest (1953)
Later intensification: from early 1980s	* market reforms; * growing exports of processed milk products to Asia; * trend for conversion from extensive grass to grass-based dairy	Local government reform, deregulation of financial markets and end of farm support mechanisms (1980's). Electoral system reformed (1996) with move to proportional representation. In 1985, Waitangi Tribunal becomes effective retrospectively to allow for claims against Crown. Introduction of Resource Management Act (1991).	New Zealand signs Rio Earth Summit Framework on Climate Change (1992)

Table 5 Overview of agricultural development in NZ (adapted from: MacLeod and Moller, 2006; Glasby, 1991; Molloy, 1980)

[47] King (2003) writes that by the 1830s, the word 'Pakeha' was being widely used among Maori to identify NZ's non-Maori subjects and notes no evidence to suggest that it was derogatory

[48] NZ's independence subsequently achieved over an extended period via a series of incremental steps

4.2 Reform and restructuring

Despite NZ's remote location[49], far from potential suppliers and target export markets, as in so many ways, NZ put its own stamp on things and by the turn of the twentieth century the country was embracing its role as "London's Farm[50]" successfully using agriculture rather than industrialisation as a route to modernisation and redefining the relationship between colony and coloniser (Barnes, 2012). In the process, farming came to be understood as the very "lifeblood of the country" (Ford 2013, Page 161) and while it has retained a special place in NZ's national identity, it is subject nowadays to an increasingly critical gaze (Gray and Le Heron, 2010).

4.2.1 Drivers of change

The Great Depression of the 1920s highlighted NZ's exposure to global market forces and the risks of relying on a relatively limited range of exports to a small number of distant markets. Concerns receded after the Second World War, as advances in farm husbandry and the application of scientific knowledge contributed to the increased productivity of NZ's farms at a time of improving world prices. For example, institutional support in the form of advisory and development programmes encouraged good practice; while technological progress such as the aerial application of artificial fertilisers, advances in electric fencing, and increasingly sophisticated genetic selection of livestock opened-up new opportunities (Dodd et al., 2008). With relatively unrestricted access for its meat, wool and dairy products to the markets of the United Kingdom (UK), NZ's agri-food sector enjoyed a so-called "long boom" (Haggerty et al., 2009, Page 769). In the 1960s, however, NZ's vulnerable position was once again exposed as the UK signalled its intention to apply for membership of the European Economic Community (EEC) (Campbell, 2009; King, 2003).

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[49] A distance that, it is claimed, prompted the philosopher, Karl Popper, to remark on his appointment to the University of Canterbury in Christchurch, New Zealand that New Zealand is "not quite the moon, but after the moon it is the farthest place in the world" (King, 2003, Page 417).

[50] More broadly, Barnes (2012) reflected how, to an extent, NZ appropriated London and in the process redefined the relationship between colony and coloniser, shrinking the 12,000 miles between the United Kingdom and New Zealand as each shaped and responded to the other.

Concerns were such that NZ's then Prime Minister, Keith Holyoake was moved to alert his British counter-part, Harold MacMillan, that safeguards would be needed if NZ's economy was to be protected from ruin[51] (The Economist, 2017). Britain, having pledged to protect NZ's interests, provided a bridge-head for NZ to develop trading relationships with continental Europe. Underlying structural problems, however, stemming from the introduction of economic instruments in the aftermath of the First World War, led to difficulties for NZ's economy in the years after the UK's entry to the EEC (Hall, 2017). Over time, these instruments had become increasingly politicised and increasingly detached from the realities of global markets (Sandrey and Scobie, 1994), leaving the supply of agricultural products out of step with demand, prices detached from market value, and decision-making processes working to the detriment of long-term economic development (Vitalis, 2007). Something had to give and in an effort to rekindle the growth that had previously characterised NZ's farming sector, various reforms were trialled by different administrations but without the desired success (Haggerty et al., 2009).

4.2.2 Radical reform

In 1984, a tipping point was reached. A currency crisis highlighted the urgent need to "correct a distorted structure of incentives and restore competitiveness" (Sandrey and Scobie, 1994, Page 1041) thereby triggering an unprecedented programme of radical, neo-liberal reform that has shaped today's agri-food sector in NZ (Smith and Montgomery, 2004). Production subsidies and price support mechanisms were withdrawn; subsidised loans for land improvement and irrigation development were reformed; the tax system was overhauled and farming-related exemptions were lost; the Ministry of Agriculture, including its established extension services, and single product export desks were restructured (Haggerty et al., 2009). Reforms were not restricted to farmers, government-funded research providers too were variously

[51] In something of a reversal of fortune, it is the UK's agri-food sector that is contemplating an uncertain future, outside the Common Agricultural Policy (CAP) of the European Union (EU) although Helm (2017) has described the opportunity to break with the CAP as representing a "once in a generation opportunity" (Page 124) to forge bespoke farm policy that determines the sector's future.

"corporatized, rationalized, and reorganized into Crown Research Institutes" (Le Heron and Roche, 1999, Page 207). By stripping away market interventions, reforms sought to incentivise the sector to become more responsive to market signals (Vitalis, 2007; Lattimore, 2006) and, at the time of their introduction, were broadly welcomed by a farming sector that recognised the need for change. In the years immediately afterwards, however, world commodity prices fell, NZ's terms of trade worsened and domestic inflation and interest rates rose. This translated into falling incomes and rising costs for farmers and contributed to a wider rural downturn (Wilson, 1995).

Initially, farmers fell-back on what they knew best, seeking to increase output and farm their way through (Haggerty et al., 2009) but by 1986, land prices[52] were tumbling and "the real incomes of sheep and beef farmers (those with the highest output subsidies) were down 60% on the previous year. Meanwhile, dairy farmer incomes fell 25%, mainly as a result of rising debt servicing costs and the removal of fertilizer subsidies" (Lattimore, 2006, Page 8). In 1986, an estimated one in three of NZ's farmers marched on parliament in protest at the pace and impact of reform, Figure 14[53]. With the surprise backing of Federated Farmers[54], the government of the day held fast (Smith and Montgomery, 2004) and for an industry that had, hitherto, enjoyed considerable political influence, this was an especially bitter pill to swallow (Dodd et al. 2008).

Figure 14 Farmers' protest march, Wellington 1986

[52] By 1987, land prices would be 50-65% lower than their 1982 peak (Lattimore, 2006).

[53] Ben Schrader, 'Parades and protest marches - Protest marches, 1980s to 2000s', Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/photograph/21120/ cockies-come-to-town (accessed 23 February 2018).

[54] Federated Farmers, a national industry group for NZ's pastoral farmers, lent government its support on the promise of reduced tariffs on imported farm inputs (Smith and Montgomery, 2004).

It has been suggested that five per-cent of commercial farmers went out of business in the wake of the reforms, some taking-up government-funded schemes to support their exit from the industry. Those that remained in the sector took steps to cut-costs by reducing inputs, postponing investments, cutting staff costs, utilising government-backed credit schemes, finding off-farm employment, and diversifying into farm tourism and alternative enterprises, and in some cases, selling-off parcels of land for development (Haggerty et al., 2009; Lattimore, 2006). For others, it was the frontier-spirit characterised by the adaptability and resilience of the family farming structure that enabled them to weather the storm (Smith and Montgomery, 2004).

It would take 20 years, almost a generation, for those that endured to begin seeing markets transform, farmland values recover and productivity increase. Although reforms exposed farmers to market forces and meant having to cope with cyclical problems, such as exchange rate fluctuations, it has been argued that NZ's farmers "…now know that business life without major subsidies anywhere in the private sector is not perfect but it is as good as it gets" (Lattimore, 2006, Page 2).

4.2.3 Dairy intensification

Among the structural changes prompted by reform was a shift away from beef and sheep production in favour of dairying[55] (Vitalis, 2007). Sometime later, reforms under the Dairy Industry Restructuring Act[56] (2001) saw consolidation of multiple smaller co-operatives and enabled the formation of Fonterra (Evans, 2004), NZ's largest dairy marketing co-operative with the critical mass to compete globally (Trechter et al., 2003). Fonterra has since become the "world's largest exporter of dairy products, responsible for about a third of international dairy trade" (McGiven, 2016, Page 17) and the sight of "New Zealand brands in the dairy chillers of foreign

[55] In the year 1984, meat accounted for 32% of NZ's agricultural exports by value, dairy for 22% and wool for 21% (Smith and Montgomery, 2004); in 2016, at NZ$13.5 billion, export earnings from dairy products were double those of meat, at NZ$6.6 billion (NZIER, 2017).

[56] Subject to comprehensive review since December 2017 (https://www.mpi.govt.nz/law-and-policy/legal-overviews/primary-production/dairy-industry-restructuring-act/dairy-industry-restructuring-act-2001-review/; accessed 05/12/2018)

supermarkets" has become familiar (Adrian Orr in ISCR Monograph, 2001, Page 1). NZ's export orientation has expanded in scope and tilted towards the emerging economies of Asia, and China in particular[57] (Saunders et al. 2017). In the process, Fonterra's presence has, arguably, become so dominant and its leading products so intertwined with dairy farming and NZ in 'brand NZ' that "thinking about New Zealand is to think about Fonterra; thinking about Fonterra is to think about New Zealand" (Gray and LeHeron, 2010, Page 1) and recent questions about its ability "to add value to its suppliers, its shareholders and the New Zealand economy" (TDB, 2018, Page 4) have, accordingly, reverberated beyond the agri-food sector.

Restructuring of NZ's dairy sector has not been confined to the processing sector. In 2007, DExcel merged with Dairy InSight to create DairyNZ, the industry-good, levy-funded body. There have also been changes at farm level as producers have taken advantage of new technologies such as high-throughput milking sheds and advanced irrigation systems, to expand and intensify their milking herds. As shown in Table 6, below, over the period 1980 to 2016, the trend has been one of a steadily, albeit slowing, increase in cattle numbers managed in fewer, larger herds.

Season	**1980/81**	**1990/91**	**2000/01**	**2010/11**	**2016/17**	**Difference 1980-2016**
National Herd (no. of head)	2,027,096	2,402,145	3,485,883	4,528,736	4,861,324	+2,834,228
Number of herds	16,089	14,685	13,892	11,735	11,748	-4,341
Average herd size	126	164	251	386	414	+288

Table 6 Trends in NZ's national dairy herd (source: LIC and DairyNZ, 2017)

Exploring the relationship between dairy farming intensity and enterprise profitability in NZ, Ma et al. (2018) found that moving to more intensive systems was associated with increased output and revenue but this was more than offset by

[57] Since signing a free trade agreement in 2008, China has become New Zealand's most significant export market, worth NZ$5.1bn in the 12 months to June, 2016 (Saunders et al. 2017).

increased operating costs, with a potentially negative impact on operating margins. Influences other than profitability were driving intensification and, in particular, managing risk; with producers replacing "farm-level production risk (that is reliance on grass growth) with financial risk (due to milk and feed price changes)" (Page 15). In the 2015/16 season, these financial risks were all too fully realised with farm-gate prices falling from NZ$8.90/kgMS to NZ$3.90/kgMS, as shown in Figure 15, below.

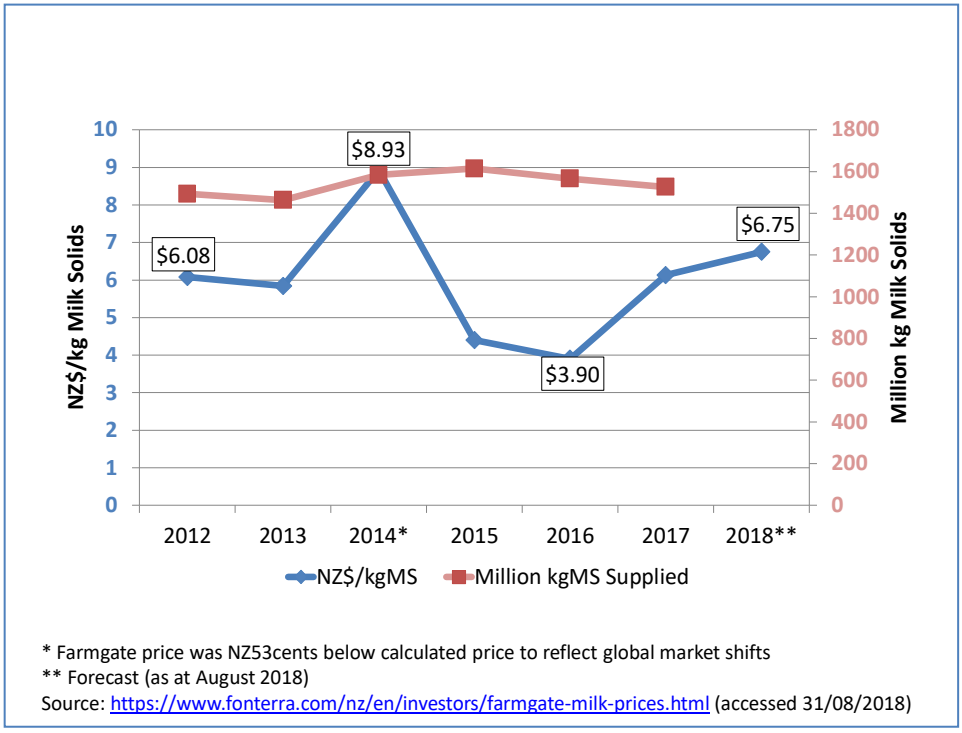

Figure 15 Trends in farmgate milk price and production of milk solids in NZ, 2012-18

Although prices have since improved, this dip highlighted the continuing exposure of NZ's dairy farmers to fluctuations in international commodity markets. Dairy NZ (2015[58]) estimated that the fall equated to NZ$150,000 in lost income for the average producer, impacting on cash-flow, spending and borrowing. Producers with borrowings to finance purchase of additional land or assets and new entrants, such as first-year share-milkers without accumulated reserves, were especially vulnerable.

[58] https://www.dairynz.co.nz/news/latest-news/support-for-dairy-farmers-ramped-up/

4.3 The 'clean and green' gap

Agriculture makes a major contribution, about half, to NZ's GHG emissions (Beukes et al., 2010 AEE). Since emissions from agriculture typically account for a small proportion of total GHG emissions in developed economies, the relatively high proportion of both GHG emissions from agriculture and export earnings derived from agriculture combine to make NZ's situation somewhat unique and to balance its farming activities with international emission reduction commitments, requires a bespoke approach (Saunders et al., 2006). A range of practical on-farm activities are already underway and, more widely, the Ministry for the Environment (MfE) consulted on its proposed Zero Carbon Bill[59] during 2018 and the New Zealand Productivity Commission (2018) reported on a large-scale project exploring options to enable NZ to transition to a low emissions economy that highlighted the need for a joined-up and innovative whole-economy approach. For the farming sector, this not only requires land use change but also improvements in both farm management and on-farm uptake of new technologies. To balance the seemingly "contradictory trajectories" (Haggerty et al., 2009, Page 776) of farming deregulation and delivering on the country's 'clean and green' promise[60] has prompted increased reflection on the environmental costs of NZ's neoliberal market reforms (Dodd et al., 2008; Smith and Montgomery, 2004) and fuelled calls to reassess NZ's dependence on dairying by investing in the wider innovation economy (Hendy and Callaghan, 2013).

4.3.1 Environmental impacts and dairying

Unlike the long-established European model, the dairy sector in NZ has developed relatively recently with significant growth in the last 30 years. In the absence of direct links made under the European Common Agricultural Policy (CAP) between environmental performance and eligibility for subsidies, NZ's government does not have the same leverage over producers (Doole and Romera, 2015). While NZ's

[59] http://www.mfe.govt.nz/have-your-say-zero-carbon

[60] A report for the Ministry for the Environment (2001) attributed a value of between NZ$241m and NZ$569m to the image of a clean and green New Zealand for exported products: https://www.mfe.govt.nz/publications/sustainability/valuing-new-zealands-clean-green-image.

dairy sector, and allied industries, make a valuable contribution to the economy at local, regional and national levels (Doole and Romera, 2015; Baskaran, 2009) it has, nevertheless, faced increasing levels of public criticism that have highlighted, in particular, detrimental impacts on: the landscape, through changes associated with farm development and conversion from extensive to more intensive production systems; air quality, through emissions of greenhouse gases (methane and nitrous oxide); soil health, through compaction, erosion and contamination; and run-off and nutrient pollution of surface and ground water supplies (Baskaran, 2009).

4.3.2 A wicked problem

The intersection of global market forces and local practice (Gray and Le Heron, 2010) has triggered disquiet with respect to the social (Holland, 2013), economic (McGiven, 2016) and environmental impacts of dairy intensification (Foote et al., 2015; Doole and Romera, 2015; Baskaran et al., 2010; Smith and Montgomery, 2004). Indeed, it has been argued (Foote et al., 2015) that "the cost to clean up effects will be far more than the costs of not polluting in the first place" (Page 9).

In the early 1990s, Glasby (1991) cautioned that "the delusion" of the "clean-green, beautiful-country image" (Page 76) risked obscuring farming's true effects on NZ's landscape. More recently, Clemens and Babcock (2004) observed a "strong, positive carry-over effect for New Zealand's agricultural products" (Page 7) of the 'clean and green' image widely used to promote NZ as a tourist destination while in their report 'The Land and the Brand', Saunders et al. (2016) suggested that a strong 'brand NZ' would be vital in delivering future growth of agricultural value chains. Comments made by Sir Charles Godfray, Director of the Oxford Martin School, during a visit to NZ and reported by NZ media (2018) pointed-to an apparent disconnect requiring "…the reality of the sustainability of New Zealand agricultural land … to catch up with perception, at least abroad" where consumers have an image of "a pristine and

wonderful environment." The fragility of global brand image and the potential risks of a perceptual gap, have been all too vividly demonstrated by recent events[61].

NZ's agri-food sector, and the dairy sector in particular, are seen as being vulnerable with respect to their greenhouse gas (GHG) emission profile and impacts on water quality (Foote et al., 2015). Addressing these issues in isolation is complex but when combined with a drive to increase export earnings and improve economic returns, the resulting challenge has all the characteristics of a so-called wicked problem (Duncan, 2017; Doole and Romera, 2015; Aerni, 2009; Baskaran et al., 2009).

4.4 Closing remarks

Reflecting the extent of change, recent developments in NZ's agri-food sector may be book-ended by McMeekan's (1961) 'Grass to milk: a New Zealand philosophy' and, some fifty years' later, Hendy and Callaghan's (2013) "Get off the Grass…" The former highlighting the benefits of harnessing milk from grass as the basis to build competitive advantage in overseas markets; and the latter arguing for less reliance on dairying and greater diversity in NZ's economy. In between times, NZ's agri-food sector has intensified and globalised. State legislation has been rolled-back but market governance, in the form of supply-chain audits and production protocols has rolled-in (Haggerty et al., 2009; Jay, 2007). Rather than deregulation, some have argued that NZ's experience will prove to be one of *re*-regulation (Le Heron and Roche, 1999) with the sector's future direction of travel informed by the requirements of globalised agri-food value chains, bringing into focus the sometimes contested interactions between local and global.

[61] In August 2013, news that exports of milk powder from NZ were suspected of being contaminated with highly toxic *Clostridium botulinum* was met with "something approaching disbelief" (Government Inquiry, 2014). Further laboratory testing "established the contaminant as the non-pathogenic bacterium *Clostridium sporogenes (C. sporogenes)*, which causes food spoilage only" (Government Inquiry, 2014, Page 16) but the false alarm was sufficient to trigger a detailed inquiry. This found evidence of process shortcomings and a number of corrective actions were recommended. While there was widespread relief at the outcome, the incident showed: the importance of NZ's dairy sector to the national economy; the complex nature of global agri-food supply chains; the potential for rapid spread of news, and views, via social media; and the vulnerability of global brand image.

Former Prime Minister of New Zealand, John Key (2009) once remarked that: "When things are going well on our farms, this flows through into the small towns, the provincial cities, and into our big cities. Conversely, when the primary sector sneezes, the New Zealand economy catches a cold." As farming has moved away from its, albeit idealised, place at the heart of the rural community (Holland, 2013), it has, however, been criticised for seeing sustainability through a productionist lens and the environment in terms of "resources for production" (Page 273) rather than in a broader context of home, heritage and nature that resonates with the general public (Jay, 2007). The resulting gap between farms and the wider community[62] has contributed to a 'them and us' culture (KPMG, 2017; Smith and Montgomery, 2004; Le Heron and Roche, 1999) and despite transformations to "the way in which agricultural policy, research and extension was carried out" (Morriss et al., 2006, Page 29) to give improved accountability, this has not achieved the necessary join-up between stakeholders. Add to this, a complex legacy of "colonial dislocation" (Coombes, 2003, Page 335) between Maori and Pakeha[63], as reflected, for example, by continuing land claims arising from the Treaty of Waitangi, and disconnections in the agri-food sector of NZ run wide and deep.

In the next chapter I explore how the Primary Innovation Programme (PIP) is contributing to debate surrounding the challenges and opportunities for NZ's agri-food sector and seeking to seed change by better joining-up the innovation activities of diverse stakeholders through the application of a co-innovation inspired approach.

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[62] KPMG's annual Agri-food agenda (2017) reported that respondents (n=80) to their annual survey of industry leaders ranked the need to increase rural/urban understanding among their Top 10 priorities (ranked 8 in 2017 c.f. 23 in 2016). While concerns with respect to water quality that featured so strongly in the country's 2017 General Election campaign were felt to have heightened awareness of this disconnect, the report points-to wider-ranging concerns, such as aspects of animal welfare. These reflect a growing proportion of the general population without family ties to farming and increasingly effective campaigns that have mobilised support via social media channels. The report emphasises the need to build bridges between these two communities by making links between food and farming, highlighting progress being made on environmental measures and emphasising farming's role as the backbone of the country's economy in the hope that some common ground will be established.

[63] King (2003) writes that by the 1830s, the word 'Pakeha' was being widely used among Maori to identify NZ's non-Maori subjects and notes no evidence to suggest that it was derogatory.

Intermezzo, co-innovation in a NZ context

In September 2017, some 60 or so representatives of the public and private sectors in NZ and beyond gathered in Wellington for a two-day workshop as part of the Primary Innovation Programme (PIP). While reflections on lessons-learned over the previous five-years marked the end of one stage, discussion of how best to achieve transformative change in years to come, signalled the start of the next.

Drawing to a close in the background was NZ's hard-fought general election. A defining theme of the campaign was fierce debate about the country's natural resources. Although the incumbent administration had been actively engaged with this issue[64], it was proposals for a Freshwater Policy[65] from Jacinda Ardern, incoming leader of NZ's then opposition Labour Party, that caught the public imagination and prompted wider consideration among New Zealanders' about their relationship with the environment. Despite broad agreement on the need to protect the country's natural resources, opinion was divided between those arguing in favour of increased regulation or self-regulation with a broad-spectrum of views in between.

Given the farming sector's heritage and continuing importance to export-earnings together with its environmental footprint and contribution to above-average national greenhouse gas emissions[66], interactions between farming and the environment are at the heart of this debate. A rebalancing is, however, needed to address the challenge of increasing agricultural productivity and improving environmental outcomes[67].

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[64] Time-lag between introducing mitigating measures and evidence of improvement (Duncan, 2017).

[65]. Dubbed a "water tax" by NZ's media for the proposed levy on commercial users, since coming into office in coalition with NZ First, proposals have been modified although the debate continues. (see, for example: https://www.economist.com/news/asia/21731435-government-data-suggests-60-rivers-and-lakes-are-unswimmable-dairy-farming-polluting-new, accessed 05/04/2018).

[66] Themes reflected by NZ's Prime Minister, Jacinda Ardern ahead of the Commonwealth Heads of Government Meeting in London, 2018 "The Commonwealth can kickstart a global offensive on climate change" (https://www.theguardian.com/commentisfree/2018/apr/18/commonwealth-global-climate-change-new-zealanders, accessed 18/04/2018).

[67] NZ's National Statement of Science Investment (NSSI).

By way of illustrating the complexity of this challenge, some delegates in the workshop highlighted the apparent mismatch between the dairy industry and the environment. Describing how, in 2002, a sector perceived as prioritising productivity over the environment had prompted accusations of 'Dirty Dairying[68].' As stakeholders' adopted increasingly polarised positions, the joined-up response needed to address the issue became more difficult to achieve and delegates were in agreement that re-framing the problem would be critical for this deadlock to be broken and diverse groups brought together to address a shared problem.

Commissioned in 2012 and inspired by work from The Netherlands, the PIP applied a co-innovation inspired approach with the aim of facilitating a more joined-up response to complex problems, such as 'Dirty Dairying', in NZ's agri-food sector. One element of the project looked at the theoretical perspective, another at in-field application and they in turn, informed wider stakeholder interactions. Rather than a blueprint for action, the PIP held space to allow for different paths, at different rates of travel. For participants, involvement was characterised by a mix of uncertainties, wrong turns and occasional break-throughs. This experience informed shared learnings and contributed to the emergence of so-called 'co-innovation kiwi-style[69].'

At the close of the ThinkTank, there was greater understanding of co-innovation among delegates and an appreciation of the challenges and opportunities associated with its application in a NZ context. There was also an apparent willingness among stakeholders to apply the principles, as appropriate, in their respective fields. By so doing they would be helping to embed co-innovation in NZ, building-on the learnings from the PIP, and contributing to the project's legacy. The challenges and opportunities accompanying the early application of a co-innovation approach and its subsequent scaling in a NZ context are the focus of the chapter that follows.

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[68] Holland (2013) reflected how the Dirty Dairying Campaign, initiated by Fish and Game in 2002 in response to rising levels of concern about freshwater quality in NZ's streams and rivers, captured the popular imagination with the phrase, Dirty Dairying, entering "the New Zealand lexicon" (Page 64).

[69] Sourced from Professor Laurens Klerkx's opening remarks, Wellington, 2017.

Chapter 5: Primary Innovation Programme, a more joined-up approach to innovation activity

The previous chapter charted the accelerated pace of change that has shaped NZ's agri-food sector over the last century. This has given rise to opportunities in the form of new and expanded home and export markets as well as contributing to challenges such as a growing disconnect between farming and the wider community, pressure on the country's natural resources and adverse impacts on the environment. In response to questions about the ability of prevailing institutions to accommodate these changes and, in particular, concerns about NZ's competitive rather than collaborative research culture, in the year 2012, the Primary Innovation Programme (PIP) was commissioned. Inspired by work from The Netherlands, this brought a more joined-up, co-innovation approach to the complex issues facing the sector.

The PIP consists of three, interconnected streams of activity: i) Stream 1, theoretical framework informed by three ex-post studies; ii) Stream 2, in-field application through five ex-ante projects; and iii) Stream 3, liaison with a wider Community for Change (CfC). In this chapter, the ex-post (Stream 1) and ex-ante innovation projects (Stream 2) are outlined. The former not only illustrating the potential for transformative gains, over sometimes extended timeframes, but also highlighting a dependence on windows of opportunity as a pathway to scale; the latter seeking to create these opportunities and, in the process, demonstrating that operationalising a co-innovation approach is as much about mind-set as method. The main focus of this chapter, however, is Stream 3; stakeholder engagement via the CfC and the accompanying synergies and tensions as co-innovation meets prevailing institutions.

This chapter begins by framing the PIP in the light of a science system adjusting to the changes of recent decades while at the same time facing-up to the pressing challenge of balancing increased agri-food productivity with improved environmental outcomes. Against this background, the PIP's structure is outlined and learnings are discussed. While the focus of this chapter is on the overarching programme-level; the chapters that follow zoom-in on two of the in-field projects, to provide an all-round perspective on the application of co-innovation in a NZ context.

5.1 Context of the case: an innovation system in flux

As Chief Science Advisor to the New Zealand Prime Minister (from 2009 to 2018), Professor Sir Peter Gluckman (2015) has commented on the changing nature of scientific research in NZ and, in particular, on the uncertainties arising from the introduction of new practices and technologies[70]. These changes are global but their impact is shaped locally by a country's prevailing research culture. In NZ, Professor Gluckman argued that this culture largely reflects the country's relatively small population[71], land-based economic heritage[72] and keen spirit of self-reliance[73]. While NZ maintains a long-standing stake in various international collaborations[74]; at home, its research sector has increasingly been defined by competition rather than co-operation (Turner et al. 2015; Davenport and Bibby, 2007; Edmeades, 2004).

5.1.1 History of fast-paced change

Prior to the 1970s, NZ's science system broadly mirrored that of post-war UK with government-funded research, beyond the universities, conducted by government departments (Devine and Webb, 2004). Calls for change came, however, as NZ's economic performance worsened relative to that of other OECD (Organisation for Economic Co-operation and Development) countries. In 1984, a wide-ranging

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[70] For example, the shift from a problem-driven to mission-led approach sees familiar, quantifiable and time-bound measures replaced by new levels of scientific freedom; and the increased application of big-data that places new and emerging responsibilities on researchers (Gluckman, 2015).

[71] In June 2017, NZ's estimated population was 4.8m (https://www.stats.govt.nz/topics/population/, accessed 12/04/2018). The relatively small population has long encouraged an outward-looking, trading orientation (Gluckman, 2015). With respect to the science sector, concerns have been expressed about capacity for internal peer review (Gluckman, 2015; Leitch and Davenport, 2005).

[72] Largely founded on the country's land-based industries, NZ's economy has developed without the "research intensive" (Gluckman, 2015; Page 129) defence, pharmaceutical and heavy-manufacturing sectors that elsewhere create diverse opportunities at multiple levels for career researchers.

[73] A culture of resourcefulness, sometimes described as a make-do and mend or "No. 8 wire mentality" (Rinne and Fairweather, 2012, Page 176) encourages a spirit of inventiveness at an individual level but is not always conducive to a collective approach to long-term problem-solving (Gluckman, 2015).

[74] For example, since its inception in 2009, NZ has had an active role in the Global Research Alliance on Agricultural Greenhouse Gases, exploring technologies and practices that will inform increased food production without increased output of GHG emissions (http://www.nzagrc.org.nz/).

programme of public-sector reforms saw government's research and policy functions separated and contestable funding introduced (Edmeades, 2004). These changes were only the first of many, as outlined in Appendix XII, prompting Leitch et al. (2014, Page 128) to describe NZ's science system as being "in a state of flux." Although not unique in restructuring its science sector, this rapid, sometimes described as remarkable, pace of reform in NZ gave rise to uncertainty (Davenport and Bibby, 2007). For example, a shift in focus from pure to strategic science thinking (Leitch and Davenport, 2005) contributed to concerns that long-term science objectives were at risk of being over-shadowed by short-term economic objectives (Leitch et al., 2014; Edmeades, 2004). At the same time, increasingly blurred boundaries between science and commerce were prompting calls for scientific independence to be protected from undue commercialisation (Leitch et al., 2014).

In a structural and functional[75] analysis of the country's agricultural innovation system, Turner et al. (2015) identified underlying, systemic problems. As shown in Table 7, below, these were described as: i) competing rather than complementary research agendas; ii) fragmentation within and between sectors; and, iii) funding mechanisms geared towards the conservative rather than entrepreneurial.

Over-arching logic	**Characteristics**
Competitive science in silos	Largely un-coordinated – and sometimes competing – innovation agendas and activities within and between sectors
Laissez-faire innovation	High proportion of SMEs and non-interventionist government approach has left gap in support, and capacity, for higher-risk entrepreneurial activities
Science-centered innovation	Contestable funding mechanism and commercial-drivers for CRI's encourage focus on revenue generation through science-driven knowledge development

Table 7 Overarching logics in NZ's agricultural innovation system (adapted from Turner et al., 2015)

[75] Wieczorek and Hekkert (2012) described seven functions (entrepreneurial activities, knowledge development, knowledge diffusion, guidance of the search, market formation, resource mobilisation, and creation of legitimacy) and four structural dimensions (actors; institutions; interactions and infrastructure) as the basis for understanding the performance and problems of an innovation system.

With divisions threatening to make "antagonists of colleagues that should be collaborators" (Davenport and Bibby, 2007, Page 188) and research institutes increasingly competing with "the industries they were designed to work with" (Edmeades, 2004, Page 90) there was growing realisation that innovation activity was being constrained and recognition that business-as-usual was not sustainable (Turner et al. 2013).

5.1.2 Strategic direction

In 2015, the Ministry for Business, Innovation and Employment (MBIE) published a National Statement of Science Investment (NSSI) to address concerns that NZ's "science investment system is more complex than it needs to be" (MBIE, 2015, Page 27) and provide longer-term strategic direction. Outlined in Appendix XIII, the NSSI envisages a simple, transparent, stable and high performing science system. Building on Mātauranga Maori[76], the body of knowledge developed by NZ's Maori population, the NSSI reflects the links between farming and the environment, at the same time recognising the challenge of increasing productivity from the former while protecting the latter[77]. In his Foreword, then Minister of Science and Innovation, Steven Joyce, confirmed Government support for continued science[78] investment with the aim of building-on NZ's reputation for ingenuity to deliver improved levels of "productivity, prosperity and wellbeing" (Page 4). Under the NSSI, work to encourage a more joined-up approach to problem solving has seen 'collaboration' embedded in the National Science Challenges (NSC) and among initiatives informing this commitment is the Primary Innovation Programme (PIP).

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[76] Vision Mātauranga is MBIE's policy framework to encourage wider appreciation of Mātauranga Maori; Kaitiakitanga is an approach to engaging with the environment based on these principles.

[77] In the NSSI, the "critical" (Page 39) contribution of primary production to NZ's economy is recognised; there is commitment to maintaining government funding but this will shift towards generation of new ideas with industry back-filling any shortfall in close-to-market research; with respect to the environment, investment is pledged to the "information and evidence base" (Page 45).

[78] NZ's gross domestic expenditure on R&D (GERD) as a percentage of GDP for 2015 was 1.3%, as reported by the OECD and below that, for example, of Great Britain, 1.7% and the Netherlands, 1.9% (http://www.oecd.org/sti/inno/researchanddevelopmentstatisticsrds.htm, accessed 12/04/2018).

5.2 The case of NZ's Primary Innovation Programme

Commissioned in 2012[79], the five-year PIP spanned NZ's pastoral, horticultural and forestry sectors. By applying an "AIS inspired co-innovation approach" (Botha et al., 2014, Page 220) to the problems facing NZ's primary sector, the project aimed to enhance understanding of the theory and operationalisation of co-innovation through shared knowledge, experience and learning. As illustrated in Figure 16, below, the PIP consisted of three interconnected streams of activity while a commitment to learning and reflexivity encouraged knowledge sharing via, for example, seminars and webinars, a project website and newsletter.

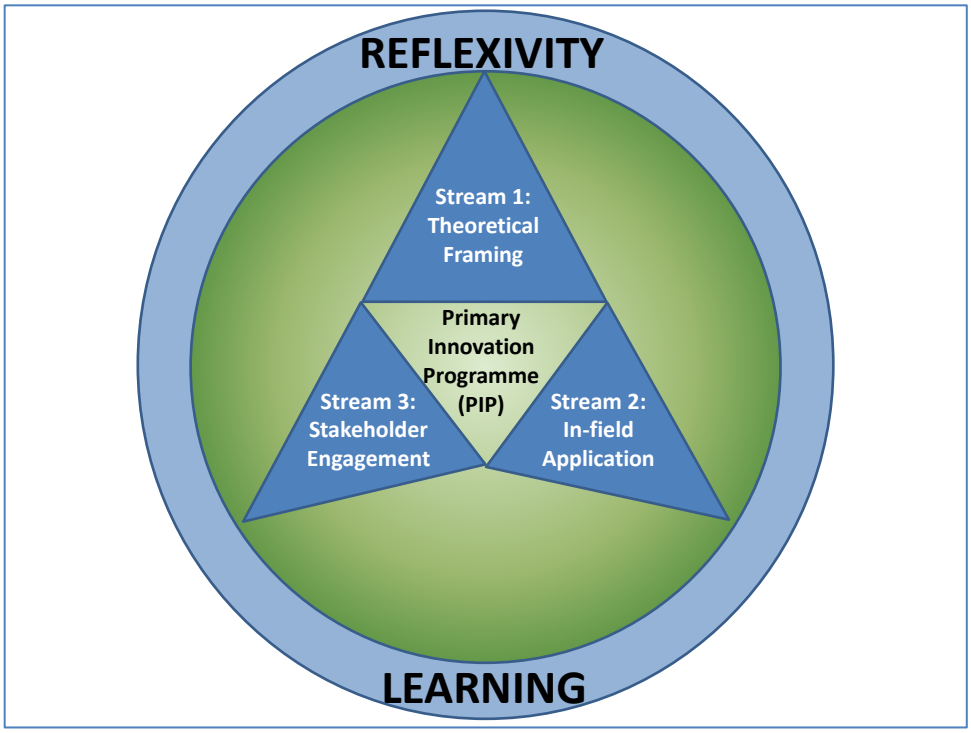

Figure 16 The three streams of the Primary Innovation Programme (PIP)

Co-ordinated by AgResearch, the PIP involved a wider community of CRIs, levy-bodies and consultancies as well as universities from NZ, Australia and Europe, and representatives of NZ's agri-food processing sector and its grass-roots producers. A

[79] NZ$7.5million of MBIE funding over a five-year period supplemented by an additional NZ$0.35million through the Strategic Science Investment Fund to support Vision Mātauranga, NZ$0.75 million of industry funding from Dairy NZ and NZ$0.90million of wider, in-kind funding.

total of 26 researchers from 11 organisations were directly involved in the PIP with a further 22 organisations that were indirectly connected. The PIP also supported this and one other PhD[80]. The focus of Stream 1 was on the underpinning theoretical framework, informed by ex-post analysis of three projects[81] through an AIS lens; Stream 2 put theory into practice via five, live projects with accompanying ex-ante analysis; and, Stream 3 facilitated engagement with a wider, so-called 'Community for Change' (CfC) comprising approximately 50 stakeholders variously representing some 20 industry, research and government bodies.

5.2.1 Sources of information on the Primary Innovation Programme

Through using case study as the strategy of inquiry, it is possible to approach a complex issue from a number of different angles with a view to gaining a rounded perspective (Thomas, 2011). Accordingly, as shown in Table 8, below, I took soundings from a broad mix of respondents made up of some actively involved in delivering the PIP, identified as PIP_ProjectTeam, and members of the wider stakeholder community, labeled as PIP_Stakeholder. My thinking was also informed by interviews more directly connected with the Heifer Rearing (HR) and Water Use Efficiency (WUE) projects. In addition, being based with AgResearch at Ruakura in New Zealand for a period of 12 months provided me with an opportunity to attend both internal and external meetings. The former included Stream 1 and Stream 3 planning meetings; while the latter included various industry discussion groups, open days and visits as well as a facilitated stakeholder discussion in Wellington in June 2015 and the closing ThinkTank, also in Wellington, in September 2017. In this way, I sought to gain both detailed insight and a broader, contextual perspective. I have used selected quotations in my text both to help amplify the points being made and to convey a sense of place through the language used.

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[80] Aniek Hilkins at Massey University explored interactions between farmers and advisors in NZ's agricultural finance sector. See, for example, Hilkens et al. (2018).

[81] Followed at a later date by a fourth project exploring Intensive Forest Systems.

Theme	Identifier used in database	Descriptor used in text for anonymity	Interviews n = 13			Interviewees n = 17	
			1	2	3	1 : 1	1 : 2
General: comprising 7 x interviews with 9 respondents							
General	_AgResearch_1	PIP_Stakeholder					
General	_AgResearch_2	PIP_Stakeholder					
General	_Beef+Lamb_NZ	PIP_Stakeholder					
General	_Farmer	PIP_Stakeholder					
General	_Veterinarian	PIP_Stakeholder					
General	_Academic	PIP_ProjectTeam					
General	_Consultant	PIP_Stakeholder					
Stream 3: comprising 6 x interviews with 8 respondents							
Stream_3	_AgResearch_1	PIP_ProjectTeam					
Stream_3	_AgResearch_2	PIP_ProjectTeam					
Stream_3	_ESR	PIP_ProjectTeam					
Stream_3	_Ministry_Primary Industries	PIP_Stakeholder					
Stream_3	_Scion	PIP_ProjectTeam					
Stream_3	_Plant+Food	PIP_ProjectTeam					

Table 8 profile of interviews and interviewees

While the emphasis of this chapter is on outward engagement via Stream 3, the sections below set the scene by first outlining Streams 1 and 2 with a 'dashboard' at the start of each section intended to help readers to navigate accordingly.

5.2.2 Overview of Stream 1: theoretical framing

→	Stream 1	Theoretical framing informed by ex-post analysis of three initiatives
	Stream 2	Ex-ante study of in-field application through five, live projects
	Stream 3	Outward stakeholder engagement via Community for Change (CfC)

The barriers and opportunities for innovation activities in NZ's primary sector were brought to life by ex-post analysis of three purposively selected initiatives: Dairy NZ's InCalf programme; the pipfruit sector's Apple Futures work; and Beef and Lamb New Zealand's (B+LNZ) Land and Environment Planning (LEP) Toolkit. These projects varied in terms of anticipated complexity from the least complex InCalf project, less contested knowledge base and less complex change mechanisms, through the more complex Apple Futures project to the most complex LEP Toolkit with its contested knowledge base and complex change mechanisms.

As shown in Table 9, and expanded in Appendix XIV, these projects unfolded over extended timeframes. InCalf from 1993 (Brownlie et al., 2015); Apple Futures from 1995 (Park et al., 2015); and the LEP Toolkit from the 1990s (Reid, 2013).

	Hardware	Software	Orgware
InCalf	*Initiated in Australia in 1996; launched there in 2003, 'InCalf' addressed deteriorating reproductive performance of dairy cows. A memorandum of understanding allowed DairyNZ to adapt InCalf for NZ where it was launched in 2008 with the aim of contributing to the achievement of improved performance targets (Burke et al., 2007)*		
	A 'plan-do-review' approach to herd fertility using a handbook, farmer action groups & network of trained advisors to advise/support producers re: improved herd reproductive performance	Developed in Australia by DairyAustralia. Adapted for NZ by DairyNZ with input from farmers, advisors and opinion leaders for delivery via DairyNZ, 3rd-party advisors and veterinarians	The 2013 Strategic Framework for Dairy Farming's Future targeted "a 6-week in-calf rate of 78% by 2015"; refreshed in 2017 to reflect changed market conditions
Apple Futures	*Launched in 2007/08 season, a co-ordinated programme to assist NZ growers to meet stringent maximum residue limits (MRLs) in EU markets and comply with exacting phytosanitary requirements for global markets. By 2009/10 season, implemented in 65% of the exported crop and underpinned launch in 2011 of the "100% Pure Apples from NZ". In 2014, follow-up funding secured for Apple Futures II (Park et al., 2015)*		
	Integrated production protocols for commercial growers built on Integrated Fruit Production (IFP) programme (1995) and PipSafe Pilot (2006) that showed proof of principle	Collaboration between Central Government, Regional Economic Development Agencies (Hawkes Bay, Nelson, Otago), industry and research scientists	Increasingly stringent MRLs in key EU markets and global pressure to maintain phytosanitary standards threatened the viability of NZ sector at a time of low margins
LEP Toolkit	*Monitor Farm activity in the 1990's a fulcrum for Meat and Wool NZ and the Regional Councils with respect to the sustainability of pastoral agriculture and contributed to the development of Whole Farm Plans (WFP). In 2010, loss of the wool levy led to change from Meat and Wool NZ to Beef and Lamb NZ and in 2011, the WFP programme was rebranded as B+LNZ Land and Environment Planning (LEP) Toolkit and relaunched*		
	A 3-tier toolkit consisting of workbooks, guidelines and training to assist pastoral land managers to combine on-farm business and environment planning	Developed by Meat and Wool NZ (more recently Beef and Lamb NZ) with input from research scientists, farmers and Regional Councils	Catastrophic flooding in Manawatu in 2004 high-lighted need for pastoral sector to practice more sustainable land management practices

Table 9 Overview of three ex-post studies

There was an appetite, and some impatience, for lessons learned from Stream 1 to inform the activities of Streams 2 and 3. To meet this requirement, preliminary analysis was presented to a PIP Workshop in 2014. Further analysis followed: including a poster presented at the 2015, Australasia Pacific Extension Network

(APEN) Conference (Botha et al. 2015) and Fielke et al's more recent paper (2017). As outlined in Table 10, below, these reflect that: as a joint endeavour, a group's pace is governed by that of its fastest and slowest members; goal orientation plays an important role in terms of providing an over-arching direction of travel; and moreover, a common understanding of the problem informs the development and sharing of knowledge. All of this requires resourcing and it was noted that 'good enough' rather than 'perfect' is sufficient in order for progress to be made.

Cross-cutting themes	Early reflections (Turner et al. 2014 – presentation to PIP)	Interim reflections (Botha et al. 2015 – APEN Poster))	Later reflections (Fielke et al. 2017 – journal article)
Actors and interactions	involvement of multiple participants necessary with brokers helping to bridge gaps and to make connections	effective interaction between diverse actors and an understanding that the group's pace will be determined by the progress of its fastest and slowest members	a shared understanding of drivers among diverse actors with a willingness to prioritise the innovation project
Goal-orientation	a systemic view of a shared problem	a shared motivation for change	a shared vision for change
Knowledge and learning	flow of ideas between diverse groups and, as learnings evolve so solutions take shape	endorsement from critical actors	recognition of the value of existing knowledge; mechanisms to diffuse emerging knowledge
Resourcing	underlying resourcing needed to facilitate the process	resources most effectively deployed when targeting 'good enough' rather than 'perfect' outcomes; while adequate resourcing a necessary component, it does not guarantee a successful outcome	sufficient capacity and capability to support the process and wider network legitimacy

Table 10 Cross-cutting themes from three ex-post studies

With Apple Futures, a "threat became an opportunity" (Park et al., 2015, Page 293) as a tightening of regulatory conditions – specifically, the European Union's (EU) increasingly stringent regulations to reduce Maximum Residue Levels of pesticides in fruit – acted as an incentive for change. For the LEP Toolkit, the prospect of

increased regulation with respect to farm environment planning was sufficient to trigger change and within the space of three months, the Toolkit was described as having moved from a push to a pull proposition among farmers in some regions of the country – although not long before it had been described by a representative of B+LNZ as "absolutely under utilised" (Reid, 2013, Page 135). Analysis of both Apple Futures and the (LEP) Toolkit highlighted the value to be gained in grasping windows of opportunity when the technology and relevant supporting actors aligned with prevailing institutions. For the InCalf example, however, it was found that success was hampered by "lack of engagement" (Fielke et al., 2017, Page 18) with vets and farmers. On this basis, it appeared that the project expected to be the least contested in terms of knowledge and change mechanisms was the most intractable.

5.2.3 Overview of Stream 2: in-field application

	Stream 1	Theoretical framing informed by ex-post analysis of three initiatives
⇒	Stream 2	Ex-ante study of in-field application through five, live projects
	Stream 3	Outward stakeholder engagement via Community for Change (CfC)

The selection of the five ex-ante projects was pragmatic. They were not intended to be exemplars of best practice but rather to provide an insight into the practical opportunities and challenges associated with operationalising a co-innovation approach in a NZ context. The projects were associated with potential opportunities for production efficiencies in the dairy sector (Heifer Rearing, HR), added value in the forestry sector (Timber Segregation, TS), enhanced environmental outcomes in the irrigated farmland sector (Water Use Efficiency, WUE) and improved sustainability in potatoes (Tomato Potato Psyllid, TPP) and grassland (Nutrient Management, NM). As with the ex-post projects, the ex-ante projects reflected different levels of expected complexity and agreement. This spanned from the least contested context of the Heifer Rearing project, through to the most contested, Nutrient Management project, as illustrated in Figure 17, below.

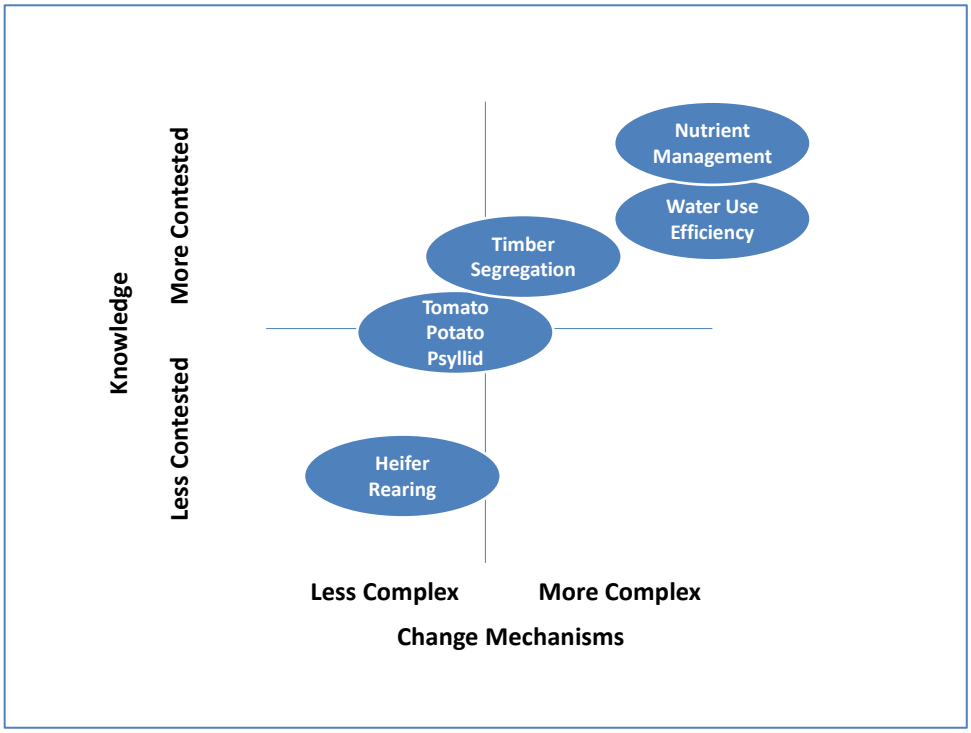

Figure 17 Anticipated complexity of five ex-ante studies

As outlined in Table 11, below, the projects were wide-ranging, each well-connected in its respective field with networks that brought a potential wealth of experience, expertise and knowledge to the process. Project goals were ambitious, varying in scope from the regional [WUE and NM], to the national [HR and TS] and wider export perspective [TPP], addressing genuine problems, in all their complexity.

Project & key stakeholders	**Goal(s)**	**Context**
Heifer Rearing: • Dairy NZ • Beef + Lamb NZ • LIC • Dairy farmers • Host-grazers	To improve dairy herd reproductive performance by increasing the proportion of heifers entering the herd at target live-weight	An estimated three-quarters of heifers enter the national herd each year at 5% or more below target weight with an associated cost to industry of NZ$120m through lost productivity. Achieving target weights has potential to deliver improved returns. To enable optimum use of grazings adjacent to the milking platform, in NZ a system has evolved whereby replacement heifers may be reared off-farm for a period of time, hence inclusion of 3rd party host grazers
Tomato Potato Psyllid: • Plant+Food (P+F) • Potatoes NZ • Foundation for Arable Research • Potato growers • Agro-chemical companies • Processors	To increase export marketing opportunities by developing an integrated pest management approach for the sustainable control of TPP in the NZ potato sector	The TPP was first detected in NZ in 2006, impacting on both the quality and quantity of the potato crop. Since 2008, it has been regarded as a major problem that has cost in the region of NZ$60m through a combination of reduced yields and increased chemical applications
Timber Segregation: • Scion • Forest Owners Association • Forest Levy Growers Trust • Nelson Pine Industries • Lake Taupo Forest Trust • Various growers, processors & Iwi • Tenon	To deliver improved returns across the supply chain by exploring the relationship between growers and processors with a view to identifying practical mechanisms to overcome the quality variation of NZ timber	The forestry sector is aiming to double export earnings to NZ$12bn by 2022. Given the extended production cycle, opportunities to add value to the growing crop will be vital to realising this aim. Although reducing the variability in wood quality may contribute to improved production efficiencies and increase opportunities for added value, the sector's fragmented structure makes implementation problematic
Water Use Efficiency: • Niwa • Irrigating farmers • Local irrigation scheme • Zone Planning Committee • Environment Canterbury (ECan)	To improve on-farm water use efficiency by supporting irrigation scheduling decisions with farm-level rainfall, soil moisture, drainage, temperature and evapotranspiration data supported by high resolution regional weather forecasts	While the production benefits of irrigated farmland are well-established, the environmental consequences are contested and gaining increased attention. Demonstrating good irrigation practice and an appreciation for the farm's environmental footprint is becoming more widely required as well as a growing awareness of farmers' responsibility to use water for irrigation as sparingly and effectively as possible
Nutrient Management: • Dairy NZ • AgResearch • Plant + Food • Lincoln University • Foundation for Arable Research • Landcare Research	To explore potential opportunities to reduce on farm nitrate leaching from pasture in the Canterbury Region through the application of novel forage seed mixes and to encourage good practice through a Monitor Farm network	The National Policy Statement for Freshwater Management (2011) requires Regional Councils to have defined quality limits for water bodies by 2030. In Canterbury, this is the responsibility of ECan. Under the industry's sustainable dairy: water accord, dairy farmers are demonstrating good management practice by implementing nutrient management plans while seeking to remain competitive on global markets

Table 11 Overview of in-field co-innovation projects (adapted from Vereijssen et al., 2017)

The five ex-ante projects were recruited to the PIP over an 18 month period. As shown in Figure 18, below, the Water Use Efficiency (WUE), Heifer Rearing (HR) and Nutrient Management (NM) projects were initiated under the PIP. The WUE and HR projects were embedded in the PIP throughout, additional funding for the NM project meant that it followed a twin-track from October 2013, part of the PIP and delivering as a stand-alone project. The Timber Segregation (TS) and Tomato Potato Psyllid (TPP) projects were already underway, prior to joining the PIP.

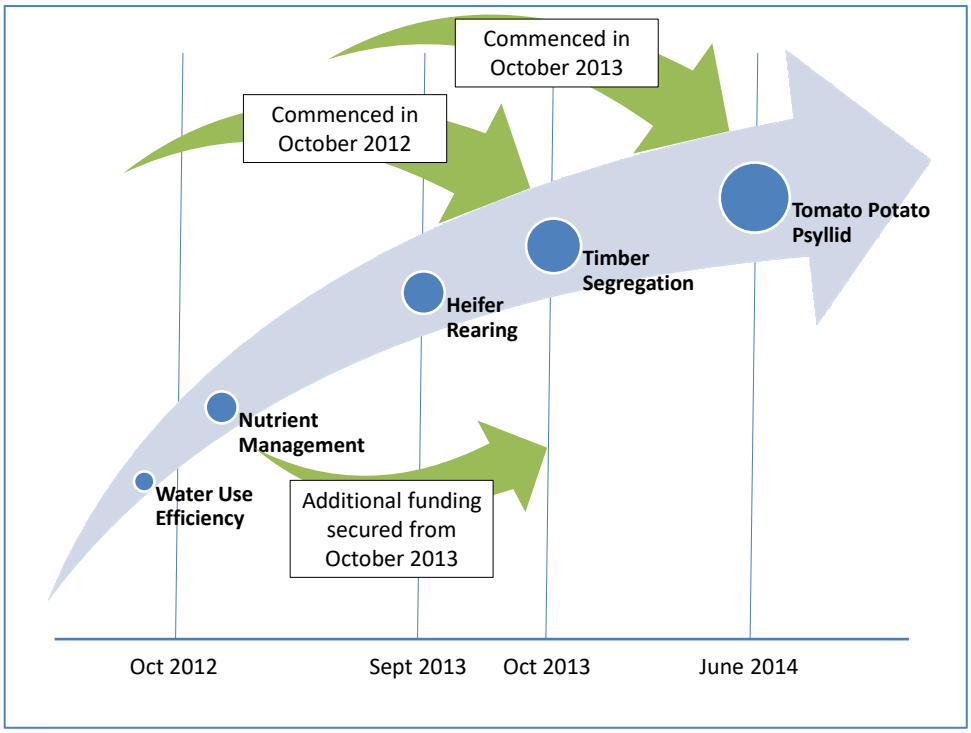

Figure 18 Timeline of innovation project recruitment (adapted from Vereijssen et al., 2017)

The delayed entry of TS to the PIP allowed lessons to be learned from work already underway. John Moore, TS Project Leader, identified (personal communication, 3 September 2015) perceived parallels with HR, in terms of the challenge of engaging with a large number of dispersed enterprises, as especially valuable in informing project planning. For the TPP project, Vereijssen et al. (2017) described the practical benefits of having a senior Plant and Food (P+F) scientist already embedded in the PIP, gaining first-hand experience of co-innovation. This 'foot in both camps' enabled learnings to be transferred between the wider PIP and the TPP project, the scientist's established role in P+F adding credibility to the process.

Among the conclusions of their cross-case analysis Vereijssen et al. (2017) found that "co-innovation requires an adaptable mindset rather than strict adherence to a single method" (Page 115). This adaptability may be illustrated, as discussed below, according to the relationship each of the three founding projects in the PIP maintained with stakeholders as characterised by the 'revolving-door' of the NM study, the 'open-door' approach of HR and the 'sliding-door' of WUE.

In their webinar (5 May, 2016[82]) on delivery of the NM study, Project Managers Ina Pinxterhuis and Paul Edwards from Dairy NZ described the challenge of balancing an ambition to achieve "cohesion from paddock to policy-maker" within constraints of time and resource, concluding that it was not feasible to involve all stakeholders in all decisions and accepting that in working with contested issues, a consensus may not always be possible. They adopted a 'revolving-door' approach whereby key stakeholders worked with the core project team as and when relevant with a commitment to transparency ensuring that the process remained open to wider scrutiny. The approach of the HR project, as described by Project Manager, Sarah Dirks from Dairy NZ (webinar, 1 September, 2016[83]), was to try and move forward subject to ongoing agreement among an over-arching industry steering group. This 'open-door' approach that sought to include all stakeholders in decision-making became problematic, however, when a consensus was not forthcoming, positions were entrenched or expectations were not in alignment. In the WUE project, as outlined by Niwa Project Manager, MS Srinivasan (webinar, 6 August, 2015[84]) a 'sliding door' approach was adopted whereby a core team met periodically with a wider body of stakeholders, for example at the annual project review meeting, to share findings and discuss next steps. In this way, the WUE project was shaped through dialogue with stakeholders but not constrained in the absence of a consensus.

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[82] https://www.youtube.com/watch?v=0p9Q7i15ufs

[83] https://www.youtube.com/watch?v=Ai1Tob6AOo8

[84] https://www.youtube.com/watch?v=xx7XHd5Gc9I

5.2.4 Overview of Stream 3: stakeholder engagement

	Stream 1	Theoretical framing informed by ex-post analysis of three initiatives
	Stream 2	Ex-ante study of in-field application through five, live projects
	Stream 3	Outward stakeholder engagement via Community for Change (CfC)

The focus of Stream 3 was on interactions with wider stakeholders via a so-called Community for Change (CfC). By engaging with this broader audience and encouraging the exchange of knowledge, the activities of the CfC were intended to contribute to an "enabling environment of change" (Douthwaite et al, 2003, page 247). Newsletters, webinars and workshops as well as a dedicated website and Linked-In group all helped to connect PIP researchers to a wider body consisting of some 50 stakeholders from "government, industry and research" with a shared interest in innovation activities and a motivation to "facilitate change among their constituencies" (Beers et al., 2018, Page 6). Engagement was underpinned by emerging learnings from Streams 1 and 2. In particular, the ex-post analysis of projects in Stream 1 that was highlighting the extended timeframes and reliance on, sometimes serendipitous, windows of opportunity; and the multiple interpretations and context-specifics involved in putting co-innovation into practice evidenced by ex-ante analysis of the projects in Stream 2. Indeed, the first-hand, practical experience emerging from the in-field application of co-innovation was, as illustrated in the quotation below, especially valued by stakeholders:

> "…having access to the examples that are coming out of this project has been absolutely critical to be able to explain that it's not just a conceptual idea but to actually say 'and here's someone that is working in this space' and talking about the complexities of it. So it is definitely providing really good illustrative examples…" (PIP_Stakeholder)

Learnings arising from engagement with the wider network of stakeholders comprising Stream 3 are considered below according to the collaborative, co-ordinated and complementary themes of co-innovation. They reflect an evolving understanding of co-innovation and its application in addressing the challenges facing NZ's agri-food sector.

5.2.4.1 Collaborative: towards a shared understanding of co-innovation

As shown in Table 12, below, a series of feedback interviews (orange cells) and interactive workshops (green cells) provided structure and support to the CfC over the course of the project with a view to gradually shifting responsibility for guiding the co-innovation process away from PIP researchers and towards CfC stakeholders.

Year	2013	2014	2015	2016	2017
Jan	1: barriers to innovation activity				
Feb			2: review impacts of PIP activities on participant's role/sector		
Mar		3: Ex-post studies; lessons learned			
Apr					8: Review barriers & opportunities
May			5: Ex-ante studies; implications for innovation		
Jun	1: AIS; barriers & opportunities				
Jul				7: AIS; barriers & opportunities	
Aug					
Sep		4: Ex-ante studies; & areas of interest			9: Think Tank; evaluate & reflect on impacts of PIP
Oct	2: Institutional context; barrier or opportunity		6: Opportunities for competitive advantage		
Nov				3: reflection of involvement	
Dec					

Table 12 Planned programme of activities for CfC engagement

These interactions between the research team and wider stakeholder network were intended to raise awareness about the PIP, to explore alternatives to 'business as usual' and to stimulate engagement and the exchange of knowledge. As captured in the following quotation, however, researchers found the concept of co-innovation difficult, at least in the first instance, to convey effectively to stakeholders:

> "…it's a concept that's quite hard to explain to people!" (PIP_Stakeholder)

With the benefit of hindsight, respondents were concerned that initial engagement with stakeholders may have come too soon. At a time, as illustrated by the quotation below, when they were still developing their own understanding of co-innovation:

> "…(we) felt a little bit exposed at times because we're having to deal with the CfC which we knew was struggling with the concepts when we were still struggling with the concepts ourselves!" (PIP_ProjectTeam)

Among researchers, there were concerns that their own lack of familiarity with the co-innovation concept was contributing to some stakeholders' forming an impression of too much uncertainty and too many unanswered questions, creating an obstacle to securing their continued engagement. Furthermore, since the concept of a collaborative approach to problem-solving chimes with everyday proverbs and phrases on the benefits of working together[85], there were also wider challenges in terms of positioning co-innovation vis-à-vis current practice. Indeed, as expressed in the quotation below, presenting co-innovation as a novel approach in the project's early stages prompted some stakeholders to reject it as 'old wine in new bottles':

> "We got pushback from people saying 'actually no, we've been doing this co-innovation thing for many years' and that's very true, it's not like we're all doing Tech Transfer all the time and that's all we do." (PIP_ProjectTeam)

With familiarity, however, comes the risk that dimensions of technological development, network evolution and institutional context, and the interactions between them at the heart of the co-innovation approach, are lost or overlooked. In line with Nettle et al. (2013), by framing co-innovation as one option among several – for example, with technology transfer at one end of the spectrum for more straightforward scenarios and co-innovation at the other end for more complex or wicked problems – practitioners have a suite of options. In this way, the emphasis is

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[85] For example, the English 'two heads are better than one'; the Dutch, 'twee weten meer dan een' (two know more than one); and from the Maori whakatauki 'Mā pango, mā whero, ka oti te mahi' (By black and by red, the work is done; literally referring to the chief (red) and worker (black) pulling together in a combined effort to achieve a shared goal; With thanks to Judith Terpstra for advice: http://maorilawreview.co.nz/2017/11/ma-pango-ma-whero-maori)

on best-fitting the approach to the problem, respecting past practice as well as encouraging a more detailed understanding of the problem-in-hand. With echoes of the parable of the six blind men and the elephant – in which each forms a different image of the elephant from their own limited contact with various component parts, the tail, trunk, tusks and so on – the quotation below highlights that a particular value of co-innovation was seen in bringing together diverse perspectives of multi-faceted issues or problems as a way of reaching a better understanding of the whole:

> "…it's systemic changes in a system so that you create a new system – co-relation of practices, technologies, policies, soft-institutions, ways-of-working, norms, and that's why you involve multiple stakeholders because they have different parts of the solution and have different perspectives on parts of the problem." (PIP_Stakeholder)

As discussed in the next section, however, harnessing the energy of the CfC with a view to stimulating change was problematic and, as the project progressed, ongoing learnings prompted some re-orientation of Stream 3's activities.

5.2.4.2 Co-ordinated: harnessing the energy of the CfC

Longitudinal social network analysis (SNA) conducted by the University of Melbourne's Barbara King (2017), and outlined in Appendix XV, reflects the fluctuating interconnections of the CfC as stakeholders' coalesced around the promise of something new in the project's early stages, their engagement faltering slightly as they struggled to differentiate co-innovation from current practice and to see opportunities for its application in their own fields.

Respondents' accepted it was too soon for a solid definition of co-innovation but there were concerns that its absence left the term at risk of being mis-interpreted, a risk that was compounded by the absence of a blueprint for action and a reliance instead on guiding principles and learning-by-doing. Project Manager, James Turner saw stakeholders as responding to the concept of co-innovation in early CfC workshops as something : i) they could engage with; ii) they would like to know more about; or iii) not giving them what they wanted to know. As illustrated in the quotation below, understanding across the CfC was correspondingly fragmented:

> "When we talk about the CfC we think it's singular, it's actually, like multi-universes – and that's the challenge for organisations, you've got to somehow navigate your way through these things." (PIP_Stakeholder)

To help consolidate stakeholder engagement, from August 2015, additional input was provided by Graeme Nicholas and Jeff Foote from ESR[86]. Their involvement prompting a renewed focus on understanding stakeholders' needs with a view to empowering them to take ownership of the process. As described in the quotation below, this not only brought a fresh perspective to the project but also served to highlight the extent of the challenge:

> "…with Jeff and Graeme coming on board, they are saying 'no, you need that resonance coming-up from the bottom then these people can actually see how their interventions play out' ... which I think does make sense, it's just a shame that we haven't got another 5 years!" (PIP_ProjectTeam)

In consultation with stakeholders, three distinct areas were identified as potential intervention points: i) embedding non-science know-how in knowledge development e.g. giving greater voice to a wider body of stakeholders; ii) improving entrepreneurial activity e.g. seeking a more equitable balance between less well funded commercialisation and implementation activities and better funded research and development activities; and iii) improving strategic co-ordination by encouraging a more joined-up innovation system. On this basis, as illustrated in Figure 19, below, engagement with the CfC became more targeted, capitalising on stakeholders' interest in co-innovation and seeking to identify key influencers with potential to catalyse wider, systemic change. At the same time, using the learnings emerging from Stream 1 (ex-post) and, in particular, Stream 2 (ex-ante) as a way of bringing the concepts to life and developing exemplars of co-innovation in practice.

[86] The Institute of Environmental Science and Research, NZ's CRI that specialises in "science relating to people and communities" (https://www.esr.cri.nz/home/about-esr/, accessed 16/08/2018)

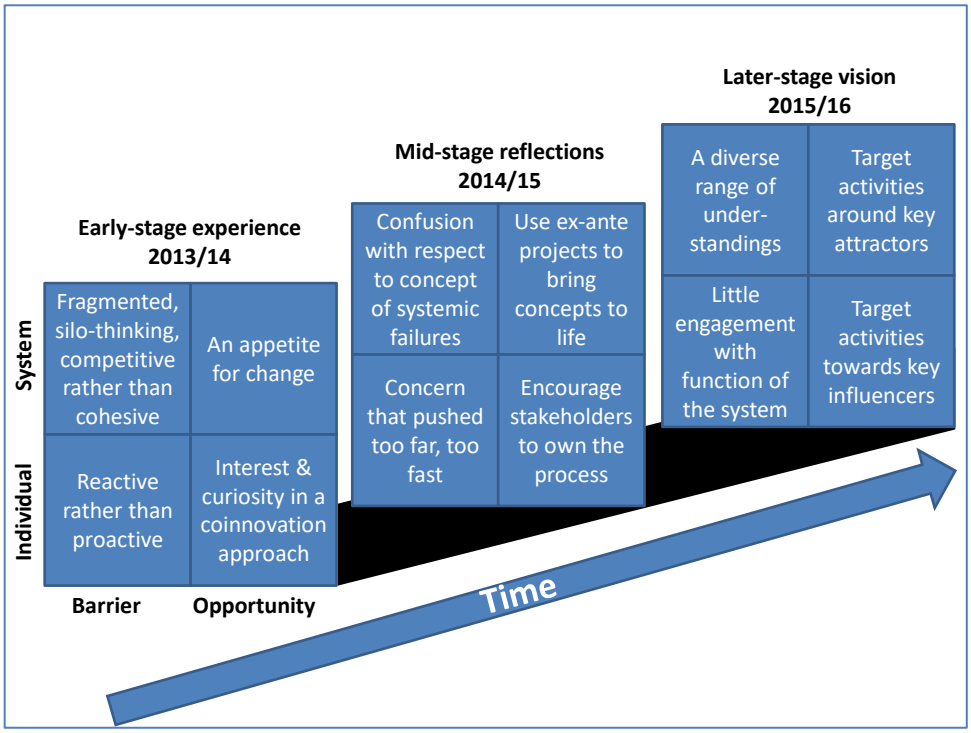

Figure 19 Shifting barriers and opportunities around CfC activities, over time

The CfC was demonstrating the challenge of working, co-innovatively, across levels and disciplines to reach a more holistic understanding of complex, multi-dimensional problems, as expressed in the quotation below, this was not a comfortable process:

> "If you're not feeling uncomfortable, and you're not feeling comfortable at being uncomfortable, then you're probably not co-innovating!" (PIP_Stakeholder)

A specific challenge for the CfC was to create conditions conducive to change and, as discussed in the following section, implementation of co-innovation in a NZ context required a balance to be found between the fluidity of co-innovation and the prevailing institutions of business-as-usual.

5.2.4.3 Complementary, outward-looking perspective

New Zealand has long-held an outward looking, export orientation and its agri-food sector operates in the context of increasingly integrated, globalised value chains that exert a powerful influence on the direction and pace of change. Also exerting a powerful influence, however, is the country's proud tradition of self-determination, as witnessed in the recent past by the rate and extent of market reforms and a

unilateral turn away from producer subsidies as well as growing debate with respect to environmental risks and responsibilities. Against this dynamic and shifting background and in the absence of a guiding precedent on responding to the complex challenge represented by these combined issues, co-innovation, as set out in the quotation below, was expected to have a vital role in helping to navigate change:

> "It's not just that there are differing opinions on what to do, actually we don't know how to do this and I think that's a really important precursor … if you have got a whole lot of smart people that have been working in the area for a long time and there's no clear direction of what is the best thing to do then it's a good opportunity for a co-innovation approach." (PIP_Stakeholder)

Transformative change, while widely anticipated by stakeholders, will both shape and be shaped by prevailing institutions in NZ's agri-food sector, variously impacting, as outlined in Table 13, below, at individual, community and system level.

Context	Category		Challenges arising in a NZ context
1. Personal	1.1	Individual	• Secure recognition for a co-innovation mindset in CRIs where publications are main measure of performance
2 Community	2.1	Team	• Cut across silo-thinking by engaging the 'right people' without constraint by sector, region or discipline
	2.2	Programme	• To 'break the mould' of more linear, science-driven thinking and refresh existing relationships
	2.3	Organisational	• To retune contractual obligations, developed along linear dimensions, to meet fluidity of co-innovation
3. System	3.1	NZ's Agricultural Innovation System	• Acknowledge that current state not completely undesired 'don't throw baby out with the bath water!' • Avoid being 'shepherded back' to more of the same • Support funding bodies navigate change and embrace 'something different' in a culture of 'business as usual' • To encourage long-term thinking that better reflects extended timeframes associated with innovation processes, farming cycles and the natural environment
	3.2	NZ-specific norms	• To preserve the 'No. 8 wire mentality[87]' of creativity and self-reliance while recognising that improvising and innovating are not one and the same thing • To engage with the wider national debate about what 'Clean and Green NZ' looks like

Table 13 Institutional challenges in a NZ context (following Klerkx et al., 2017)

[87] The 'No. 8 wire' mentality describes a resourcefulness arising from necessity among New Zealanders, see for example Rinne and Fairweather (2012, Page 176)

In the context of the personal, putting co-innovation theory into practice highlighted practical impacts for individuals. For example: some respondents reported difficulties placing articles, an important measure of individual performance in the CRI's, on co-innovation in target science journals; more widely, co-innovation is resource intensive, involving a range of facilitation, project management and networking skills that do not align with existing work recording processes; likewise, the flexibility of following a 'learning by doing' approach does not sit easily with established administrative processes and time-driven contract milestones. Also, the rapid pace of change in NZ's science sector in recent decades, the competitive rather than cohesive culture and the relatively small size of the research community create an operating context that is at once close-knit and fragmented. Close-knit as it is a relatively small community with a shared history involving movement of individuals between organisations; at the same time fragmented as science-thinking has tended to take place in silos and is informed by a culture of competitive funding.

At the wider community level, on the one hand, New Zealanders' rightly take pride in their reputation for getting things done with a mix of self-reliance, resilience and resourcefulness. On the other hand, this so-called 'Number 8 wire' approach is sometimes criticised as a quick-fix rather than a lasting solution. Some respondents cautioned of the risk in confusing improvisation with invention and innovation and there were calls for a wider, national conversation about how an innovation culture might be encouraged in a NZ context. To this end, with innovation processes, the environment and farming all associated with extended timeframes, respondents' saw value in the relationships that underpin co-innovation being informed by a long-term perspective, emphasising also the importance of embracing different world views and observing not just the word but the spirit of Matauranga Maori (the body of knowledge developed by NZ's Maori population). As expressed in the quotation below, co-innovation was coming to be seen as a timely alternative to the status-quo:

> "It's an idea that's time has come, I think for NZ a lot of the low-hanging fruits have probably been plucked so to get that value-add and to really produce something quite special, we're going to have to co-innovate." (PIP_ProjectTeam)

Nevertheless, the challenge of achieving systemic change in the context of a science-based system that has been characterised as competitive rather than cohesive and conservative rather than entrepreneurial was not under-estimated. For example, respondents' pointed to the dominant economic position of NZ's dairy sector that overshadows other sectors to such an extent that even a small uplift in dairy sector profitability is significant, with this dominance, however, comes the risk of becoming locked-in to delivering more of the same at the expense of exploring new opportunities. Stakeholders' recognised it will take time to adapt and that navigating change will give rise to tensions. As reflected in the quotation below, co-innovation was becoming better understood as an agent of change rather than compromise:

> "…a key bit that was missing for us was that co-innovation is negotiation so it's working through the fact that innovation creates winners and losers. We come with different agendas that we're seeking to achieve, we're not all miraculously going to come together as one to achieve the collective." (PIP_ProjectTeam)

The fluidity of the co-innovation approach – mindset rather than method, without a blueprint and informed by ongoing learning – does not readily fit with NZ's largely technology-driven system and efforts are needed by a wider network, such as the CfC, to cultivate an enabling environment to support its application. As articulated in the quotation below, understanding the loci of decision-making powers is vital to identifying stakeholders with potential to champion change at the system level:

> "…who holds the keys of governance to make either the institutional change in terms of policy regulation or release resources or, whatever, to actually effect change at a much higher level than we get at the moment where it's often reacting to individual issues as and when they occur." (PIP_ProjectTeam)

The CfC may exert pressure for change on the norms of 'business-as-usual' but the converse is also true with the inertia of the status-quo resisting pressure to change. Learnings emerging from Stream 3 were demonstrating the value of identifying and engaging with stakeholders in positions to influence systemic change.

5.3 Discussion and conclusions from the case of the Primary Innovation Programme

Having an over-arching programme in place to support the in-field application of a co-innovation inspired approach at project level was of value. Each benefitting from the reflections of the other so that the whole became greater than the sum of its parts. Against a background of fast-paced change in NZ's agri-food sector and in the light of pressing concerns about the environmental and social impacts of contemporary farming practice, the PIP was timely in prompting sometimes difficult questions about the sector's direction of travel and challenging the ability of a business-as-usual approach to innovation activity to provide the necessary support.

The ex-post (Stream 1) studies provide a reminder of the extended timeframes involved in realising the impacts of innovation activity that, in these examples, were unfolding over a period of 20-30 years. Reviewing them through an AIS lens gives an insight into the constraints of operating in a science-led system that has been described as laissez-faire rather than entrepreneurial. While the Apple Futures and LEP Toolkit projects reflect the value of a collaborative approach in aligning practice, network and institutions in response to emerging windows of opportunity, they also highlight concerns that, as 'islands of success', their success was achieved in spite of rather than because of prevailing institutions, as borne-out by the InCalf experience. The latter, although apparently the least complex of the three projects, proving to be the most problematic. These examples highlight the need for a nuanced framing of co-innovation, acknowledging good practice but recognising scope for improvement in responding to a complex challenge that, given its unprecedented complexity, can only be addressed through learning-by-doing.

The potential opportunities for innovation in a NZ context were demonstrated by the ex-ante (Stream 2) projects. For example: the TPP project was responding to estimated production losses over the last decade of NZ$60 million in the potato sector; the HR project was addressing lost productivity costing the dairy sector an estimated NZ$120 million per annum; and for TS, there was the prospect of contributing to a doubling of export earnings from forestry to NZ$12 billion by 2022.

By challenging the status-quo through application of a co-innovation approach, these projects were seeking to be the architects of change, creating their own windows of opportunity. In so doing, they were demonstrating the practicalities of implementing a co-innovation approach, highlighting there is not a 'one-size-fits-all' approach but rather multiple interpretations, based upon shared principles and sensitive to context.

The requirement for Stream 3 and the wider Community for Change (CfC) was to better understand how to support projects in this endeavour by challenging the inertia of business-as-usual and creating conditions conducive to change. In what has traditionally been a science-led, silo-ed and competitive science sector, the fluidity of the co-innovation approach is at particular risk of becoming a 'square peg in a round hole' and it is to the credit of Stream 3's activities that the learnings emerging from the PIP gained traction. As evidenced, for example, by stakeholder support voiced at the thinktank described at the start of the chapter, the PIP demonstrated proof-of-principle in a NZ context with accompanying insights. As expressed below:

> "…this has been a foundational piece of work that has provided us with some tangible on-the-ground experiences to make sense of conceptually which has been invaluable, absolutely invaluable." (PIP_Stakeholder)

In the process, stakeholders involved in Stream 3 came, in particular, to appreciate: the challenge of putting co-innovation into practice as evidenced by the experience of building interest in, and maintaining commitment to the CfC; the value of learning by doing as reflected by shifts in emphasis as the project developed; and the tensions associated with breaking-away from business-as-usual as witnessed by the comments and observations of participants. In this way, the experience of Stream 3, mirrored that of the projects in Stream 2. In the following chapters, I zoom-in on two of these on-the-ground projects. Firstly, Heifer Rearing, to explore how a co-innovation approach was applied in the context of NZ's dairy sector and, secondly, the Water Use Efficiency study in the context of contested water management in Canterbury. Cross-case learnings then inform the overarching Discussion in Chapter 8, and the Conclusions and Recommendations in Chapter 9.

Intermezzo, realising replacement heifer potential

Stream 2 of the Primary Innovation Programme (PIP), out-scaled and applied the principles of co-innovation in various scenarios. Emerging, ex-ante learnings then informing the thinking of the Community for Change (CfC) as well as feeding into the other Stream 2 projects. One of these five projects, Heifer Rearing (HR), was led by DairyNZ, the levy-funded, industry-good body for New Zealand's dairy farmers.

Dairy NZ's website reflects the influence of heifers on overall herd performance with sections on general health and development as well as specifics of rearing, feeding, weighing and mating. Each taking into account that as heifers develop they may be variously managed as individuals (newly-born calves and freshly-calved heifers) or on a whole-herd basis (growing young-stock and lactating cows), also allowing for different production systems. Target live-weights at key growth stages allow heifer development to be tracked while industry estimates suggest scope for improvement with lost productivity of an estimated NZ$120 million per annum attributed to under performance. As a rule of thumb, Dairy NZ[88] advises a '30-60-90' approach. That is, for heifers to be at 30% of their target mature weight by 6 months of age; 60% at 15 months (first-mating); and 90% by 22 months (pre-calving). By meeting these targets, it is argued that heifers will be well-placed to join the milking herd and – critically, for a sector seeking to balance increased productivity with improved environmental outcomes – fulfil their potential in subsequent lactations.

As growing heifers may spend some time away from the main herd, there is information too for third-party graziers and a reminder for producers that while heifers may be out of sight, this should not mean out of mind. This has not always been so clearly understood. By highlighting the importance of not only managing growing heifers but also paying close attention to the relationship between producers and graziers, a co-innovation inspired approach, as applied in the HR project, brought fresh insight to established practice. This chapter explores this process.

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[88] https://www.dairynz.co.nz/animal/heifers/liveweight-targets/

Chapter 6: Heifer Rearing, breaking-away from business as usual

Described by some as the 'engine of growth' driving the rural economy but criticised by others for its adverse environmental impacts, a pressing challenge for NZ's dairy sector is to deliver increased returns and improved environmental outcomes. In the short to medium term, the focus is on optimising productivity per head and one aspect coming under an increased level of scrutiny is herd fertility. In 2008, DairyNZ, the levy-funded industry-good body, launched 'InCalf' with the aim of driving improved herd reproduction performance. Informed by comprehensive research from Australia and NZ, this practical 'plan-do-review' approach has since endured as the basis of DairyNZ's overarching herd fertility strategy. The uptake of InCalf at farm level has, however, fallen below expectations.

A cornerstone of the InCalf approach is the rearing and management of replacement heifers and, under the Primary Innovation Programme (PIP), this was developed as a stand-alone Heifer Rearing (HR) project to explore application of co-innovation in a NZ dairying context and to refresh established, on-farm heifer rearing practices. In particular, the HR project sought to address a gap between target and actual weights at key growth stages that cost the sector an estimated NZ$120 million per annum.

This chapter explores the application of a co-innovation approach in the HR project. I find creation of a co-innovation space provides a basis for diverse participants to come together with a view to addressing shared concerns about established heifer rearing practice. This leads to a realisation that it is about managing not only the heifers themselves but also the relationships between producers and graziers, culminating, among other things, in a simple checklist to help both parties to formalise previously informal arrangements and, more importantly, providing a starting-point for dialogue. In terms of the co-innovation process, this prompted stakeholders to reflect on their perception of the problem, to take stock of existing relationships and to challenge institutionalised thinking. Unfolding against a backdrop of structural reform and market volatility, I begin this chapter by reflecting on evolution of the InCalf programme to provide the foundations for the HR project.

6.1 Context of the case: herd fertility management

On one side of the coin, NZ's dairy sector is referred to as the 'engine of the rural economy' contributing some 5% to GDP and employing almost 30,000 workers across rural NZ (NZIER, 2017). On the other side of the coin, the sector faces damaging accusations with respect to its environmental impacts (Duncan, 2017; Holland, 2013; Campbell, 2009). For a country that depends, in part, on its 'clean and green' image to appeal to tourists and as a platform to promote agri-food exports in distant markets (Saunders et al., 2016; Clemens and Babcock, 2004), addressing contemporary[89] concerns about 'dirty dairying' while improving productivity, with competing priorities[90], has all the complexities of a wicked-problem[91] (Frame, 2018). Despite recognition that business as usual is not sustainable there is not, as yet, clarity as regards an alternative. In the meantime there is an emphasis on improving output per unit of production by way of better balancing demand for NZ's dairy products with improved levels of environmental protection (Chobtang et al., 2017).

6.1.1 Barriers and opportunities

One area associated with potential productivity gains is herd fertility management[92]. As described by Beukes et al. (2010 ARS), it demands close attention to individual animal recording and the ability to maintain accurate records across seasons; it is

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[89] Accusations of 'dirty dairying' are not new in NZ. Towards the end of the 19th century, the emergence of tuberculin-tested milk and a better understanding of the links between hygiene and public-health prompted veterinarians and public-health officers to call for improved on-farm hygiene standards, bringing them into conflict with the country's milk producers (Ford, 2013).

[90] The resilience of the sector is further tested by an ongoing surveillance programme to eradicate bovineTB from NZ by 2055(see: https://ospri.co.nz/our-programmes/tbfree/about-the-tbfree-programme/purpose-and-plan/) and, more recently, by an outbreak of Mycoplasma bovis (M.bovis). First detected in NZ on 22 July 2017, and prompting implementation of widespread testing, animal tracing, compulsory culling and enforced movement restrictions (prior to this outbreak, NZ was one of only a few countries worldwide to be free of M.bovis and the NZ government has committed to an eradication programme http://www.mbovis.co.nz/) in an effort to regain NZ's M.bovis-free status.

[91] Ashton (2012) summarised a wicked problem as: i) potential solutions reveal hitherto unrecognised aspects of the problem; ii) no definitive solution; iii) solutions are not right or wrong; iv) each problem is unique; v) not all solutions identified; and vi) implementing solutions changes the problem.

[92] https://www.dairynz.co.nz/environment/climate-change/mitigation-options/ (accessed 05/12/2018)

subject to variation caused by the weather and available nutrition, making links between "reproductive performance, production and profitability" (Page 46) complex and difficult to discern from the wider farming system. For these reasons, the cost-benefits of herd reproduction management are difficult to apportion at farm level, acting as a disincentive to herd-managers and encouraging them to prioritise other on-farm activities with benefits that may be more readily attributed (McDougall et al., 2014). Furthermore, since it largely depends on individual animal observations made by the stockperson(s), herd fertility management becomes more challenging as herds expand and intensify (Blackwell et al., 2010), as has been the trend in NZ.

The dairy sector in NZ has largely developed competitive advantage on the basis of its ability to produce milk from grass (Macmillan, 2002). A seasonal, block-calving pattern underpins this strategy, enabling optimum use to be made of Spring grass (Beukes et al., 2010 AEE). To maintain this cycle, producers work systematically towards a Planned Start of Calving (PSC) date; based on an average gestation period of 282 days; the PSC + 83 days determines the Planned Start of Mating (PSM) date[93] (Macmillan, 2002). The 'six-week in-calf rate' gives a standard measure of the calving pattern for the season to come, expressed as a percentage of the herd that test in calf, 42 days after the start of mating (Brownlie et al. 2013). At 68%, the average for NZ herds (Blackwell et al. 2010) is well-below the target 78% (Dairy NZ, 2017). Closing this gap is associated with potential for improved efficiencies and modeling work by Beukes et al. (2010) has demonstrated an economic benefit of NZ$4/cow for each percentage point improvement in a herd's six-week in-calf rate. Industry estimates, meanwhile, have suggested potential benefits of NZ$90million/annum if target fertility measures are achieved across the sector (Blackwell et al., 2010).

Over time, these economic incentives have prompted a number of interventions in an effort to help producers to manage herd fertility and achieve target calving dates, including: calving induction, synchronised oestrus, improvements in heat detection

[93] For example, if the PSC is 18/10, this date +83 days gives 10/12 as the start of the serving period (https://www.dairynz.co.nz/media/5789569/facts_and_figures_web_220617.pdf accessed 03/12/2018)

and improved artificial insemination (AI) products and processes (Blackwell et al., 2010). Rising consumer awareness of and resistance to some of these practices, such as induced calving (Macmillan, 2002), has, however, seen a turn away from artificial intervention and growing interest in working with the herd's natural breeding cycle.

6.1.2 The InCalf initiative

Comprehensive herd fertility studies[94] in Australia (1996-2000) and NZ (1998-2000) found that management practices helped to explain some between herd variation in fertility (Blackwell et al., 2010). From the Australian work, six herd management factors influencing reproductive performance – i) calving pattern; ii) pre-calving live-weight of heifers; iii) pre-calving body condition scores; iv) oestrus detection rates; v) artificial insemination (AI) practice; and vi) the management of bulls – informed the development of Dairy Australia's InCalf programme (Brownlie, 2012).

A Memorandum of Understanding between Dairy Australia and DairyNZ allowed the latter to adapt the programme for NZ's conditions and in 2008, InCalf was launched in NZ (McDougall et al., 2014). Working with trained advisors and informed by continuous assessment, this applied a 'plan-do-review' approach in the form of a four-step programme: i) assessing herd reproductive performance; ii) identifying areas for improvement and potential benefits; iii) weighing-up options for change; and iv) implementing the preferred approach (DairyNZ, InCalf, 2007).

To provide structure, the production year is broken-down into four discrete periods: calving, mating, lactation and dry periods. Within each of these, body condition scoring is reviewed alongside selected priority topics: i) calving, to include review of calving spread and animal health; ii) mating, to include review of heat detection and AI/bull management; iii) lactation, to include review of pregnancy rates and heifer management; and iv) dry-period, to include review of planned calving spread (McDougall et al., 2014). Supporting these activities are an InCalf Book; Fertility

[94] InCalf was developed on the basis of research involving 40,000 dairy cows across 200 herds in Australia, validated for NZ by research involving 50,000 cows in some 200 herds (Dairy NZ, 2007)

Focus Report and Herd Assessment Pack as well as a training programme for farmers and their advisors. Given that multiple stakeholders have an interest in a herd's fertility management, InCalf promotes Farmer Action Groups as a way of bringing stakeholders together, for example: veterinarians, consultants, and recording officers. Convening these meetings before and after each of the four periods then provides a platform to discuss and agree actions and to review outcomes (Brownlie, 2012).

In a large-scale randomised control trial to explore the impacts of InCalf in a NZ context, McDougall et al. (2014) found that despite a "small positive effect on herd reproductive performance" (Page 208) this was expected to fall short of delivering the wider industry objective of an uplift in the average six-week in-calf rate within the target timeframe. It was also found that: attendance at meetings was patchy; and that only a small proportion (less than 5%) of objectives arising from these meetings was in the intended SMART (specific, measurable, achievable, realistic and time-bound) format, impacting on participants' ability to follow-up effectively. In addition, to provide sufficient expertise to support the programme within farm animal veterinary practices tended to result in one or two veterinarians adopting the role of InCalf 'practice experts' and this required client interactions to be routed accordingly, creating a potential bottleneck that interrupted practice work-flow.

6.2 The case of Heifer Rearing

According to DairyNZ's '30-60-90' advice[95], at 22 months of age, dairy heifers should be at 90% of their target mature weight. A gap between actual and target weight at this stage has, however, been associated with lost productivity of some NZ$120 million per annum[96]. Under the PIP, alongside four other ex-ante studies[97], the heifer rearing component of the InCalf initiative was developed as a stand-alone, Heifer Rearing (HR) project to apply a co-innovation approach with a view to better

[95] https://www.dairynz.co.nz/animal/heifers/liveweight-targets/

[96] Mark Paine and Rob Brazendale, Dairy NZ; PIP Workshop, Auckland University, February 2015

[97] Water Use Efficiency; Nutrient Management; Timber Segregation; and Tomato Potato Psyllid.

understanding the factors behind this gap and to develop remedial measures. At the same time, providing insight into the application of a co-innovation inspired approach. In this section, I explore how, informed by lessons learned from the InCalf programme, co-innovation was implemented in the HR project.

6.2.1 Sources of information on Heifer Rearing

Gilham (2008, Page 3) argues that the value of a case study lies in the insight into respondents' understanding of themselves and the setting in which they operate. Complemented by associated information, for example in the form of documents and reports, the process involves a weighing-up of diverse evidence from multiple sources. On this basis, my information gathering was inclusive but at its heart were personal interviews with key members of the project team and the wider stakeholder community. As shown in Table 14, below, these are identified in the text, respectively, as HR_ProjectTeam, and HR_Stakeholder. My thinking was also informed by interviews in connection with the over-arching Primary Innovation Programme (PIP) and Water Use Efficiency (WUE) projects. Based at Ruakura with AgResearch in New Zealand for a period of 12 months, gave me an opportunity: to consult some interviewees more than once in order to explore their emerging thinking and to take soundings on my developing ideas; to collect information more informally, for example through lunchtime discussion groups and local farm visits; and to join an innovation workshop at DairyNZ's Newstead offices in February 2015 to gain a wider perspective on the opportunities and challenges facing the sector.

Theme	Identifier used in database	Descriptor used in text for anonymity	Interviews n = 16			Interviewees n = 11	
			1	2	3	1 : 1	1 : 2
Heifer Rearing (HR): comprising 16 x interviews with 11 x respondents							
HR	_Consultant	HR_ProjectTeam	a	b	c		
HR	_DairyNZ_1	HR_ProjectTeam	a	b	c		
HR	_DairyNZ_2*	HR_Stakeholder					
HR	_DairyNZ_3	HR_Stakeholder					
HR	_DairyNZ_4	HR_ProjectTeam	a	b			
HR	_DairyNZ_5	HR_Stakeholder					
HR	_Farmer_Beef	HR_Stakeholder					
HR	_Farmer_Dairy	HR_Stakeholder					
HR	_LIC*	HR_Stakeholder					
HR	_AgResearch_1	HR_ProjectTeam					
HR	_AgResearch_2	HR_ProjectTeam					
** Interviews conducted by a third party*							

Table 14 Profile of interviews and interviewees in HR

6.2.2 From InCalf to Heifer Rearing

As described in the InCalf manual (Dairy NZ, 2007), managing the different aspects of herd fertility is complex, involving a series of incremental steps with benefits that accrue over time. In the HR project, participants sought both to build-on InCalf's knowledge base and to benefit from lessons learned in its development. In particular, as was later reported by Fielke et al. (2017), a lack of engagement in the planning and design stages "…with vets as pivotal actors, as well as farmers themselves" (Page 18) appeared to have hindered InCalf's on-farm uptake. As illustrated in the quotation below, while participants' respected the technical strengths of InCalf, they were mindful of its limited success in breaking-through among producers:

> "…in terms of getting together a technical publication with all the details then it (InCalf) was highly successful. In terms of training rural professionals and getting them up to speed on herd reproductive management performance then it was also probably very good. In terms of getting practice change out into the real world then it was probably less successful." (HR_ProjectTeam)

Initiated and largely funded by DairyNZ, the HR project ran for four seasons from 2013/14 (Year 1) through to 2016/17 (Year 4). Downward pressure on farm-gate milk prices – as shown in Figure 15 (Page 67) – in the period 2014-16, prompted DairyNZ's 'Tactics for Tight Times' campaign. This provided additional support and advice to the sector and although it took priority over other activities, funding for the HR project was maintained. Indeed, some stakeholders argued that the downturn heightened the project's relevance as it was tackling a practical production problem in real time and exploring a novel approach with potentially wider application.

The HR project consisted of overlapping phases of: problem scoping and information gathering in year one; knowledge development in year two; knowledge sharing in year three; and review and reflection in year four. Strategic leadership was initially

provided by an Industry Advisory Group[98] (IAG). From year two this was replaced by an Industry Leadership Group (ILG) with four sub-groups working on themes of: i) Leadership; ii) Relationship Management; iii) Economics; and iv) Knowledge. An indicative timeline of activities is shown in Figure 20, below. This illustrates the connections between early herd fertility studies in the late 1990s, the InCalf initiative from 2008 and, from 2013, the co-innovation inspired HR project as part of the PIP. The latter generating a range of outputs, including focus-farm workshops and producer guides, as well as more general contributions to PIP seminars and papers.

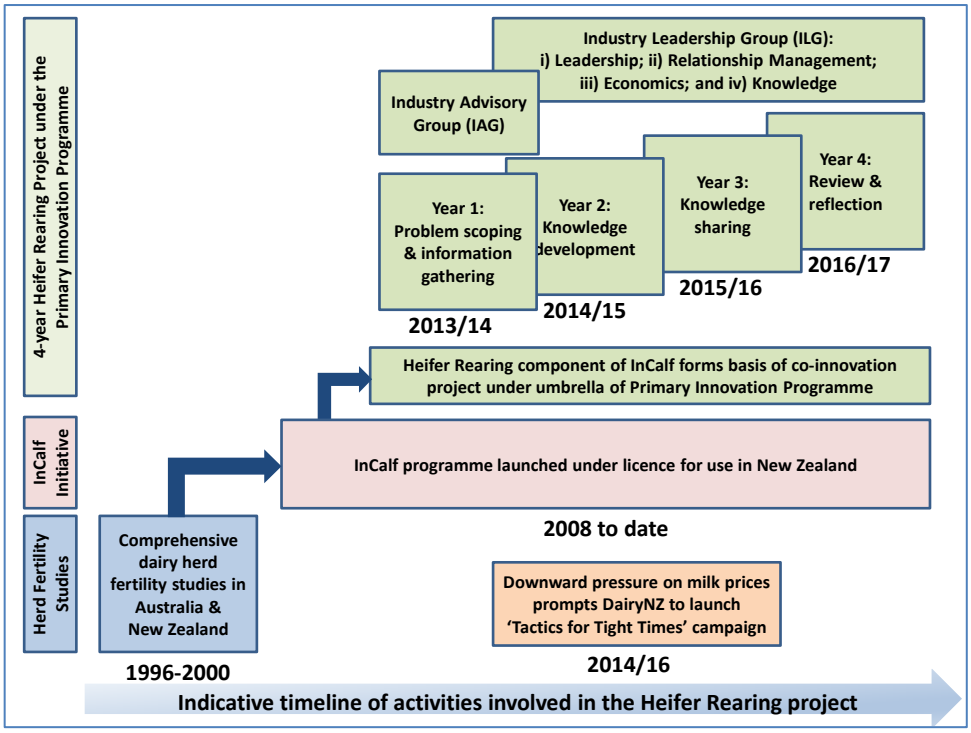

Figure 20 Indicative timeline of activities contributing to Heifer Rearing

6.2.3 Co-innovation in the Heifer Rearing project

In applying a co-innovation inspired approach, the HR project was overlapping with existing networks, such as the sector's vibrant Discussion Groups, and overshadowed by past interactions. For example, one respondent described inter-personal

[98] Including representatives of: Fonterra (1); LIC (2 x scientists & 2 x advisors); Graziers (1); Grazing Companies (2); Dairy Farmers (2); Dairy NZ (1 x scientist, 3 x developers & 1 advisor); AgResearch (1 x social scientist) and 1 x independent.

relationships, underpinned by mutual trust, as the basis of existing, often informal, co-working networks; another reflected on the corporate memories of good and bad experiences of past interactions between organisations, stretching back over many decades; and a third drew attention to the legacy of NZ's fast-changing science landscape that has variously witnessed a coming-together and breaking-up of public bodies with impacts that continue to resonate through the sector to the present day.

Against this background and to assist with understanding how the co-innovation approach was applied in the HR project, I draw on Bitzer and Bijman's (2015) concept of co-innovation as collaborative, co-ordinated and complementary processes that together contribute to a 'co-innovation space' (Coutts et al., 2017).

6.2.3.1 Coming together in a spirit of collaboration

In the context of the HR project, collaboration was dependent on a coming together of diverse stakeholders with a shared interest in dairy heifer production from many and different standpoints. While promising an all-round perspective of the problem, this would only be realised if knowledge, in all its forms, was both shared and respected. A more immediate challenge, however, was to engage stakeholders in the process and to frame co-innovation in such a way that it offered a clear proposition.

Engaging with stakeholders

In light of criticisms of InCalf for insufficient stakeholder engagement, this aspect was emphasised in the HR project. Accordingly, early engagement with stakeholders was both welcomed and valued. It was also recognised, however, that with early engagement comes the challenge of sustaining interest over an extended timeframe. A number of respondents expressed frustration at the project's seemingly slow rate of progress and the resulting hiatus between launching the HR project to stakeholders and being in a position to follow-up with new information. This caused particular concern for DairyNZ's frontline staff, requiring them to balance client expectations with the wider demands of the group. As reflected in the quotation, below, their respective timeframes were not always in alignment:

> "…it's interesting for scientists to explore new ideas but when you've actually got a job to do on the ground, you just want to get on with it!" (HR_ProjectTeam)

There was a breadth of interest in the HR project in its early stages. The Project Manager estimated several hundred interactions between the project and a wide range of stakeholders including farmers, grazing agents, accountants, genetics companies, bankers and others. Again, informed by the experience of InCalf, there was particular concern to ensure that the HR project adopted an inclusive approach. At a practical level, this required the project to accommodate a broad spread of experience. In terms of end-user engagement, as illustrated in the quotation below, this revealed that every-day practice for some was wholly unfamiliar to others:

> "From the dairy industry point of view, we've engaged with our end-users for decades … for others, it's so outside their norm." (HR_ ProjectTeam)

The value not just in involving different organisations but engaging with the right people within these organisations; those with drive, connections and leverage to "make things happen" (HR_ProjectTeam) was emphasised. Some respondents wondered if and how they might be purposively identified in order to streamline the process. Through language such as "deadwood" and "drag" a sense of frustration about the involvement of stakeholders without the desired appetite for change was articulated. Others were more sanguine with one external observer remarking "…you have to work with the hand that you are dealt" (PIP_ProjectTeam).

The challenge for any project in reaching-out beyond immediate participants, sometimes referred to as the 'usual suspects', to the so-called 'hard-to-reach' stakeholders was acknowledged by respondents. Some cautioned that as more is asked of participants in terms of contributing their time, energy and resources to participative approaches, such as co-innovation, so they may themselves become harder-to-reach, in an effort to manage or limit their commitments.

Although not hard-to-reach, a gap was identified with respect to Rural Professionals, for example independent book-keepers, accountants, nutritionists, agronomists, consultants and advisors. A group with extensive on-farm contacts and frequently

delivering services and advice to farmers, they may, however, be wary of committing their time to the demands of ongoing projects given a likely requirement to sacrifice on-farm, fee-earning opportunities for non fee-earning project work. Likewise, although Beef and Lamb NZ (B+LNZ), the representative body of a large proportion of graziers, was supportive of the HR project – and broadly represented in the project by farmer members – this did not extend to providing access to its specialist advisors. Since DairyNZ was making its wider resources available, this created something of an imbalance and, albeit unwittingly, perpetuated divisions along sectoral lines.

Framing co-innovation

Concerns were expressed by some respondents that co-innovation was too readily described vis-à-vis a more linear, technology transfer approach and, on this basis, it risked being positioned as 'not technology transfer' rather than established according to its own merits. In part, this was a reflection that respondents found the concept of co-innovation difficult to perceive clearly and consequently difficult to explain to wider stakeholders. It also reflected the absence of a co-innovation 'blueprint' and an emphasis on learning by doing that led respondents to interpret co-innovation, as reflected in the quotation below, as something of a mindset rather than a method:

> "…there isn't really methodology for this … it kind of depends on the context and what you're trying to deal with. I think it's more of a mindset actually than a methodology." (HR_ProjectTeam)

A part-science/part-art interpretation, "airey-fairey" in the words of one respondent, did not sit comfortably in the context of NZ's science-driven dairy sector and a more concrete description of co-innovation was sought. Participants across the ex-ante projects, including the HR project, turned to Nederlof et al's (2011) nine principles for a collaborative approach to innovation[99]. Although these provided a much-valued basis for describing the 'what' of co-innovation, they did not provide details of the 'how' leaving practitioners to feel somewhat exposed. By introducing the co-

[99] Nederlof et al (2011) identified: learning and reflection; contextual awareness; shared vision; understanding; engagement; flexibility; honesty and openness; inclusivity; and perseverance.

innovation approach on the basis of these principles to a wider audience some stakeholders were prompted to respond, as illustrated in the quotation below, that they reflected existing perceptions of good practice rather than new or novel practice:

> "I've talked to people and they're going 'I don't really see why that is called co-innovation'. What does that do for this community, and what does it do to the term co-innovation as well? It's not helpful on both fronts, it's just sort of saying that I can't distinguish between what we do normally and what we do in this thing called co-innovation." (HR_Stakeholder)

There was concern that the 'USP' (unique selling point) of co-innovation, was not being effectively communicated and the approach risked being undermined. It came to be understood, however, that interpretations of good practice did not equate with common practice and the challenge for the HR project began to be seen in terms of better embedding good practice in everyday practice. In this way, a more nuanced framing was developing that, as expressed in the quotation below, sought to strike a balance between acknowledging the sector's track-record and seeding future change:

> "Do you say 'we're going to turn it around, do it differently, do it much better' … to me, that's quite a dangerous route to go down, telling people that what they used to do is not much good and we can do it better… or you could start off and say 'we've done reasonably well but how can we do better?'…" (HR_ProjectTeam)

For one respondent this then raised the question of how best to determine the most appropriate response to any given situation, prompting the suggestion of a decision tree or similar to help users in weighing-up the relative strengths and weaknesses of different approaches, from technology transfer to co-innovation.

6.2.3.2 A co-ordinated approach to working together

A co-ordinated approach involved establishing a common understanding of language and agreeing-on working definitions of relevant terms. While it required a sharing of ideas and resources, it also required an ability to see the bigger picture and a recognition that no single organisation holds all the answers. In the context of a

competitive science environment, commercial drivers were never far from consideration and mutual trust was a vital, if fragile, ingredient in this process.

Developing a shared vision for change

As described in the quotation below, despite a shared interest among stakeholders in improved heifer rearing practice, there was no consensus in terms of how to proceed:

> "…a shared vision is one thing but I don't think there's necessarily a shared vision of the pathway that you would use to get there!" (HR_ProjectTeam)

The formation of an IAG was intended to provide the required direction and reflected a concern that producers had for too-long been at the receiving end of "conflicting messages and different views" (HR_ProjectTeam) with respect to heifer rearing practice. For some respondents there was an element of frustration at the time taken to establish a common understanding of underlying terminology, for example: agreeing on a working definition of heifers; and to the protocols of weighing. Farming respondents, however, welcomed these efforts to establish consistency, commenting that it would be time well-spent if it achieved a more joined-up message across the sector. The group also took time to reflect on previous initiatives that have variously tackled heifer rearing as a management, economic or communications problem.

In the light of this developing understanding, potential responses to the problem began bubbling to the surface. For some, greater levels of interaction with veterinarians were required while others argued for closer attention to growth rates or a better understanding of target weights and weighing. Championed by individuals rather than emerging from a co-ordinated process, these multiple interpretations left the group at risk of fragmenting. To provide some guidance, the IAG took soundings from the wider farming community via a nationwide series of focus groups. This process required something of a 'leap of faith' from stakeholders as they risked seeing the group move away from their preferred responses. The results, however, were to prove a turning point, bringing a fresh perspective to the problem.

The focus groups reflected multiple perspectives of the problem, chiming with stakeholders' experience. One finding, however, brought a new dimension to the debate. As described in the quotation below this revealed that heifer rearing was as much to do with managing relationships between producers and graziers as it was to do with the management of the heifers themselves:

> "…it's a people problem it's not a heifer problem, it's about relationships between dairy farmers and graziers..." (HR_Stakeholder)

None of the group had a prior 'knowledge claim' on producer:grazier relationships and by demonstrating that no-one held all the answers, the outcome succeeded in reinforcing the value of a co-ordinated approach. By introducing a new perspective of a long-standing problem some stakeholders, however, were prompted to question whether or not they had the necessary expertise to effect change in this area.

Equitable relationships

In the same way that DairyNZ's frontline advisors expressed concerns with respect to the conflicting timeframes of the co-innovation process, timescales were also proving to be problematic for stakeholders operating in a commercial environment. As reflected in the quotation below, they too were under pressure to deliver results:

> "…demanding timeframes are part of corporate life that's not going to change, if co-innovation can't cope with having to move fast at times then it's going to struggle." (HR_ProjectTeam)

Reflecting the group's fragile, early connections, some cautioned that if conflicting timings became too much of an obstacle then stakeholders would go their own way. Indeed, although the HR project was described as outwardly giving every appearance of "going swimmingly" (HR_ProjectTeam), this disguised the challenge of ensuring that behind the scenes, the administrative aspects of inter-organisational relationships – for example; intellectual property rights, commercial confidentiality and contract matters – kept pace with developing informal relationships through co-innovation processes. In particular, a lack of clarity with respect to Intellectual Property (IP) hampered the development of trust between stakeholders and, as illustrated in the

quotation below, for some this pointed to an underlying gap between the general principles of co-innovation and the commercial realities of NZ's dairy sector:

> "…what constitutes intellectual property and if there's any generated who actually owns that idea … there are 20 year histories of some of these companies working together and feeling like they've been taken advantage of … coming up with ideas and somebody else going away and creating the product off the back of their good ideas…"
> (HR_ProjectTeam)

There was concern that grey areas, such as this, allowed inconsistencies to develop. For some stakeholders, co-innovation meant working on heifer rearing exclusively within the HR project; for others, it was not understood as a mutually exclusive endeavour. Tensions arose when these different interpretations came to the surface. These issues were worked through but trust in the co-innovation process and between the participants' involved was checked and stakeholders were left to reflect that an early 'declaration of interest' may have been sufficient to avoid a misunderstanding.

Within DairyNZ, the project benefitted from internal support at a senior level, a champion, not for co-innovation, but for the provision of time and space to explore new approaches, such as co-innovation. The value of this support was demonstrated by DairyNZ's ongoing commitment to the project in the face of severe downward pressure on milk prices in the 2014/16 season. Indeed, a Senior Manager with Dairy NZ observed that, if anything, the price crisis heightened the importance of the HR project and wider PIP in exploring new approaches to innovation. As project host, DairyNZ was well-placed to appreciate the high level of internal commitment and resourcing needed to support the HR project. This was recognised and appreciated, to an extent, by other participants. At the same time, however, felt to be in line with DairyNZ's remit as the industry-good body. For DairyNZ there was concern that without a financial stake, other participants were, however, at liberty to walk away from the project. It was suggested that if the approach was repeated then other organisations would be asked to provide co-funding to put the project on a more 'even-keel' and to secure a more tangible commitment from participants.

6.2.3.3 A complementary vision

There was some concern among respondents that the Heifer Rearing project was providing a 'case of convenience' and that applying a co-innovation approach to the problem of rearing heifers to target weights was, to coin a phrase, like 'using a sledgehammer to crack a nut.' Although aspects of the problem were complex, it was seen primarily as a management problem, rather than a wicked problem, and best addressed through established knowledge transfer mechanisms. As the project progressed, however, and the complexities of breaking-away from business-as-usual came to be better understood so attitudes softened and perspectives began to shift.

Breaking away from business as usual

At the farmer level, it was observed that producers had readily and widely adopted off-farm grazing of dairy heifers. However, with agreements typically "done on a handshake" (HR_ProjectTeam) the process was, at best, inconsistent. A grazier voiced his frustration with producers' delivering heifers in indifferent condition; coming back for them a year or so later, with little in the way of farmer-to-farmer engagement in the meantime yet expecting to see a transformation in their condition, in his own words:

> "…expecting us to make a silk purse out of a sow's ear!" (HR_Stakeholder)

Meanwhile, a dairy farmer reflected on the inertia of routine practice and the temptation to continue the status-quo. In this example, illustrated in the quotation below, the farmer's cattle had been going off-farm to the same grazier, achieving mediocre results for many years. The farmer, talking in terms of 'better the devil you know' was reluctant to change given the difficulties and expense of finding new grazings, and, in the absence of information to the contrary, the grazier assumed the service being provided was meeting the customer's requirements:

> "… you've been with someone for so long and these are the heifers we get back, we're used to seeing them like that..." (HR_Stakeholder)

Although graziers and producers were doing what they had long done, both parties welcomed the opportunity for an improved understanding of one another's

expectations, more clearly defined responsibilities and, crucially, better outcomes in terms of heifers produced to target weights. In short, "beneficial for both parties!" (HR_Stakeholder). Provision of a simple, third-party checklist provided a mechanism to help stimulate change, to open fresh dialogue and to break-away from the constraints of 'business-as-usual'. Early drafts covered basic aspects such as the duration of the grazing contract; health planning; weighing protocols and targets; and contingency plans in the event of disease outbreak or requirement for buffer feeding and have since contributed to development of more comprehensive pro-forma[100]. It was emphasised, however, that these forms were intended as a means to encourage dialogue and a basis to build relationships rather than seen as an end in themselves.

In a similar way, organisations' faced operational challenges in working across different structures, to different financial years and with different corporate cultures. The organisations themselves were sometimes both competitors, for example for science funding, and collaborators; sometimes existing relationships were being reset and sometimes new relationships were being forged, all of which created a complex network informed by the legacy of change in NZ's science sector. Against this background, co-innovation became, as reflected in the quotation below, something of an 'awkward alliance' between research and commercial drivers and subject to all the tensions of a competitive environment:

> "…an awkward alliance between research and operational activities, friction and tension is part of progress but it's not always comfortable…" (HR_ProjectTeam)

The HR project was demonstrating, however, that co-ordination was possible with discussion among respondents of barriers being broken-down as organisations supported one another, for example delivering side-by-side at farmer-facing events. Something, it was remarked, that would not otherwise have happened. Nevertheless, there was, as illustrated in the quotation below, inertia to be overcome:

[100] https://www.dairynz.co.nz/animal/heifers/contract-grazing/

> "…a desire to change and a desire to have impact but a resistance to do things differently!" (HR_ProjectTeam)

As well as differences between organisations, some respondents encountered a sense of dissonance, a 'co-innovation gap' between the behaviours espoused in the HR project and their day-to-day experience as they moved back-and-forth between the project and their day-to-day responsibilities. Some spoke too of the challenge of feeling their way with the co-innovation process, in the absence of previous experience, trying to sense when time was needed for the group to deliberate and to recognise when the process was at risk of stalling and needed to be moved on. They reflected too on the uncertainty that they had experienced, not only in implementing a co-innovation approach but also adapting to learning-by-doing. As illustrated by the quotation below, in time this discomfort came to be recognised as part of the ebb and flow of the co-innovation process but it was, at least initially, uncomfortable:

> "…I think people haven't quite understood that progress in a collaborative sense can often be uncomfortable and when you are feeling uncomfortable, it's not bad." (HR_ProjectTeam)

Responding to change and uncertainty

Although NZ's science sector has witnessed extensive change over recent decades this was seen as an ongoing process of evolution. Indeed, as illustrated in the remarks below, realising the gains of previous change depends, in part, on an ongoing commitment to see through the delivery of these changes:

> "…the job isn't done yet in terms of NZ's science system and what we've gone through since all of the privatisation and corporatisation of science in the mid-80s..." (HR_Stakeholder)

Several respondents reflected on the direction of change, expressing concern about the capacity of NZ's science system to accommodate the sheer complexity of delivering growth and improved environmental outcomes. There was discussion too about DairyNZ's responsibilities and, in this way, the HR project was seen as not only about improving heifer rearing practice but also contributing to a wider debate. One respondent, in particular, used powerful language to express concerns about the

performance of the science system that, as set out in the quotation below, reads as something of a wake-up call to the sector and the wider research community:

> "I'm not losing sleep over the performance of heifers but I am losing sleep over the performance of our science system and whether or not it's actually getting us anywhere and that's the real heart of it." (HR_Stakeholder)

Interest among respondents in the origins of the co-innovation approach as applied in the PIP prompted several respondents to reflect on the long-standing links between AgResearch in NZ and Wageningen University in the Netherlands (NL) that had, over the years, contributed to an ongoing dialogue and inspired the co-innovation pilot. Others highlighted the different farming practices between the two countries, contrasting NZ's 'freedom to farm' ethos with more highly regulated Dutch farming. Change, however, was seen as common to both and it was associated with a tightening of regulations in NZ and a pulling-back from regulations in the NL. Differences between NZ and the NL were seen as extending beyond farming to include wider cultural traits and the Dutch reputation for 'telling it how it is' was contrasted with a more deferential approach in New Zealand. As illustrated in the quote below, on the ground this translated into a different approach to co-innovation:

> "…it's slightly ironic that one of the initiatives within the HR project is getting farmers and graziers to have difficult conversations with each other but even within the project, people aren't willing to have difficult conversations!" (HR_ProjectTeam)

The export orientation of NZ's agri-food sector was acknowledged as critical and informed much thinking. By the same token, the enduring capacity of the country's farmers to innovate and adapt was widely recognised. There was concern, however, that the global and the grass-roots were not always joined-up and addressing this disconnect was a strong motivation behind co-innovation. Some respondents talked in terms of the 'innovation imperative' driving competition in world markets and expressed their concern, as voiced in the quotation below, that NZ's ability to compete was hampered by the institutional constraints of the prevailing system:

> "…a lot of our technology developed in New Zealand is really good technology but it's actually not developed to answer questions that farmers ask …Why aren't you using it? Well the question was never asked, it was just developed by a scientist!" (HR_ProjectTeam)

For some respondents, a pushing-back of boundaries in order to bring wider institutional factors into consideration was central to the argument for piloting a co-innovation approach in a NZ context. This was seen as especially timely given the challenge of balancing calls for increased export revenues with rising levels of concern about the agri-food sector's environmental impacts. A challenge that was only expected to become more complex. One respondent drew on specific local examples to illustrate the problematic trade-offs on the horizon as early-wins, such as Lake Taupo, are followed by more complex cases, for instance the Upper Waikato basin. In the latter region, any steps to "de-power" dairying in an effort to deliver environmental improvements risked jeopardising the region's economy, raising questions of a different order of magnitude to the rearing of heifers.

6.3 Discussion and conclusions from the case of Heifer Rearing

Through application of a co-innovation inspired approach in response to a persistent, production problem, the HR project bridged multiple levels, bringing together producers, graziers and wider stakeholders. It was informed by lessons learned from the InCalf initiative and, in particular, by concerns that despite its technical strengths, insufficient engagement with veterinarians and farmers in the project's planning and design stages had inhibited uptake of InCalf among producers at the sector's grass-roots. Time will tell whether or not the HR project breaks through more effectively but early indications are encouraging.

The promise of a more collaborative approach resonated with stakeholders and there was a high level of interest in the project and the co-innovation approach in its initial stages. The research sector's deeply embedded science-driven culture meant, however, that many stakeholders sought the reassurance of a more familiar, scientific approach and felt uncomfortable with the concept of 'mindset rather than method.' Stakeholders were not alone in feeling uncomfortable, researchers too voiced their

uncertainties as they felt their way with the concept of co-innovation and the 'learning by doing' process that left them feeling somewhat exposed. At the outset of the project, there were difficulties differentiating co-innovation from accepted good practice. Consequently, it risked being positioned as 'not technology transfer' rather than on the basis of its own merits. Over time, a more nuanced message was developed that reflected a spectrum of different approaches, each with its own strengths and weaknesses, and potential applications and this was better received.

Early engagement gave rise to the challenge of sustaining interest. Respondents were in agreement about the risks of promising too much, too soon and recognised that managing expectations was an important part of the co-innovation process. Those in farmer-facing roles expressed particular concern at the challenge of keeping farmers engaged. Since a vital ingredient in sustaining interest was the provision of new and emerging information, farmer-facing advisors were, to an extent, dependent upon the outputs of researchers and scientists and this highlighted the different relative timeframes of the two groups and the challenge of bringing them together.

As well as early engagement, breadth of engagement also had to be allowed for and this meant communicating with a broad cross-section of stakeholders. For some, end-user engagement was embedded within their *modus-operandi*, for others it was almost wholly unfamiliar with a broad range of experience in between. Sometimes, engagement was not felt to be broad enough and respondents reflected on the challenge of engaging with so-called hard to reach communities and reaching beyond the 'usual suspects'. It was observed that demands on stakeholders' time are increasing all the time and there were fears that this may result in more becoming hard to reach as they seek to manage their time and commitments. Although the value in working with the 'right' stakeholders was emphasised, those with the drive, connections and leverage to make things happen, selection was not always in the gift of the project and the need to work with available resources was recognised.

The involvement of diverse stakeholders brought multiple perspectives of the problem to discussions. It also became apparent, however, that participants were using language in different ways and attaching different meanings to terms. All of

this took time to work through and gave rise to some frustration, especially in light of a desire for progress to be made and for findings to inform dialogue and maintain the interest of a wider audience. There was also a risk of participants' paying lip-service to the co-innovation concept as many had preferred solutions in mind, ready for the group to endorse. Only by consulting with a wider group of farmers was a shared understanding reached that the relationship between producers and graziers was an integral part of the problem. Provision of a simple third-party checklist provided the basis to open new avenues of discussion between these two parties and to begin the process of putting previously informal agreements onto a more formal footing.

Relationships between organisations were also relevant to the process. These were sensitive not only to past interactions and the lasting legacy of NZ's science reforms but also to the current structure of competitive science funding. This gave heightened importance to the challenge of building personal relationships as well as ensuring the smooth-running of administrative aspects of organisational relationships around confidentiality, contracts and intellectual property rights. While Dairy NZ's support and ongoing commitment to the project, for example in the face of falling farm-gate milk prices, was acknowledged, it also created some imbalance and it was suggested that a more equitable sharing of costs and resources would be of benefit.

Seen by some as primarily a knowledge exchange problem, the challenge of breaking away from business as usual and the effort needed to overcome the inertia of the status-quo – be that with respect to accepted heifer rearing practice, the relationships between producers and graziers, or between organisations operating in a competitive science funding landscape – added-up, however, to a more complex challenge. Applying a co-innovation approach inspired by work from the NL to NZ in response to this challenge highlighted the context-specificity of co-innovation and the value of a bespoke rather than off-the-shelf approach, informed by guiding principles.

More widely, addressing the sector's adverse environmental impacts and finding an equitable balance for the future while responding to pressure to increase export revenues represents a more complex challenge still. To hear senior industry figures speaking in terms of 'losing sleep' over perceived shortcomings in the capacity of

NZ's prevailing innovation system to respond underlines the urgency of the situation. Applying a co-innovation approach to the problem of heifer-rearing demonstrated that through collaborative, co-ordinated and complementary processes, it was possible to accommodate: a breadth of expertise among stakeholders; variation in language and understanding; different levels of experience with respect to end-user engagement; a range of different perspectives on the problem and a mix of potential responses; variation in relative timeframes from the more immediate pressures for stakeholders in farmer-facing roles to the longer time horizons of scientists and researchers. The next chapter zooms-in on the functioning of the co-innovation space in the contested arena of agricultural water use in the Canterbury Region.

Intermezzo, informing on-farm irrigation practice

Against a backdrop of contested freshwater management and in response to concerns about on-farm irrigation practice, the Water Use Efficiency (WUE) project in NZ's Canterbury Region applied advanced information systems to bring-together field-level soil moisture and drainage data with detailed local weather forecasts. By analysing this data and communicating information to on-farm decision-makers, the project aimed to demonstrate potential for more sustainable irrigation practice.

The management of freshwater in NZ has tended to be "…more 'top down' than 'bottom up'…" (Memon et al., 2010, Page 37). In the Canterbury Region, however, there have been signs of change, a "collaborative turn" (Memon et al., 2012, Page 7) towards a more joined-up, Integrated Catchment Management (ICM) approach. The "institutional inertia" (Ferguson et al., 2014, Page 2) of the status-quo, nevertheless, may exert a barrier to change with prevailing institutions so deeply embedded that it takes the shock of "water shortages and serious environmental consequences" (Meinzen-Dick 2007, Page 15202) to raise awareness of emerging issues, challenge accepted practice and drive through change. In Canterbury, a series of severe droughts triggered the first stage of the Strategic Water Study (1998-2002) followed by a second (2004-2008) and third stage (2006-2008) before culminating, from 2008, in the Canterbury Water Management Strategy, or CWMS (Lomax et al., 2010). Along the way, the process, strategy and underlying science were all contested, contributing to a legacy if not of distrust then of scepticism between stakeholders.

The co-innovation inspired approach underpinning the WUE project chimed with the rationale of the 'collaborative turn' but the project's success was dependent upon overcoming any lingering scepticism in order to bring stakeholders together in a spirit of collaboration. In this chapter, I explore the associated challenges and opportunities and find that the space held by the WUE project, provided stakeholders with a forum to discuss shared concerns from multiple perspectives and to identify and implement potential pathways to respond. I find too that these pathways took occasionally unexpected turns, giving rise to new challenges and opportunities.

Chapter 7: Water Use Efficiency, going with the flow of institutional change

The focus of this chapter is the five-year Water Use Efficiency (WUE) project. It began in 2012 as one of five ex-ante projects[101] applying a co-innovation inspired approach under the Primary Innovation Programme (PIP). Located in the Waimakariri Zone of Canterbury, a region with a history of contested water management, the WUE project used the increased connectivity of farming businesses as a platform to deliver farm-specific soil moisture and local weather forecast data in the form of a daily electronic Farm Weather Briefing (FWB), assimilating otherwise diverse data with the aim of supporting on-farm decision-makers in moving towards adoption of more sustainable irrigation practice (Srinivasan et al., 2019).

Through application of a co-innovation inspired approach, diverse stakeholders were brought together and afforded the opportunity of contributing to development of the FWB. I follow the role of co-innovation in facilitating these interactions and find that it is consistent with the "collaborative turn" described by Memon et al. (2012, Page 7) to reflect an increasingly integrated approach to water governance in the region. I find too that in the context of contested agricultural water management in Canterbury, the premise of the FWB aligned with the aim of hard, regulatory drivers, for more sustainable irrigation practice. A challenge for the project, however, was to find alignment with the soft institutions or established norms of on-farm irrigation practice and I explore to what extent co-innovation facilitated this process.

To set the scene, I begin this chapter by outlining the context of the case. I reflect on the complexity of freshwater systems, increasingly required to take into account dynamic interconnections across and between sectors and levels and I consider the challenge of balancing competing demands arising from changes in land-use and public perceptions of resource management as they impact in the Canterbury Region.

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[101] Others being Heifer Rearing; Nutrient Management; Timber Segregation; and Tomato Potato Psyllid.

7.1 Context of the case: contested agricultural water management

The World Bank[102] (2016) has argued that the impacts of global climate change will be felt by many through changes in the local water cycle. The inflexibility of often centralised "command and control" models of governance, however, leaves them ill-equipped to respond to these changes and highlights a need for systemic alternatives better able to accommodate diverse sectors, for example, agriculture, water and environment; and multiple levels, for example the river basin or nation, irrigation system or catchment, and farm (Pahl-Wostl, 2015). On the basis of these levels and to contextualise the WUE case, I reflect below on the features of agricultural water management as they apply in NZ, the Canterbury Region and the Waimakariri Zone.

7.1.1 Agricultural water management

By its very nature, the hydrologic cycle means "one person's use of water generates externalities for others" (Meinzen-Dick, 2007, Page 15200). Taking place adjacent to other rural enterprises or on the fringe of urban areas, farming activities typically involve a sharing of natural resources with mutual responsibilities and, when it comes to securing change, a need for some form of "collective action" (De Loe et al., 2015, Page 191). Since prevailing institutions, hard in the form of regulations and soft in terms of the norms of on-farm practice, are not always aligned then this may give rise to complications (Nettle and Paine, 2009). Moreover, while passing almost unnoticed when supplies of water are plentiful, interactions risk becoming problematic if supplies are diminished or compromised, for example through pollution, requiring some form of institutional intervention to "clarify rights and responsibilities" (Meinzen-Dick, 2007, Page 15200). Further practical challenges may arise in the event that this involves connecting otherwise diverse catchments and disparate user-groups (Renner et al., 2013; Hedelin, 2007; Kolavalli and Kerr, 2002).

[102] The World Bank (2016) identifies three, interlinked policy areas that underpin its concept of Smart Water Policy: i) closer attention to planning and incentives to optimise use of scarce water resources; ii) investment in infrastructure as part of an holistic approach that allows for system interactions; and iii) better preparedness for extreme weather events and increased levels of uncertainty (Page ix).

For example, with respect to the need to develop a shared vocabulary, managing data in various forms from multiple sources, and, not least, allowing time for "…building trust and a mutual commitment to work together" (Ayre and Nettle, 2015, Page 25). The consequences of neglecting this process or of perceived or actual inequalities arising from its implementation, such as prioritising expert knowledge over local knowledge, can result in damaging divisions within communities (Wheeler et al., 2018) prompting calls for greater awareness of social vulnerabilities with respect to implementing potentially transformative change (Alston et al., 2018).

7.1.2 Water quality concerns in New Zealand

Intensification of dairy farming in NZ is exerting increased pressure on the environment and the challenge of reducing losses of nitrogen from dairy farms to the water system has been described as "one of the most pressing issues facing not only the dairy industry but the country in general" (McCloy, 2014, Page 49). Elsewhere it is referred to as the country's "leading environmental issue" (Doole and Romera, 2015, Page 15). Indeed, Rowarth (2013) has argued that over the last 20 years, public understanding has passed a "tipping point" (Page 85) as perceptions of the sector as "one of the most efficient and environmentally benign ruminant livestock industries" (FAO, 2012, Page 277) have shifted, sparking action such as the 'Dirty Dairying' campaign calling to account NZ's dairy sector for its environmental impacts (Duncan, 2017). Until relatively recently – and in contrast to the European Union's Water Framework Directive – NZ's response has been via a mix of non-regulatory community action groups and industry initiatives (McDowell et al., 2017). Of the latter, the Dairying and Clean Stream Accord (2003-2012) and, from 2013, the Dairy Environment Leadership Group, saw central and local government work with Fonterra, NZ's largest dairy co-operative, to promote good practice. While a reported strength of these schemes was their focus on local issues, in a reflection of the difficulty of working across different levels, this came at the expense of a national overview (McDowell et al., 2017). The Ministry for the Environment's (MfE) National Policy Statement for Freshwater Management, 2014, sought to correct this imbalance and the 'Swimmable Rivers' initiative has pledged to make

'90% of rivers and lakes swimmable by 2040' while industry too is taking steps to promote responsible water use via an 'Action Plan for Water Quality.'

7.1.3 Legislative lag

The Resource Management Act (1991) is the mainstay of NZ's environmental policy and responsibility for its implementation rests with the country's Regional Councils. Their "territorial jurisdiction" was informed, in part, by catchments with a view to facilitating "an integrated approach to natural resource management" (Memon et al., 2010, Page 35). Despite this aspiration and subsequent amendments to the RMA, for example in 2005, aiming to encourage greater integration, there are concerns that NZ's environmental policies have not kept pace with developments in farming (Fenemor et al., 2011; Aerni, 2009; Memon et al., 2010). In recent decades this disconnect has contributed to a decline in the quality of NZ's freshwater resources (PCE, 2015) prompting the MfE to commit to halting "degradation of New Zealand's waterways so that water quality is materially improving within five years, and to restoring them to a healthy state within a generation" (MfE, 2019, Page 5). Setting this process in motion is the 'Action for healthy waterways' initiative[103] and among the options it explores for the farming sector are: limits on further intensification of land use, feedlot production and stock holding areas; the exclusion of livestock from water courses; and steps to reduce nitrogen loss from agriculture through more responsible winter grazing and increased uptake of farm environment plans (FEPs).

With their activities coming under increased levels of scrutiny, it has been suggested that farmers' gain some validation of their role "as responsible and worthy recipients of the portion of the freshwater resource that they have been allocated" through implementation of regulations (Myles et al., 2015, Page 9). For example, prior to FEPs becoming mandatory in the Canterbury Region in 2017, the prospect of them becoming mandatory was sufficient to prompt their voluntary uptake among some growers by way of not only applying but also demonstrating good farming practice.

[103] https://www.mfe.govt.nz/consultation/action-for-healthy-waterways

7.1.4 The Canterbury Region

Over recent decades, the pace of change in agricultural land use in the Canterbury Region has been especially rapid with reduction in extensive dryland beef and sheep enterprises, and some forestry, and an increase in irrigated grassland for dairying (Myles et al., 2015; Weber et al. 2011). While these changes have brought economic benefits to the region, they have also increased pressure on natural resources and sharpened the focus on agricultural water management in the region (Memon et al., 2010). Responsibility for these issues and for implementing the relevant legislation, primarily the Resource Management Act (1991), rests with Environment Canterbury (ECan), the largest of NZ's Regional Councils[104]. Given the tensions between, on the one hand, the economic importance of irrigation to the region's agriculture with the prospect of further expansion; and, on the other hand, the pressure on wider ecosystems exerted by the quality and quantity of freshwater resources, this task has been said to have all the characteristics of a 'wicked problem' (Weber et al., 2011).

Former Professor of Strategic Water Management at the University of Canterbury and Lincoln University and before that Chief Executive of Canterbury Regional Council, Bryan Jenkins (2018, Page 4), draws on his local knowledge to highlight six defining characteristics of Canterbury, depicting a Region where: i) "…58% of New Zealand's water for consumptive use" is allocated making the allocation of water a major consideration; ii) water allocation has become increasingly contested with "current methods of abstraction (primarily run-of-river offtakes and groundwater bores) reaching sustainability limits" in some areas; iii) irrigation is of high importance with some 500,000 hectares or "70% of New Zealand's irrigated land" located; iv) there is estimated to be sufficient suitable land available to allow for a doubling of this irrigated area to around one million hectares; v) the "braided rivers, high country and coastal lakes, as well as lowland streams and wetlands" are vital to local ecology; and vi) there is increasing public concern about the impacts of current

[104] In NZ, there are 11 Regional Councils, 12 City Councils, 54 District Councils, and Auckland Council. Collectively, the City, District and Auckland Councils are referred to as Territorial Authorities and among these, six have the powers of a Regional Council (www.localcouncils.govt.nz)

levels of abstraction reflected by "declining ecological health of lowland streams and coastal lakes as well as water quality in surface and ground water." Canterbury is also shaped by the devastating series of earthquakes in 2010-11 that resulted in the deaths of some 285 citizens, transforming the city of Christchurch and impacting on the surrounding landscape and the communities living and working there (Potter et al., 2015; see Appendix XVI). More widely, there is also a requirement across NZ that "Mäori customary values and the guardianship concept of kaitiakitanga are to be recognised in decision making around water" (Fenemor et al., 2011, Page 13).

7.1.5 Water management in Canterbury

In the Canterbury Region, a Strategic Water Study (1998-2002) was initiated in the aftermath of a series of severe droughts. This was followed by a second (2004-2008) and third stage (2006-2008) that, from 2008, became the Canterbury Water Management Strategy, or CWMS (Lomax et al., 2011). In the process, ECan's elected representatives fell-foul of both environmentalists and the agri-food sector; the former objecting to an apparent failure to curb abstraction and the latter taking issue with the perceived slow and costly allocation of consents (Eppel, 2014). At the same time, competing theories[105] about the region's groundwater resources were contributing to a so-called "societal impasse" (Weber et al., 2011, Page 49). In 2010, with the process at risk of stalling and becoming deadlocked, in a dramatic move elected officials were replaced by government-appointed officials charged with developing and delivering the CWMS on the premise that there was potential to: i) satisfy the requirements of producers and to realise environmental improvements; ii) increase the available volume of water through improved irrigation efficiency and investment in storage ponds; and iii) streamline the existing structure of rights and permits that has tended to develop in a piecemeal fashion over an extended period.

[105] Weber et al. (2011, Page 50) contrast the 'Aqualinc' model that allows "the presence of less permeable layers which could lessen the immediate impact of taking water from deeper aquifers to upper aquifers" with the 'Bathtub' model that "takes a 'big picture' approach that proposes relatively continuous flows between aquifers, thus implying that a withdrawal from one area immediately impacts water levels and availability throughout the entire region" - each with its advocates.

7.1.6 The Waimakariri Zone

A network of 10 Zone Committees (shown in Figure 21, below) was set up to embed the CWMS in the fabric of local communities. One of these, the Waimakariri Zone, lies to the North of the Waimakariri River as it flows from Arthur's Pass National Park, over the Canterbury Plains to the Pacific Ocean, North of Christchurch. Each zone has its particular challenges, as reflected, for example, by the designated 'Red' status of some, including the Waimakariri, to indicate raised water quality concerns or 'Water Outcomes not Met' (Canterbury Land and Water Regional Plan, 2015).

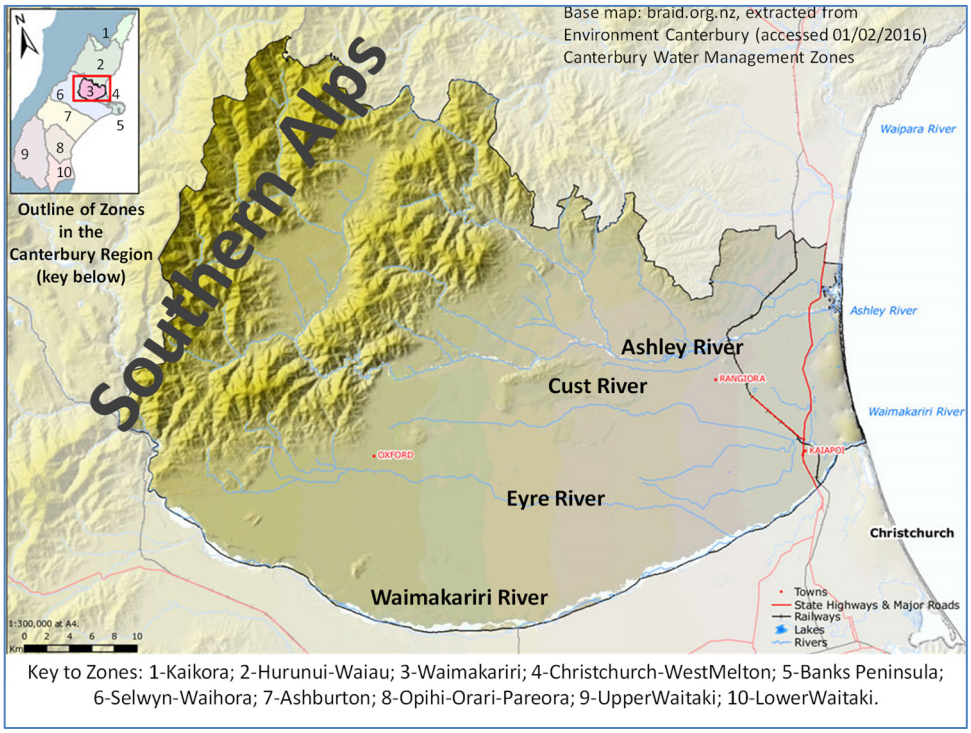

Figure 21 The Canterbury Region's Zone Committee structure, highlighting the Waimakairi

The Waimakariri River supports the varied ecology of the region; is enjoyed by local residents, visitors and recreational users; as well as being a source of stock-water and supplying Waimakariri Irrigation Limited (WIL) with irrigation water for farm-land. In the Foreword to his history of the Waimakariri irrigation scheme, Richard Allison (1999, Page 1) highlights the transformation effected by the opening of the first water-race in 1896, noting also "…what people in the future choose to use the water for may be quite different than what we see today..."

7.2 The case of Water Use Efficiency

Initiated by NIWA (National Institute of Water and Atmospheric Research), the WUE project progressed the concept of a Farm Weather Briefing (FWB) as a vehicle to provide on-farm decision-makers with access to timely, location-specific data to inform day-to-day irrigation management. Delivered to participating farmers' smart phone or computer, the FWB collates data relating to: observed rainfall and irrigation; soil moisture and temperature; drainage; estimates of evapotranspiration; as well as NIWA's 2, 6 and 15-day weather forecasts. Under the wider Primary Innovation Programme (PIP) and using a co-innovation inspired approach, ongoing development of the FWB took place in the Waimakariri Zone with its evolution informed by participant feedback and it, in turn, feeding-back into the wider PIP.

7.2.1 Sources of information on Water Use Efficiency

Yin (2004) highlights the case study's ability to accommodate data from multiple sources and, moreover, to be strengthened by drawing on diverse sources. Although personal interviews were the basis of my investigations – and, as shown in Table 15, below, respondents consisted of members of the project team and wider stakeholder community – I drew also on relevant reports and personal, in-field observations.

Theme	Identifier used in database	Descriptor used in text for anonymity	Interviews n = 18			Interviewees n = 20	
			1	2	3	1 : 1	1 : 2
Water Use Efficiency in the Waimakariri: comprising 18 x interviews with 20 respondents							
Waimakariri	_Farmer_Arable	WUE_Stakeholder					
Waimakariri	_Farmer_Dairy_1	WUE_Stakeholder					
Waimakariri	_Farmer_Dairy_2	WUE_Stakeholder					
Waimakariri	_Farmer_Dairy_3	WUE_Stakeholder					
Waimakariri	_Farmer_Mixed	WUE_Stakeholder					
Waimakariri	_DairyNZ	WUE_Stakeholder					
Waimakariri	_EnvironmentCanterbury_1	WUE_Stakeholder					
Waimakariri	_EnvironmentCanterbury_2	WUE_Stakeholder					
Waimakariri	_Environment_Officer	WUE_Stakeholder					
Waimakariri	_Irrigation_Support	WUE_Stakeholder					
Waimakariri	_Irrigation_Acceleration_Fund	WUE_Stakeholder					
Waimakariri	_Irrigation_NZ	WUE_Stakeholder					
Waimakariri	_AgResearch	WUE_ProjectTeam					
Waimakariri	_NIWA_1	WUE_ProjectTeam					
Waimakariri	_NIWA_2	WUE_Stakeholder					
Waimakariri	_Irrigation_Scheme	WUE_Stakeholder	a	b			
Waimakariri	_Zone_Committee	WUE_Stakeholder					

Table 15 Profile of interviews and interviewees in WUE

My thinking was also informed by interviews in connection with the over-arching Primary Innovation Programme (PIP) and Heifer Rearing (HR) projects. While in New Zealand, I was primarily located with AgResearch at Ruakura. However, I spent a period of one month, during May 2015, with NIWA at their Christchurch offices. By providing me with a base in the region this enabled me to interview participating farmers on-farm, to make farm visits and to engage with wider NIWA scientists. I was also able to participate in the annual end-of-season stakeholder meeting that was attended by members of the WUE project team, representatives of Waimakariri Irrigation scheme and neighbouring schemes, as well as wider stakeholders. As a result of these interactions, I was invited to contribute to the proposal-writing for NIWA's follow-on 'Irrigation Insight' project and have maintained an overview of this work since it was awarded in September 2016.

7.2.2 Project overview

As shown in Figure 22, and discussed below, the broader concept of improved WUE was being explored in various ways, unfolding over an extended timeframe.

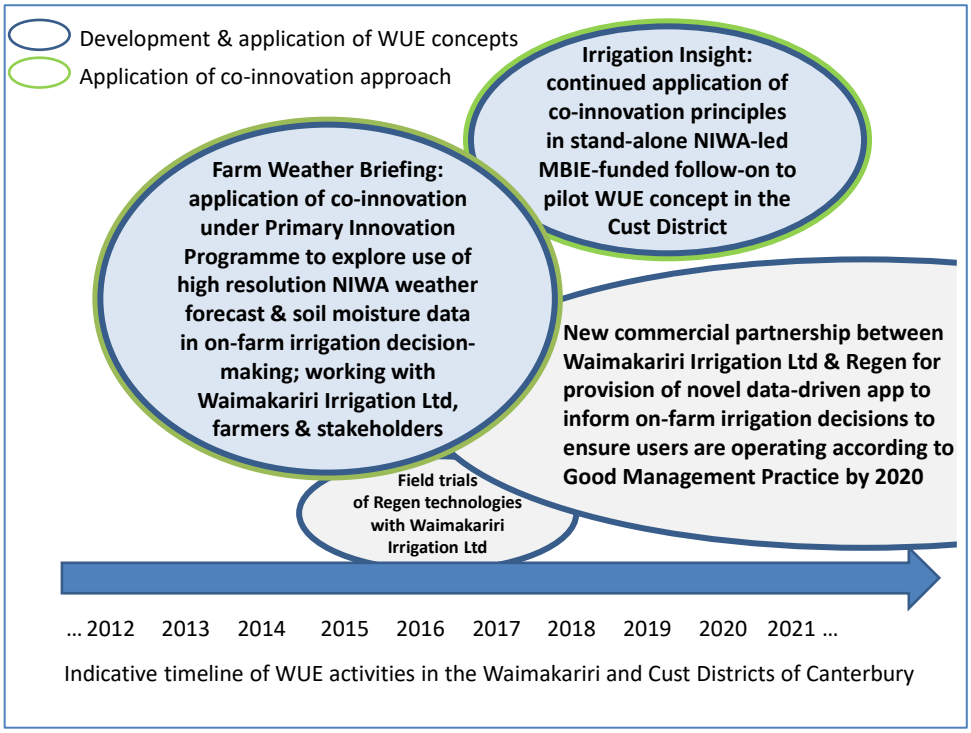

Figure 22 Pathway of concept development and application of co-innovation

With a shared aim of achieving improved water use efficiencies in the Waimakariri, NIWA worked closely on the WUE project with Waimakariri Irrigation Limited (WIL), the local irrigation scheme providers. In parallel, WIL was trialling another decision support technology in the expectation that one or other would hold the key to irrigating the existing area with a lower volume of water or irrigating an expanded area with the same volume, while at the same time demonstrating good irrigation practice. In due course, WIL awarded funding for ongoing provision of services to the alternative provider as this met their requirements at the time for an 'off-the-shelf' solution. As this door was closing for NIWA's project, however, another opened and in September 2016, NIWA's Irrigation Insight (II) proposal was successful in MBIE's Contestable Research Funding round for that year. It proposed a five-year, co-innovation inspired programme in the Cust District to better understand the potential for 'maximising the economic benefits of irrigation' through application of the FWB, building-on the proof-of-principle demonstrated in the Waimakariri Zone.

NIWA's ongoing commitment to applying co-innovation and MBIE's support for the WUE follow-on provide examples, respectively, of scaling of the co-innovation approach, as it gains traction within NIWA, and scaling of an innovation, as the concept of the FWB moves from proof-of-principle in the Waimakariri District to pilot stage in the Cust. In the sections that follow, I seek to better understand the role of co-innovation in anticipating these scaling processes.

7.2.3 Co-innovation in the Water Use Efficiency project

As illustrated in Figure 23, below, the main irrigation season in Canterbury runs over NZ's summer months from November through to February. In the two months either side of this period, the so-called shoulder seasons, it may be necessary to start irrigating earlier and/or continue later, depending on annual variation. Figure 23 also indicates the number of recipients of the FWB as it expanded, from 9 to 28, over the course of the project and the five phases of the WUE project, as identified by Srinivasan et al. (2019). Although these phases are illustrated iteratively, each leading into the other, in practice the phases overlapped and interlinked. Broadly,

the emphasis of Phase 1 (Concept Development) was on the technological considerations of the project; Phases 2 (Trust Building) and 3 (Knowledge Synthesis) were structured around network development; while Phases 4 (Extended Outreach) and 5 (Project Legacy) considered wider institutional aspects.

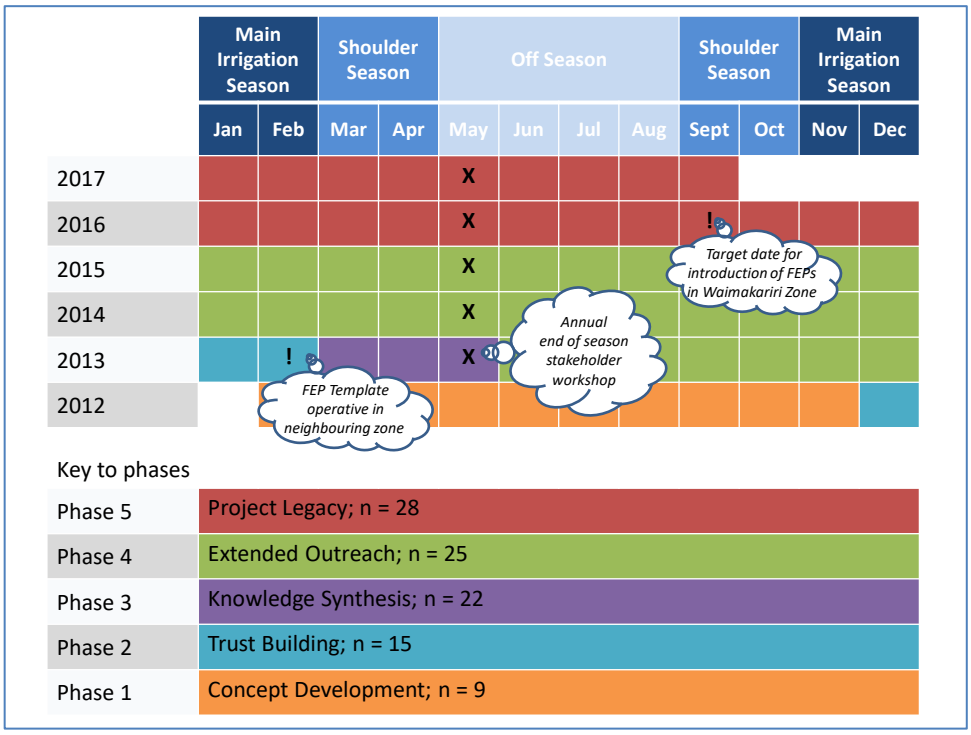

Figure 23 Indicative timeline of phased WUE project (adapted from Srinivasan et al., 2019)

Informed by these phases and drawing on Bitzer and Bijman's (2015) concept of collaborative, co-ordinated and complementary processes of co-innovation that together give rise to a 'co-innovation space' (Coutts et al., 2017), I explore below how co-innovation was understood and applied in the WUE project.

7.2.3.1 Collaboration around emerging technologies

During Phase 1, concept development, discussions took place within NIWA (the project hosts) and between NIWA and the PIP team as well as between NIWA and WIL and wider stakeholders. Reflecting on the somewhat happenstance events that first connected NIWA's WUE concept with the PIP, Project Manager, Dr Srinivasan from NIWA, and the project's Reflexive Monitor, Dr Bewsell from AgResearch described an external perception of NIWA as having a "…very linear, very technology transfer focus…" while within NIWA there was some uncertainty as to

the requirements of the PIP "…we didn't know what they were talking about!" Nevertheless, a connection was made on the basis of a shared "ambition for change."

Transformative change

Participating scientists, farmers and advisors were all mindful of ongoing change. Scientists' spoke of the growing body of knowledge that informs decision-making and an ever-evolving understanding of: NZ's complex water systems; the soil and water resources that characterise the Canterbury Region; and the impacts that various activities, including agriculture, have upon them. Advisors' reflected on changes in the management of water for irrigation in the Region. They recalled a system that, until relatively recently, relied on faxed requests for water submitted by farmers to the irrigation scheme with faxed confirmations by return and an associated 48-hour time lag. Nowadays, real-time communications via text and e-mail are transforming the way that water is being managed. Likewise, automated races have replaced manual sluice-gates, not only giving operators' greater levels of control but also releasing time spent on routine tasks for other, value-added activities that, as reflected in the quotation below, were seen as an important outcome of change:

> "…the revolution wasn't just the technology, it was freeing-up the scheme manager's time to think about things…" (WUE_Stakeholder)

Technology was also impacting at farm level and farmers' spoke in terms of the transformation brought about by irrigation. Cropping farmers – mindful that crops, as a general rule, are less tolerant than grassland to over or under watering with less capacity for recovery – are producing an expanded range of crops, with varying soil moisture requirements. The shift from extensive, dryland beef and sheep to irrigated dairying was, however, described as the most striking change.

One respondent recalled how, a generation ago, the prospect of irrigation was the deciding factor behind his family's move to the area in order to allow them the opportunity to develop and expand their dairy farming enterprise. They, and others like them, have made multi-million dollar investments in dairy cattle, milking platforms and irrigation infrastructure with associated financial risk for their farming businesses and their backers. Under pressure to maximise returns from grassland, as

explained in the quotation, below, irrigation tends to be seen by farmers as the key to unlocking the potential of seasonal grass-growth:

> "…until October/November – a dryland farmer and an irrigated farmer will be growing pretty much the same level of grass. After that, if you don't irrigate it drops off very quickly for the dryland farmer whereas the irrigated farmer can keep producing more grass – so that is what the irrigation is offering, that option. After the middle of March, there's little to choose between them but between November and mid-March that is when irrigation can make a real difference…" (WUE_Stakeholder)

In the field, respondents from the farming community spoke from experience of the risks of "going dry" in a farming system that largely relies on access to fresh grass without the reserves of hay or silage more familiar in European systems.

Technological alignment

The concept of the FWB is consistent with wider systems developments. For example: increasingly detailed and accurate weather forecasting capabilities; the technological advances that enable automated data collection from multiple, remote sites; the connectivity of farmers and decision-makers; and the increasingly sophisticated irrigation infrastructure that allows greater levels of precision and control. Crucially, at the same time, there was an enthusiasm among producers to apply these technologies at farm level, as illustrated in the quotation, below:

> "…it is incredible what technology there is out there. I've been introduced to soil moisture data and you can see the temperature and you don't really believe it sometimes but that's what it is. Then you start thinking, well I've got land with different soils, different aspects so you start to think about how you could mix and match across the farm – it's quite amazing really." (WUE_Stakeholder)

As an organisation, NIWA is well-placed to understand and respond to these changes, it has access to advanced local weather-forecasting capabilities that inform the FWB and the connectivity of farms makes it practical and possible for the timely distribution of information to participants' computers and smart-phones. At the same time, increasingly sophisticated irrigation systems at scheme and farm level allow

irrigation managers to respond to incoming information – although there is wide variability in irrigation infrastructure among producers, ranging from older, manual systems to more up-to-date, semi-automatic centre-pivot systems, as pictured below (Figure 24). A number of respondents noted that access to more sophisticated systems did not always equate with best irrigation practice being followed while users of manual systems had a particular incentive to make sure that they were used to optimum effect, given the labour required to move them from field to field.

Figure 24 Centre-pivot irrigator operating on grassland in the Canterbury Region

Timely delivery of accurate briefings was important in establishing the credibility of the FWB. In fact, participants commented that "you can set your watch" by delivery of the reports and this was important in helping them to incorporate the FWB into their daily routine. However, it was provision of accurate data that was the key requirement and participants' accepted that short-term forecasts were more reliable than longer-term predictions and although the FWB provides 2, 6 and 15 day forecasts, recipients' reported making most use of the 2-day forecast. It was originally envisaged by NIWA that the FWB would only be provided during the irrigation season (September to April). However, in response to demand from

participants, NIWA committed to provide the FWB year-round and it became embedded not only in participants' decision-making processes with respect to irrigation scheduling but also came to provide a source of information for other farming, as well as some non-farming activities, throughout the year.

7.2.3.2 Cross-sector co-ordination

Reflecting the particular features of Canterbury's river systems consisting of: i) the snow-fed alpine rivers, flowing from the Southern Alps and peaking during the summer months (including the Waimakariri); ii) the foot-hill rivers with rain-fed catchments and winter peak flows; and iii) the lowland, groundwater-fed streams (Jenkins, 2015), one scientist observed that the problem was sometimes expressed not in terms of "Canterbury running out of water but the water running out of Canterbury." That is, the water volumes are there but not always at the time they are needed. Indeed, a particular feature of the Waimakariri River is the variable, at times unreliable, water supply that, as expressed in the quotation below, tends to result in farmers over-watering 'just-in-case' volumes available for irrigation are restricted:

> "…it's better to have your land damp rather than dry – if the river goes off and your land is dry then you're going to dry-out real quick. That's what irrigators' do with unreliable water, they water too much." (WUE_Stakeholder)

Minimising the impacts of this constraint requires effective interactions between various stakeholders and in Phase 2, trust building, and Phase 3, knowledge synthesis, the emphasis was on further developing the network through, for example, site visits, knowledge exchange and, from 2013, an annual stakeholder meeting.

Constraints of the scheme

With a view to improving the scheme's reliability for shareholders, WIL is seeking to develop scheme-level storage ponds to be filled during periods of high flow rates and to be drawn on in times of low flow. In the meantime, some farmers have adapted to the constraints of an unreliable supply by investing in on-farm storage ponds, for others, there is a powerful logic for adopting a 'just-in-case' approach at the farm-level that has become deeply embedded or institutionalised in day-to-day practice. There are potential risks, however, in this model in the form of over-

watering and excess run-off or drainage in the event that water is applied shortly after or in advance of rainfall events or when soil moisture levels are close to capacity. In the absence of significant on-farm water storage, there are, however, barriers for growers in moving to a 'just-in-time' alternative. Through provision of data tailored to a farm's type and location, the FWB sought to empower on-farm decision-makers. Helping them to make improved irrigation management decisions within the constraints of the scheme and to take a step towards 'just-in-time', irrigation scheduling that resonates with wider understandings of good-practice.

Network development

The foundations of the WUE project in the Waimakariri Zone lie in the long-standing working relationship between NIWA and WIL that goes back over at least 20 years. In operationalising the project, NIWA's aim was to include a mix of farm types and a geographic spread across the zone reflecting various soil and climate conditions. For farmers, participation in the project was, however, not without risk. For example, they were reliant on timely delivery of accurate briefings to inform their day-to-day decision making with respect to irrigation scheduling. Also, with other farmers in WIL taking an interest in the project, local farming reputations were at stake. Respect for NIWA was a reassuring factor and on being approached, all five target farms agreed to participate. Early support by WIL's Chairman, one of the first farmers that volunteered to participate, and the endorsement of WIL's General Manager went a long way towards inspiring the confidence of others.

Over time, by delivering on its promise to support participants, for example through the ongoing maintenance of on-farm instruments, the timely delivery of daily briefings, prompt response to technical queries and a spirit of transparency, NIWA encouraged the development of mutual trust. With this came a willingness among participants to commit their time and energy to the project; both in the day-to-day on-farm application of the FWB and in contributing to additional activities in the form of hosting site visits, attending meetings and providing feedback.

The commitment of all participants to learn and adapt set the tone for the project and encouraged a culture of openness and enquiry in response to shared concerns around

management of water quality and quantity. This was highlighted in the end-of-season workshops that played a key role in providing a platform for both the exchange of ideas among participants and engaging with wider stakeholders. Each year, the scope of the meetings broadened-out as the confidence of the group developed. From a closed-forum in Year 1, by Year 3 the meeting saw representatives from: the Zone Committee; the Regulators, a neighbouring irrigation scheme; as well as some non-participating farmers from within WIL's membership taking part, not just as observers but as active participants in discussion around shared issues with respect to water management. This discussion stimulated new ideas that informed activities in the following season. For example, as a science-based institute, NIWA sees nutrient management as strongly linked with water (irrigation) management and has data that show irrigation taking place at the same time as drainage is occurring. For producers this represents money "down the drain" but if nutrients are being carried by the water then there are potentially wider, environmental consequences also. For the Project Manager, this suggested that "irrigation is being done very inefficiently" but at the same time it raised the question of whether or not "others would agree with that interpretation?" This topic was explored at the Annual Review (Year 3) and found to resonate with participants, regulators and observers alike and following-up these links between irrigation and drainage went on to form a core strand of the project in the following years.

The process of sharing data through the workshop format with a wider network of stakeholders to reach a commonly-held conclusion was described as providing the basis for a much more powerful argument for change than if the conclusion had come from NIWA alone. Ideas were triggered among the wider group as well. For example, concerns expressed by some producers about the difficulty of diverting water once it has been ordered in the event that their requirements change, revealed a willingness among others with access to on-farm storage to accept their allocation and provide a temporary 'holding tank.' By working together in this way, the scheme could become more flexible and, if run-off is prevented, more sustainable.

Extending discussions into neighbouring irrigation schemes and including representatives of these schemes in the annual review meetings highlights the level

of shared interest in exploring solutions to a changing regulatory landscape and in responding to an overarching strategy, in the form of the CWMS, that has indicated that business as usual is not a sustainable option. The exchange of information is not confined to the project meeting, as data are increasingly being shared within participants' farming businesses; and between participants and their neighbours, as witnessed by the expansion from 9 to 28 recipients of the FWB. As well as interactions with external actors, existing working relationships within NIWA were being redefined as adjustments were made to accommodate a more participatory and less technology transfer oriented approach.

7.2.3.3 A complementary vision

Farm Environment Plans (FEPs) represent a tangible intersect between regulations and farming activities and their introduction in the Waimakariri Zone brings a particular focus on reducing the discharge of nitrogen from agricultural activities to water-courses. A key element of this is believed to lie in encouraging farmers to adopt a more informed approach to irrigation activities so as to avoid run-off or excess field drainage by, for example, irrigating in advance of rainfall events or irrigating soil with a high moisture content. By empowering farmers to make better-informed decisions, the FWB is consistent with this direction of travel and, through the activities of Phase 4, extended outreach, and Phase 5, project legacy, the WUE project sought to build on this favourable alignment.

Aligning with institutional change

There was a widely-shared awareness among participants of the benefits extending from irrigated dairy production to the wider community. As articulated below, the local economy was seen, by some, as having been revitalised by the arrival of dairying:

> "…it's a tremendous thing for the district, if this irrigation scheme wasn't here and we were still dryland farming, then it would be in a pretty depressed state…" (WUE_Stakeholder)

This farmer went on to expand on these impacts. As articulated in the quotation below, he described the employment opportunities created within their enterprise,

reflected many times over across the region, contrasting this with the dryland farming that irrigated dairying had replaced:

> "…we've grown our entity with 7 staff plus ourselves, if it was dryland sheep farming it would perhaps be ourselves plus half another – and that would be the same all the way through. It's been huge – there's grass growing in the paddocks, there are people rushing-about and the yields people are talking about are far greater than we ever dreamed of – it's tremendous to see." (WUE_Stakeholder).

These reflections were, however, counter-balanced by an awareness of the impacts of irrigated agriculture, and dairying in particular, on the wider, social and natural environment and some comments, as expressed in the quotation below, hint at the growing sense of disconnect between the Region's farmers and their critics:

> "On the West Coast, if you're involved in dairying it's positive – it's jobs, it's the economy, it's positive. Over here, up comes the question, 'what do you do?' and I say that I develop dairy farms – gee, I've been lectured, called a polluter, blamed for this and that – there's a strong public opinion..." (WUE_Stakeholder)

Trying to strike a balance between these contrasting points of view, The Waimakariri Zone Implementation Programme, ZIP (ECan, 2011), guides implementation of the CWMS in the Waimakariri Zone. Although it is not a statutory instrument, it has the support of a number of statutory bodies. The Zone Committee describes the ZIP as a 'living document' that will be reviewed and updated on an ongoing basis. With respect to water use in the agricultural sector, the priority outcomes of the ZIP include: availability of reliable irrigation water supplies; good management practice of water and nutrients; and an improved contribution to the regional economy from the Zone. Reflected in these outcomes is recognition of agriculture's key role in the local economy, as well as the need for reliable water supplies to support irrigation activities. At the same time, however, the inclusion of 'good management practice' is intended to ensure a balance between farming and the environment.

A tangible point that environmental regulations impact at farm level is through the requirement for Farm Environment Plans (FEPs). In the Waimakariri Zone, the

focus of FEPs is on reducing nitrogen discharge and an element of this is believed to lie in scheduling when irrigation water is applied and encouraging farmers to adopt a considered approach that takes into account a range of factors, including soil moisture requirements and forecast weather. Using the FWB goes some way towards helping farmers to meet these requirements and also helps them to demonstrate good practice to a wider audience. In this way, the changing regulations represent an opportunity. Nevertheless, reflecting on the challenge associated with changing established behaviours, a senior industry commentator was prompted to observe that uptake of existing soil moisture technologies had remained resolutely low, at about one in five irrigators, since their introduction almost fifty years ago:

> "The percentage of people actually measuring, making objective decisions using soil moisture information, is about the same as it was in the mid-1980s. I don't think that it's more than about 17-18%, of course there's a whole lot more irrigators now, but I still think it's no more than 20%." (WUE_Stakeholder)

In order to deliver good management of water and nutrients, the ZIP recommends Audited Self Management Frameworks be developed with the express wish that Waimakariri Irrigation Limited (WIL) takes the lead in this process. In line with these recommendations, WIL is implementing a three-pronged approach: i) development of an Environmental Management Strategy; ii) implementation of Water Supply Agreements between WIL and its shareholders that will represent the legal contract to supply water for irrigation purposes and require shareholders to complete, and adhere to, a Farm Environment Plan (FEP); and, iii) using the FEP as an action plan for each shareholder, tailored to their farm and location. The start of the 2016/17 irrigation season was set as a nominal deadline by WIL for completion of shareholders' FEPs. With respect to irrigation management, FEPs set out the good-practice that WIL expects irrigators to observe and this includes monitoring and responding to soil moisture thereby providing an incentive for increased uptake of soil moisture technologies in the region.

7.3 Discussion and conclusions from the case of Water Use Efficiency

In their study of innovation activities in the water sector, Nair and Howlett (2015) emphasise the value in gaining political support and aligning with policy direction in order to facilitate scaling. While this highlights the advantages of 'going with the flow' it also points to the challenge of 'swimming against the tide' in the event that this support and alignment are absent. The WUE project seems well-placed to benefit from the former. The "collaborative turn" described by Memon et al. (2012, Page 7) and the increasingly integrated, stakeholder-driven approach to developing and delivering water strategy in the Canterbury Region having sown the seeds of a co-working culture. Through the application of a co-innovation inspired approach, the WUE project reflects these themes of co-operation and co-ordination. At the same time, the project's aim of contributing to improved fresh water management outcomes in the Waimakariri Zone through provision of the FWB chimes with the aspirations of the irrigation company and the farming sector, as well as the objectives of regulators as evidenced by the introduction of Farm Environment Plans (FEPs).

The potentially transformative gains to be made by harnessing technology were recognised by participants. Among farming respondents, many referred to the increased connectivity provided by their smart-phones and these were spoken of in terms of a 'portable office.' Other respondents' recalled the irrigation scheme's introduction of automatic race-gates. These were associated with an almost immediate freeing-up of operators' time, creating an opportunity to shift resources from the tactical to the strategic and opening-up new ways of operating. There was an appetite for change and the concept of the FWB was timely, building on technological developments that both i) enable a diverse range of high-resolution data to be collected; and ii) allow close to real-time provision of bespoke information to decision makers by taking advantage of the increased connectivity at farm level. Irrigation technologies are also developing, providing improved levels of control and precision (although users of older technologies also identify benefits from their application of the FWB). At the same time, the ability of third parties to monitor for adverse impacts arising from ill-timed irrigation events is also increasing.

The WUE project provided proof-of-principle that diverse data can be effectively collected, analysed and communicated in a timely manner. Furthermore, that on-farm decision-makers are receptive to the concept of the FWB, using it to support day-to-day decision making with respect to irrigation scheduling as well as wider, farming activities and even going on to share information within their own farm and family networks. Wider networking activities developed around the concept of the FWB, bringing together diverse stakeholders with concerns about agricultural water management and a desire to see improved water quality outcomes in the Canterbury Region. This saw connections established between NIWA and, for example, WIL, the Zone Committee and Environment Canterbury. While the connections made with regulatory bodies are associated with upscaling, links with neighbouring irrigation schemes hint at outscaling to come. The inclusion of a broad cross-section of participants in the WUE project, with a range of farm types and variety of conditions, is expected to be of value in terms of providing a basis to engage with this wider audience. Although the challenge of changing prevailing behaviours – for example the 'just-in-case' approach to irrigation management in the Waimakariri Zone –will be a critical determinant in the pace and extent of future uptake. In this respect, a particular value of co-innovation lies in providing the basis to develop a mutual understanding of different perspectives between diverse stakeholders.

Connections between diverse stakeholders were most visible in the annual, end of season workshops. These workshops facilitated discussions and the sharing of knowledge as well as stimulating ideas. By reflecting on lessons learned from the previous season and identifying key topics to explore in the season to come, they were effective in maintaining momentum and engagement. Of particular interest, for example, were the on-farm cost:benefits associated with adopting the FWB. These impacts are being actively explored by the follow-on, Irrigation Insight project in the Cust District. This project is of wider interest since it also reflects NIWA's commitment to continuing with the application of a co-innovation inspired approach, a scaling-out of co-innovation. In the absence of the over-arching PIP, NIWA's experience will be of value in terms of understanding how co-innovation is embedded and enacted over the longer-term.

Chapter 8: Discussion

In this chapter I discuss the cumulative findings from my study into the application of a co-innovation approach in the context of NZ's agri-food sector as interpreted by the Primary Innovation Programme (PIP) and the Heifer Rearing (HR) and Water Use Efficiency (WUE) projects. Between them, as shown in Table 16, below, these examples provide insight across sectors and regions and at varying levels of expected complexity from the 'less complex' HR project to the 'more complex' WUE project.

	Regional	**National**
Sector-specific		Dairy Heifer Rearing (HR) project (expectation of less contested knowledge & less complex mechanisms of change)
Cross-sector	Water Use Efficiency (WUE) project (expectation of more contested knowledge & more complex mechanisms of change)	Over-arching Primary Innovation Programme (PIP)

Table 16 Project overview

To structure my discussion and to help reveal the complex interactions across and between multiple actors, dimensions and levels, I draw on Rip's (2012) interpretation of the context of the innovation journey. This describes ever-present and evolving layers of niche, regime and landscape that, depending on the stage of the journey, exert varying degrees of influence on "local practices and novelty creation" (Page 161). Guided by Rip's framework, I portray NZ's agri-food sector as being on the cusp of transformative change as it seeks a more equitable balance between economic, social and environmental outcomes. Such is the complexity of this change, unprecedented and outwith the capacity of business-as-usual, that it creates new opportunities for alternatives. In this context and with reference to the PIP and HR and WUE projects, I explore how a novel, co-innovation approach was received and how it anticipates scaling. I find holding the so-called co-innovation space is pivotal and, using Elzen at al.'s (2012) concept of anchoring as a proxy for the fluid processes of scaling, I discuss how this space functions to support fragile technological, network and institutional connections as they solidify into more enduring links. To close, I reflect on the limitations of my research and consider its wider generalisability, setting the scene for the following and concluding chapter.

8.1 An appetite for change

In 2012, at the start of the PIP, there was growing awareness among stakeholders of the need to rebalance NZ's agri-food sector so as to deliver economic growth with improved social and environmental outcomes. The prevailing innovation system's capacity to support this change was, however, giving cause for concern to some.

8.1.1 Contextual framework

The context of innovation activities may be interpreted according to ever-present layers of niches, regimes and landscape (Rip, 2012). As visualised in Figure 25, below, these layers are characterised, respectively, as dynamic, evolving and shifting with "actions, interactions and practices" within and between layers variously encouraging or constraining "what happens locally" (Rip, 2012, Page 159).

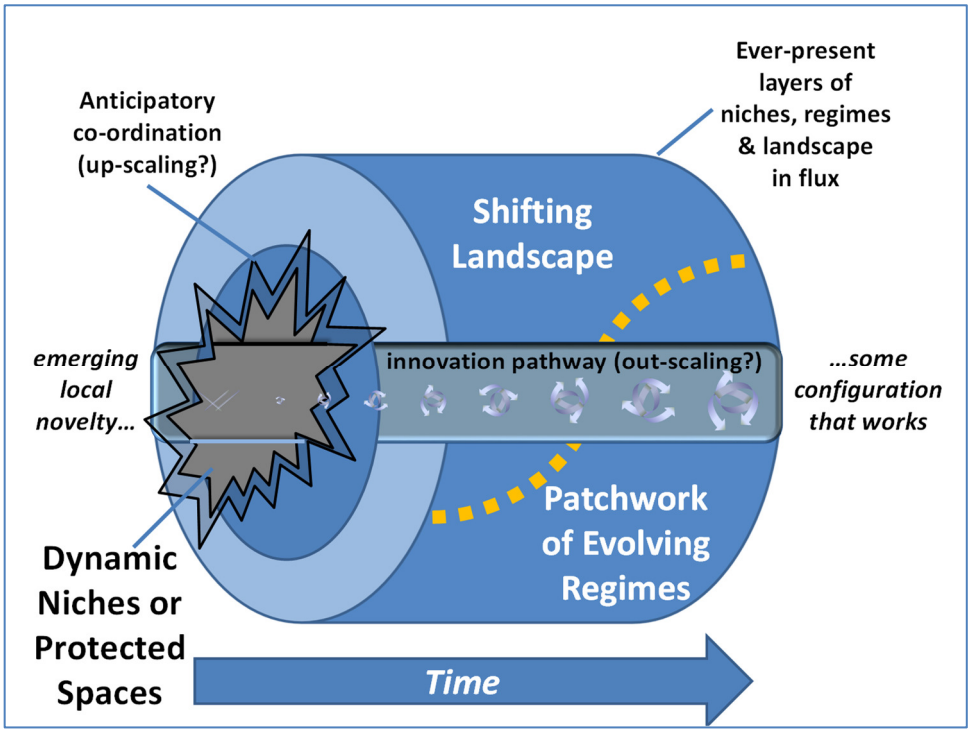

Figure 25 Scaling processes in the context of the innovation journey (adapted from Rip, 2012)

While the 'gravitational pull' of institutions, enabled by the landscape and supported by prevailing regimes, puts innovations at risk of becoming 'locked-in' to some form of path-dependency, it has been argued that this energy may instead be harnessed, at least in the early stages, to inform the direction of travel (Rip et al., 2002). By using

a transitory space to connect the needs of stakeholders with the benefits of envisaged change through a process of so-called 'anticipatory co-ordination' (Rip, 2012) the risk of lock-in is countered by facilitating an "enabling environment" (Douthwaite et al, 2003, page 247) or conditions of "institutional readiness" (Webster and Gardner, 2019, page 1). Guided by Rip's (2012) framework, I discuss, below, the changing context informing agri-food innovation activity in NZ.

8.1.2 A shifting landscape

Shifts in the landscape layer are signalling a move away from the pursuit of an increased share of global commodity markets and towards a premium position in selected export markets. There is also pressure to develop a more sustainable production base to deliver improved environmental and social outcomes. A growing expectation in target, high-value markets for agri-food products to demonstrate 'environmental integrity' means that these aims are not un-connected. The challenge of delivering change on multiple fronts is, however, complex and this is prompting rising levels of interest in systems thinking to provide the necessary join-up.

The neo-liberal reforms of the 1980s were a watershed for the economy of NZ (Peet, 2012) and, with respect to the agri-food sector, effectively reset the relationship between government and producers (Leitch et al. 2014; Davenport and Bibby, 2007; Edmeades, 2004). Root and branch restructuring of the sector followed (Vitalis, 2007; Lattimore, 2006) with an emphasis on raising productivity to increase NZ's share of global commodity markets and boost export earnings. More recently, the focus has shifted to developing added-value activities (Hartwich and Negro, 2010).

The natural environment is integral[106] and increasingly visible in NZ's added-value proposition. For example, at the 2019 United Nations (UN) Climate Action Summit, NZ's Prime Minister, Jacinda Ardern, announced a joint-commitment with Norway,

[106] The Resource Management Act (1991) is the mainstay of NZ's environmental legislation. It has continued to evolve over time, as witnessed by amendments in 2005. Support for the Rio Earth Summit Framework on Climate Change in 1992, and the Paris Agreement in 2015, reflect NZ's ongoing commitment to improving environmental outcomes, including reduction in GHG emissions.

Iceland, Costa Rica and Fiji to apply differential trade rules and eliminate tariffs on environmental goods, the 'Agreement on Climate Change, Trade and Sustainability' (ACCTS). While at the same time, stating her government's intention to position NZ as the world's most sustainable producer of food with plans to equip the sector with the systems necessary to 'measure, manage and monitor' farm emissions in the next five years (KPMG FieldNotes, 03/10/2019). In October 2019, the NZ government made good on this commitment, announcing proposals that it described as "one of the most significant developments on climate action in New Zealand's history[107]."

The five-year plan to reduce emissions was jointly developed by government and industry leaders while responsibility for delivering improvements rests with the primary sector[108]. Through the use of language such as 'join forces' and working 'shoulder to shoulder' accompanying announcements reflect increased levels of collaboration between government and industry, building on commitments made in the 2015, National Statement of Science Investment (NSSI) for a more joined-up approach to policy development and delivery. By institutionalising a collaborative approach in this way, so the direction of travel is becoming more conducive to the application of collaborative, systems-thinking approaches, including co-innovation.

8.1.3 Regime and niche dynamics

By exerting pressure for change on the prevailing agri-food regime, these shifts in the landscape create new opportunities and openings for more disruptive niches that, in turn, exert additional pressure on the regime from various directions. The status-quo, however, seeks to preserve business-as-usual by resisting these pressures to change or by modifying them in-line with established institutions. With an outcome that remains uncertain, this complex and evolving scenario is sometimes characterised in terms of a "transition in the making" (Elzen et al., 2011, Page 263).

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[107] http://www.beehive.govt.nz/release/world-first-plan-farmers-reduce-emissions (21/11/2019)

[108] Subject to demonstrating to the Climate Change Commission that it is on target to do so, by 2022.

The patchwork of regimes includes, for example, health, transport, education, energy and agri-food, inter-connected through multi-regime interactions[109] (Sutherland et al. 2015). Worldwide, the agri-food regime largely reflects a dominant agro-industrial paradigm of mass-production (Lang and Heasman, 2000; Bonney et al., 2007). As the associated social, animal welfare and environmental impacts of industrialised agriculture become better understood and more widely appreciated, however, so the rationale for this approach is increasingly questioned (Gaitán-Cremaschi et al. 2019; Pant, 2016; Duru et al., 2015) to exert pressure for change. A limited response to date – that has been described in terms of "weak ecological modernisation" (Horlings and Marsden, 2011, Page 444) – is creating opportunities for alternative, so-called niches that promise more radical reform (Levidow et al., 2014), as characterised, for example, by the agro-ecological paradigm (Lang and Heasman, 2015).

Although NZ's agri-food regime is no exception to these changes, the pace of change has, arguably, been especially rapid and the consequences, more immediate. The die was cast towards the end of the nineteenth century when emerging mātauranga Māori or knowledge systems, sympathetic to the relationship between people and the environment, were all but overwhelmed by the arrival of a second-wave of settlers. By the mid-1900s, post-war agro-industrial thinking gave licence to the sector to pursue growth through strategies of diversification and intensification (MacLeod and Moller, 2006; Glasby, 1991; Molloy, 1980). Accelerated by the reforms of the 1980s, this resulted in expansion of grass-based dairying and, just as extensive beef and sheep farming had underpinned early development, forever embedding farming in national identity (Ford, 2013), so a newly dominant dairy sector was coming to be regarded as the 'engine of the rural economy' (Vitalis, 2007). Indeed, by 2010, it was observed that NZ's leading dairy co-operative, Fonterra, had become so powerful that "thinking about New Zealand is to think about Fonterra; thinking about Fonterra is to think about New Zealand" (Gray and LeHeron, 2010, Page 1).

[109] It has, for example, been argued that a shared, and sometimes competing interest in use of land for the production of renewable energy connects agri-food and energy regimes (Sutherland et al. 2015).

There was, however, growing disquiet about the social, economic and environmental consequences of dairy intensification (McGiven, 2016; Foote et al., 2015; Doole and Romera, 2015; Baskaran et al., 2010; Dodd et al., 2008; Smith and Montgomery, 2004) as reflected, for example, by the 'Dirty Dairying' campaign that began in 2002. It brought concerns about the sector's environmental performance to wider public attention and called for improvements to be made (Holland, 2013). In a NZ context, these concerns have a particular significance since the country's agri-food exports benefit through association with the 'clean and green' image of 'brand NZ' (Saunders et al., 2016; Clemens and Babcock, 2004). This prompted Sir Charles Godfray (2018) to caution of the pressing need to correct an apparent disconnect between 'reality and perception' in order to better deliver on this green promise.

Industry can point to a number of initiatives that aim to address these environmental concerns[110]. However, the time-bound programme jointly-announced by government and industry in 2019, placing responsibility for delivering measurable improvements on the primary sector has, to coin a phrase, 'upped the ante'. Despite an acceptance that business-as-usual is not sustainable, the implications and uncertainties of change have been described as having all the characteristics of a so-called wicked problem (Duncan, 2017; Doole and Romera, 2015; Aerni, 2009; Baskaran et al., 2009). In part, this complexity reflects the relative importance of the agri-food sector to NZ's balance of payments (NZIER, 2017) and the extent that it is integrated into local, regional and national economic activity (Doole and Romera, 2015; Baskaran, 2009). As former Prime Minister, John Key (2009) remarked: "…when the primary sector sneezes, the New Zealand economy catches a cold." Although the innovation system is expected to play a vital role in enabling the agri-food sector to respond, concerns have been expressed about its capacity to do so, including, for example, that it is competitive rather than collaborative (Turner et al., 2015; Davenport and Bibby, 2007; Edmeades, 2004); overly conservative rather than entrepreneurial (Turner et al., 2015); and not sufficiently joined-up (Turner et al., 2015; Morriss et al., 2006).

[110] Including, for example, the Dairy Environment Leadership Group.

8.2 A window of opportunity

Subject to these shifting layers of influence, I discuss below how a Dutch-inspired co-innovation approach was received in a NZ context. In particular, I explore how co-innovation was understood and operationalised and, using the concept of anchoring as a proxy for dynamic scaling processes, how this informed scaling of both the co-innovation approach and innovations emerging from its application. I begin, however, by briefly reflecting on the principles of co-innovation and my rationale for using the concept of anchoring to illuminate the dynamics of scaling.

8.2.1 Paving the way for a co-innovation inspired approach

Agricultural Innovation Systems (AIS) thinking emerged in response to the need for a more joined-up understanding of dynamic innovation processes (Klerkx et al., 2012; Spielman and Birner, 2008). Previously, linear interpretations of innovation activity made little allowance for the flow of knowledge between parties (Koutsouris, 2012; Biggs, 1990) and tended to describe a process of knowledge transfer, from researcher to producer (Crivits et al., 2014; Darnhofer et al., 2012). In contrast, AIS thinking offers a more three dimensional perspective, interpreting innovation activity in terms of interactions between diverse actors, informed by wider awareness of the opportunities or constraints afforded by the prevailing institutional environment (Klerkx and Nettle, 2013; Basu and Leeuwis, 2012; Leeuwis and Aarts, 2011). In this way, AIS thinking encourages a rounded interpretation of: network (software), made up of representatives of the public and private sectors, research institutes and producers; emerging technology (hardware) in the form of a novel product or process; and institutional setting (orgware) that comprises both hard institutions, for example regulations, and soft, such as prevailing logics (Hermans et al., 2016).

Informed by AIS thinking, a co-innovation inspired approach describes the coming together of a broad coalition of stakeholders variously contributing resources – including funding, time, knowledge and skills – to a joint endeavour in response to a shared problem. It adds to, rather than replaces linear approaches thereby expanding the range of available options and, in this way, technology transfer may be envisaged at one end of a continuum with co-innovation at the other (Nettle et al., 2013).

By accommodating evolving aspects of software, hardware and orgware through iterative processes of reflection, negotiation and learning (Turner et al. 2015; Dogliotti et al. 2014), co-innovation affords a high level of context-specificity (Boyce et al., 2016). There is, however, a cost to this flexibility in the form of "implementation challenges" (Klerkx and Nettle, 2013, page 75). Rather than a blueprint or template for action, co-innovation is applied through guiding principles of collaboration, co-ordination and complementarity (Bitzer and Bijman, 2015) that together give-rise to a so-called 'co-innovation space' Coutts et al. (2017).

8.2.2 Evolving co-innovation space

By connecting otherwise disparate actors, a co-innovation inspired approach shares the 'Janus-like' ability of boundary organisations to face in multiple directions at the same time (Brand and Jax, 2007). However, whereas boundary activities tend to be associated with functions of "mediation" (Cash, 2001, Page 432) and "stabilisation" (Guston, 1999, Page 88) that sometimes prompt accusations of ambivalence, a co-innovation space also has the ability to pursue change in a way that makes it as likely to be disruptive as either mediating or stabilising (Schut et al., 2013). On this basis, it has some characteristics in common with the concept of 'hybrid forum' as used by Elzen et al. (2012) to depict "…the location where translations take place" (Page 15).

As illustrated in Figure 26, below, the co-innovation space is flexible, at times accommodating multiple perspectives of a complex problem and at other times, driving through change that while creating opportunities for some, may represent a barrier for others. In this way it variously functions as a boundary activity and hybrid-forum, reflecting the stage of the innovation journey. That is, as interpreted by Boyce et al. (2016) more conciliatory in the early stages, to support the development of an all-round perspective of a complex problem; and more purposeful or performative in later stages as the emphasis shifts towards making change happen. Given the vagaries of the innovation journey, this interchange may occur time and again, according to the needs of the project.

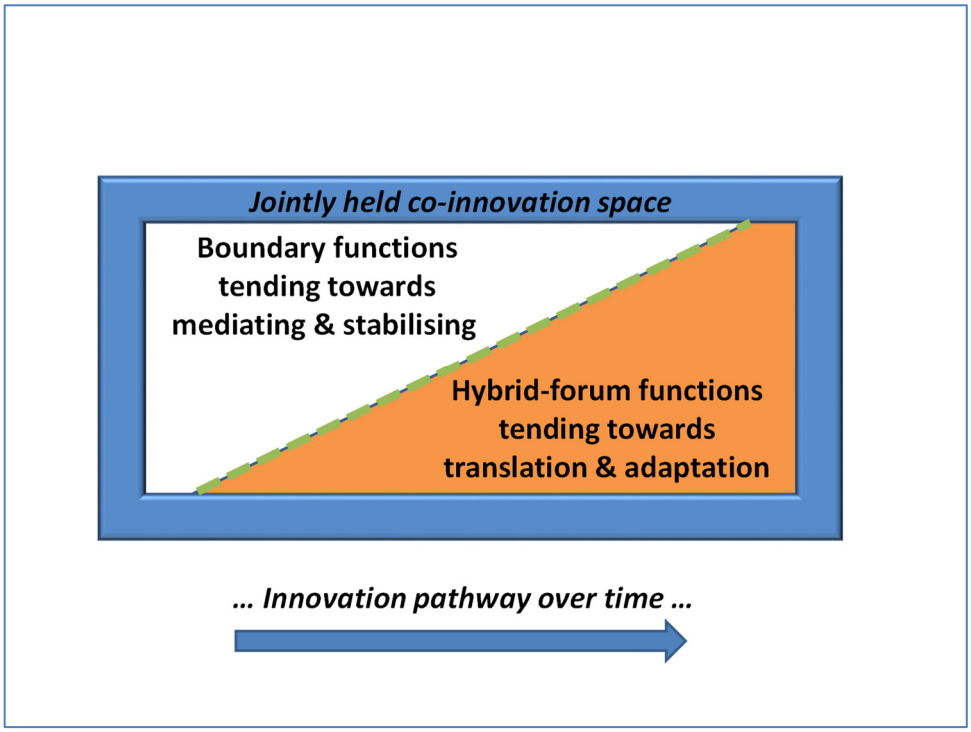


Figure 26 A multi-functional co-innovation space

While processes of commercialisation, as understood by concepts such as Roger's diffusion of innovation theory, are central to technology transfer models; these and wider scaling connections are less visible in participatory, AIS-inspired approaches (Crivits et al., 2014). To better understand and interpret these connections as they apply to co-innovation, I draw on the concept of anchoring (Elzen et al., 2012).

8.2.3 Scaling through an anchoring lens

Conveying the fluidity of both scaling and context, scaling has been described as a "move into the mainstream" (Westley et al., 2014, Page 235). There is a sense of purpose, as expressed by 'moving into' rather than a 'swept-along by' with echoes, respectively, of 'anticipatory co-ordination' versus 'path-dependency.' However, with everything in flux – evolving novelties, developing niches, an adapting regime and shifting landscape – associated interactions are inevitably complex.

The concept of anchoring (Elzen et al., 2012) acknowledges the sensitivity of connections to their environment. It identifies processes of "continuous probing" (Elzen et al., 2012, Page 4) in the making and breaking of technological, network and institutional connections within and between novelties, niches and regimes while an

intermediate space or 'hybrid forum' (Elzen et al., 2012) functions as an "adaptive zone" (Ingram, 2015, Page 72), a place "where translations take place" (Elzen et al., 2012, Page 15). The ongoing probing for connections is enacted through five drivers (Elzen and Bos, 2016) that, as shown in Figure 27, below, I label as comprised of technological; techno-network; techno-institutional; network; and institutional to reflect the various overlaps. While these interconnections help to cross-brace fragile, early connections (Sutherland et al., 2015), even if they break the resulting learnings usefully inform subsequent activities. A convergence of technological, network and institutional anchoring has been found to contribute to more enduring links (Elzen et al., 2012) that may, as here, be equated to scaling (Wieczorek, 2018).

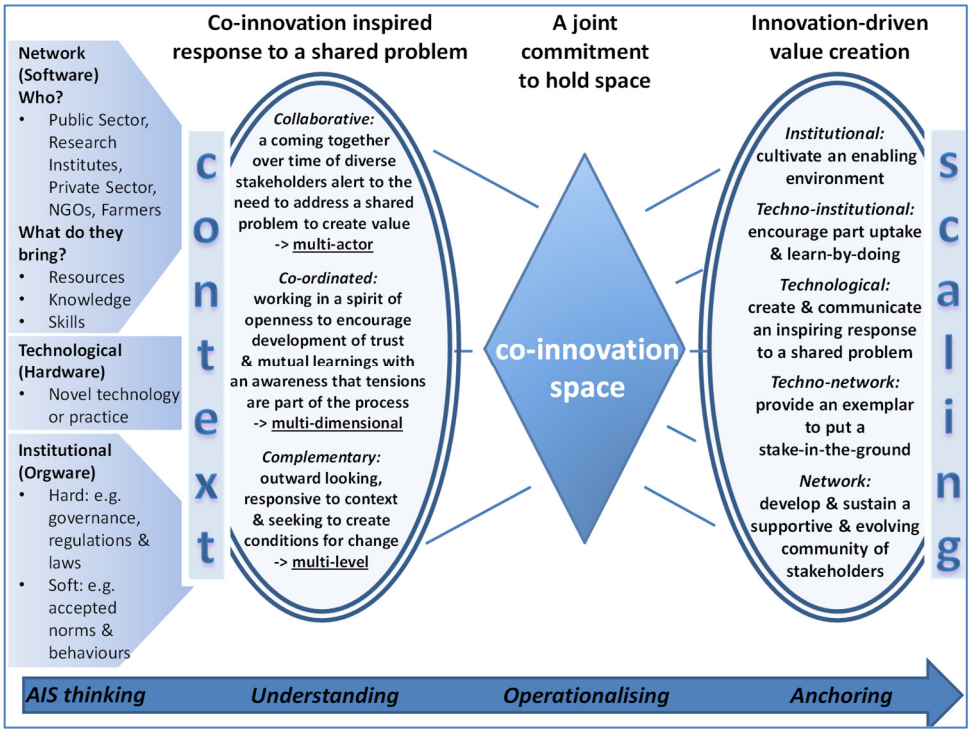


Figure 27 The co-innovation space as a catalyst for scaling

With a view to better understanding the dynamics outlined in Figure 27, and, in particular, to explore how co-innovation anticipates scaling, I discuss below how co-innovation was understood and operationalised in a NZ context and, guided by the concept of anchoring, how its application supports processes of up and outscaling.

8.2.4 Anchoring co-innovation in a NZ context

Work in the Netherlands (NL) around AIS thinking, including co-innovation – as reflected, for instance, by development of the Rondeel, high-welfare poultry housing (see: Elzen and Bos, 2016; Klerkx et al., 2010) – was followed with interest in NZ via, for example, long-standing links between DairyNZ and AgResearch in NZ with Wageningen University in the NL. In due course, funding of the PIP provided an opportunity to apply a co-innovation approach for the first time in a NZ context. Care, however, was needed in transferring a Dutch-inspired approach to a NZ setting, raising questions of local "constraints and enablers" (Klerkx et al., 2017, page 276) and, chiefly among the former, the challenge of implementing a 'mindset rather than method' (Klerkx and Nettle, 2013) in NZ's largely science-driven agri-food sector.

8.2.4.1 The enabling function of the Community for Change

The PIP was made up of three interconnected streams of activity: Stream 1, Theoretical Framing; Stream 2, In-field Application; and Stream 3, Stakeholder Engagement via a so-called Community for Change (CfC). The latter, as I will argue below, was instrumental in the network and institutional anchoring of co-innovation.

At the start of the PIP, as the CfC was taking shape, early stakeholder engagement revealed a weight of expectation attached to the novelty of a co-innovation inspired approach. Some came to the process in the hope that it would be the 'silver bullet' they were seeking to address concerns about the prevailing system or, to borrow a phrase from the UK's newly elected Prime Minister, an 'oven-ready' solution. First impressions, however, prompted some to push-back with comments such as "we've been doing this co-innovation thing for many years" (Stream3_ProjectTeam) that reflected a perceived disconnect between the promise of something new and echoes of the familiar. Others took a broader view of the innovation system. This was best demonstrated by their reaction to the success of the Apple Futures project – one of the ex-post studies informing Stream 1 of the PIP – interpreted, not as evidence of a well-functioning innovation system but as an 'island of success' and highlighting the need for systemic change to ensure its success was more widely replicated. From the perspective of this group, co-innovation was understood not as a method, per se, but as a means of opening up new ways of thinking about the wider innovation system.

As the PIP progressed, it was these stakeholders, united by a shared awareness of the constraints of business-as-usual and with a mutual appetite for change that provided the basis for **network anchoring** of a co-innovation inspired approach in a NZ context. Their contacts providing outward links to a wider network, beyond the CfC, in positions to help make change happen; and their profile as influencers helping to attract and sustain interest in the activities of the PIP within their respective sectors.

Informed by learnings emerging from the wider PIP, the thinking of the CfC was developing over time and the need both to manage stakeholders' expectations and to position co-innovation distinctively vis-à-vis current practice was increasingly recognised. The process of co-innovation was also coming to be better understood as one of negotiation with all its inherent tensions and compromise. And it was coming to be valued for raising awareness about the opportunities and threats afforded by the prevailing innovation system, opening-up new and sometimes difficult conversations about the strengths and weaknesses of current practice and prompting consideration of alternatives to business-as-usual. By holding space that encouraged and facilitated critical thinking about the innovation system, the CfC was contributing to the development of an "enabling environment" (Douthwaite et al., 2003, page 247) more receptive to the concept of co-innovation, consistent with **institutional anchoring**.

There were cross-overs in the development of institutional and network connections that contributed to more enduring links being cemented or anchored. For example, an evolving understanding of the strengths and weaknesses of the innovation system helped to identify intervention points that the evolving CfC might usefully target in pursuit of change. While networking activities assisted in identifying and facilitating access to stakeholders in positions of influence with regard to prevailing mind-sets or soft institutions. By working across layers of influence and envisaging change for a wider audience, together these network and institutional anchoring activities may be described as contributing to upscaling processes of 'anticipatory co-ordination.'

Benefitting from these enabling conditions and gaining traction at the project level were technological connections. Broadly understood as being made up of: technological, gaining the buy-in of stakeholders to the emerging idea or concept;

techno-network, the interface between the novelty and target users; and techno-institutional, the partial take-up or implementation of an emerging innovation in the belief that it will help towards embedding the wider concept (Elzen and Bos, 2016).

8.2.4.2 The dual functionality of the Heifer Rearing and Water Use Efficiency projects

Within the PIP, the application of a co-innovation inspired approach via five, in-field projects with accompanying ex-ante analysis formed the basis for Stream 2, theory into practice. In this section, I reflect on the findings from my study of two of these projects, the Heifer Rearing (HR) and Water Use Efficiency (WUE) projects.

These projects were performing a dual-function. On the one hand, seeking to deliver applied innovation outcomes – in the form of improved heifer rearing practice for HR; and improved on-farm irrigation practice for WUE – while on the other hand, they were exploring the in-field implementation of a novel, co-innovation inspired approach. I will argue that by developing technological connections to support their respective in-field activities, these projects were instrumental in supporting the technological anchoring of the novel, co-innovation inspired approach.

As described above, in NZ the landscape and emerging niches are exerting pressure for change on the prevailing agri-food regime. On the one hand are concerns over an apparent disconnect between the country's 'clean and green' image and the negative impacts of agro-industrialism; on the other hand, pressure to increase export revenues through development of added-value activities. Balancing the two gives rise to a complex, so-called wicked-problem, prompting calls for systemic reform. While in the more immediate future, there is an ongoing focus on closing the productivity gap between, for example, actual and target performance. The HR and WUE projects speak to both. That is, co-innovation offers a potentially transformative alternative to business-as-usual innovation activity and, at the same time, is of value in addressing shorter-term, farm management concerns.

Techno-institutional connections

Be it the 'handshake' that symbolised the heifer rearing contracts or the 'just-in-case' approach to irrigation management, working through a co-innovation space helped

stakeholders to develop a better-informed appreciation of the soft institutions and underlying logics of prevailing practice. Through this more rounded understanding, potential opportunities and barriers with regard to practice change were more clearly understood. This, in turn, provided a practical insight into the benefits, and barriers, of applying a co-innovation approach to the wider PIP and the CfC, in particular.

There was awareness among stakeholders in the HR project that despite its technical strengths, the preceding InCalf initiative had not broken-through as expected, in terms of achieving on-farm practice change. Nevertheless, for some participants, having access to a well-developed and comprehensive understanding of herd fertility suggested that a technology transfer approach would be the most appropriate strategy in terms of communicating to producers about the topic of heifer rearing with the aim of encouraging practice change. Had it not been for stakeholders' varied interpretations as to which elements of technical understanding to emphasise, this argument may have prevailed. However, by taking soundings from a wider body of producers with a view to gaining some direction, the group came to understand that the relationship between farmers and graziers was a critical, if hitherto overlooked aspect in the production of growing heifers. In light of this, the under-performance of growing heifers ceased to be seen as a purely technical issue, giving stakeholders a fresh perspective on a long-standing problem. Applying a co-innovation inspired approach contributed to moving the group towards this shared understanding.

In the same way that the HR project was disentangling the prevailing logics governing the relationship between farmers and graziers, so the WUE project was coming up against the institutions, soft and hard, surrounding on-farm irrigation management. In a run of the river scheme, the prevailing soft institutions or logics have evolved in response to an unreliable water supply. Producers are cognizant of the risks of 'getting it wrong' where this is understood as allowing growing crops or grass to dry out. This underpins a strong argument for a 'just-in-case' approach to irrigation management and, in these circumstances, applying water only where and when it is needed, a 'just-in-time' approach, represents a step-too-far at this time. The 'justified irrigation' model proposed in the WUE project offers a 'middle way' but it requires a new understanding of 'getting it wrong' that extends beyond the

immediate on-farm impacts to wider, external environmental impacts. As reflected, for example, by the risks of field run-off. Regulatory or hard institutional change, however, is coming, as reflected by the introduction of Farm Environment Plans (FEPs). Their introduction not only raising awareness of and interest in actions to mitigate risks to the wider environment but also redefining the consequences of 'getting it wrong.' The concept of the Farm Weather Briefing (FWB) to support on-farm irrigation decision-making and to demonstrate good practice aligns with this direction of travel. Through the application of a co-innovation inspired approach, space was held to facilitate discussion between diverse stakeholders united around a shared interest in water management in the Canterbury Region. This space was of value in providing a forum to consider the potential opportunities for the FWB to bridge the prevailing soft institutions of on-farm irrigation practice and the shifting hard institutions as reflected, for example, by the introduction of FEPs.

Techno-network considerations

The host organisations of the HR and WUE projects, DairyNZ and NIWA respectively, came to the PIP from two very different starting points, their positions moving closer towards one another over the course of the project as they took learnings away from the application of a novel, co-innovation inspired approach. At the same time, their in-field experience of the practicalities of putting co-innovation into practice were informing wider understanding of co-innovation among the CfC.

In the HR project, a participatory approach tended to be associated with interpretations of good or best practice. While implementing a participatory approach was familiar to some stakeholders, it was alien to others. Against this backdrop, a co-innovation inspired approach required careful positioning and there were mixed reactions to the concept in the project's early stages. Some stakeholders' rejecting it in the first instance as 'old wine in new bottles' and others looking for greater clarity as regards points of difference with their understanding of existing good practice. As the project progressed, a more nuanced positioning emerged, respecting past practice while acknowledging that 'good practice' did not always equate to 'applied practice'. Calls from farmers' representatives within the group for a more joined-up approach between organisations, helped to encourage a pragmatic

approach towards finding a way to make things work for the common good of the sector, with a view to delivering a consistent message to on-farm decision-makers.

For the WUE project, a co-innovation inspired approach chimed with calls in the Canterbury Region for a more integrated approach to catchment management. On this basis, co-innovation was embraced by the project as a framework to help structure activities in a sector with a largely science-driven culture. In contrast to the scepticism of some in the HR project that co-innovation was not sufficiently differentiated from current practice, reservations within the WUE project tended to reflect concerns that co-innovation was a step-too-far from the sector's more established, science-led approach. A critical challenge was to demonstrate the value of a co-innovation inspired approach to stakeholders, not least to the project's hosts, NIWA. Described at the outset of the project as coming with a "…very linear, very technology transfer focus…" there is evidence of NIWA's commitment to further exploring a co-innovation approach, a scaling-out of co-innovation, through its continued application in the follow-up, Irrigation Insight project in the Cust Region.

Technological considerations

The HR and WUE were at different stages. The former bringing stakeholders together around a common problem while the latter was at the stage of exploring the on-farm implementation of the Farm Weather Briefing (FWB) concept. That both were able to implement a co-innovation inspired approach reflects the flexibility of the approach and its ability to adapt to different contexts and circumstances. Nevertheless, the concept of a 'mindset rather than method' and the process of 'learning by doing' did not sit easily in NZ's largely science-led culture.

Reflecting on the HR project, one participant was prompted to speak of it in terms of something of an "awkward alliance" and in much the same way that producers were being encouraged to reflect on their heifer rearing practices, so stakeholders were themselves having to adjust to new ways of operating. Although participatory approaches were familiar to some, this did not always extend to a track-record of working with one another. This required new roles and relationships to be negotiated with tensions surfacing as different interpretations and understandings came up

against one another. Interactions were overshadowed by the legacy of NZ's fast-changing science system that has, at different times, involved a restructuring of research providers. This, however, was more than offset by an awareness of the impending challenge to come and a shared recognition that business-as-usual would not be sufficient to deliver the change required. On this basis, there was not just a preparedness to take part in a co-innovation inspired approach but a deeper commitment to give it the benefit of the doubt and to work through early friction and tensions. In the process, links within the project began to strengthen. As evidenced, for example, by organisations supporting one another in farmer-facing events in ways that, some stakeholders reflected, would not previously have happened.

The concept of the Farm Weather Briefing (FWB) pre-dated the PIP, prompting some external observers to comment that the WUE project was 'retro-fitting' the approach to the problem. Nevertheless, through exploring proof of principle of the FWB concept, the WUE project was informing and facilitating wider discussion. Of particular value in this process were the end of season workshops that brought together participants in the WUE project and an expanding group of stakeholders. To an extent, these workshops represented the manifestation of a co-innovation inspired approach with information and ideas being freely exchanged and discussed and, sometimes, actioned. Participants were able to see how their input had informed the direction of the project in the year just gone and to generate ideas for the year ahead. In the process, strengthening connections between a diverse group with a shared interest in improved irrigation practice and, given the history of contested water management in the Region, this itself represented a positive outcome.

8.2.4.3 The modulating function of the co-innovation space

Early technological, network and institutional connections are fragile and liable to break before becoming embedded or anchored on a more durable basis (Elzen et al., 2012). Exerting pressure on these early connections are mismatches or misalignment between scales (Olsson et al., 2014; Lovell et al., 2002). For example, between the local and global, shorter term and longer term and the conforming and reforming. Drawing on the HR and WUE projects, I explore how co-innovation supports early connections to withstand these tensions and become better embedded or anchored.

The HR project was included in the PIP not so much on the grounds of its expected complexity but as a practical opportunity to explore application of a co-innovation inspired approach in the context of NZ's dairy sector. For the host organisation, DairyNZ, it was an opportunity to demonstrate its support for the PIP while contributing to wider debate about the challenges and opportunities shaping the future direction of the country's innovation activities. For some participants, this introduced an early source of tension with concerns expressed that applying a co-innovation approach to the question of heifer rearing was, to coin a phrase, 'like using a sledgehammer to crack a nut.' Some stakeholders came to the process with a more outward-looking, longer-term export orientation and an awareness of the 'innovation imperative' driving competition in overseas markets. Others brought a more inward-looking, shorter-term emphasis on, for example, day-to-day production, all too aware that despite its technical strengths, the preceding InCalf initiative had not broken through on-farm as quickly or as widely as expected. Differences tended to be aggravated rather than alleviated in the project's early stages as stakeholders, informed by the legacy accompanying the sector's history of fast-paced change, adjusted to a co-innovation inspired approach. Added to this was the additional challenge of downward pressure on farmgate milk prices during the course of the HR project. Nevertheless, the HR project sustained interactions between otherwise diverse stakeholders in a challenging context. By coming to a fresh understanding of the under-performance of dairy heifers, the concept of co-innovation became, if not embedded, then tentatively anchored among stakeholders.

In the Canterbury Region, a history of contested freshwater management adds to the complexities of moving towards a more integrated, catchment management approach. Against this background, through the application of a co-innovation inspired approach, the WUE project was successful in bringing together diverse stakeholders with varied perspectives. For the host organisation, NIWA, inclusion of the WUE project in the PIP provided an opportunity not only to contribute to wider, national debate but also the space to explore its own ability to move from a more linear to a more open approach to innovation. Building-on a long-standing, science-based working relationship with Waimakariri Irrigation Limited (WIL), the project

harnessed technology to pilot the concept of the Farm Weather Briefing (FWB) and, over the course of the project, successfully demonstrated proof of principle. Discussions at the end of-season stakeholder workshops informed the direction of the project from year-to-year and interest expressed in the economic costs and benefits is informing the next stage in the form of the follow-on, WUE work in the Cust Region.

In both the HR and WUE projects, a co-innovation space provided a forum that, by bringing together diverse perspectives around a shared concern, led to a more rounded understanding. In the case of HR, drawing attention to the importance of relationships between farmers and graziers cast new light on a persistent problem. In the case of WUE, a co-innovation inspired approach provided a guiding framework that was consistent with the move towards more integrated catchment management in the Canterbury Region; while the concept of the FWB aligned with the introduction of Farm Environment Plans helping to bridge changing soft and hard institutions. Learnings from the HR and WUE projects were also of wider value, to the PIP and the CfC, demonstrating the challenges and opportunities associated with the in-field application of a co-innovation inspired approach.

8.3 Closing remarks

The shifting landscape, evolving regimes and dynamic niches that together make up the context of NZ's agri-food sector cast a long shadow, variously shaping and informing the country's innovation activities. Their influence is felt especially keenly as the sector responds and adjusts to the forces of change and finds a way to rebalance production with improved social and environmental outcomes. Whether or not this takes a more transformative turn in response to the break-through of an emerging niche or a more conformative turn through adjustment of the prevailing regime remains to be seen. A co-innovation inspired approach has potential applications in both. From my research, it has a role to play in bringing a systems perspective to wider discussions about the sector's direction of travel at a strategic level; as well as providing a framework to support more tactical, innovation activity.

With its roots in Agricultural Innovation Systems (AIS) thinking, co-innovation highlights the complex interconnections between a novel technology or practice,

supporting network and wider, institutional context. In this way, it helps to raise awareness of the wider system and the barriers and opportunities associated with systemic change. In contrast, however, to linear thinking on innovation activity that is relatively transparent about scaling, this aspect, although integral, is more opaque from an AIS perspective. My study sought to make more transparent the connections between co-innovation and scaling. In the absence of a theory of scaling and to provide a framework to guide my enquiries, I drew on the concept of anchoring. I was interested to explore the progression or not of fragile, early technological, network and institutional connections to more firmly embedded links; and, in particular, to understand how co-innovation anticipated this process.

From my investigations, I find that by introducing a novel, co-innovation inspired approach into a New Zealand (NZ) context, the co-innovation process and the novelties emerging from its application were linked, each supporting and informing the other. The structure of the Primary Innovation Programme (PIP) saw the co-innovation approach benefit from the technological anchoring activities of the in-field projects; while the in-field projects benefitted from the institutional and network anchoring activities of the PIP that performed an upscaling or 'anticipatory co-ordination' function. The ongoing activities of the in-field projects, and the follow-on WUE project in particular, in the absence of the PIP, will test the extent to which a co-innovation inspired approach has become more enduringly anchored.

A particular value of the co-innovation approach lies in holding space to facilitate a coming-together of diverse stakeholders around a common theme, problem or issue. In this way, it is a broad church but it is also dynamic. Shifting between a more consensual, problem understanding mode and acting as a more purposeful, driver of change with proverbial 'sparks flying' as it ebbs and flows between the two. Mitigating these tensions is the 'modulating' function of the co-innovation space that adjusts or allows for interactions within and between spatial, temporal and institutional scales that may otherwise hinder or block the scaling pathway.

There are limitations that I identify with respect to the ability of my research to address my research questions. These concern the extended timeframes associated

with the innovation or scaling pathway; and the challenge of working with co-innovation and scaling that might both be described as nebulous rather than clear-cut.

The extended timeframes associated with processes of scaling and innovation are demonstrated by the examples informing Stream 1 of the PIP. The InCalf initiative began with work in Australia in 1993 before being launched, under licence, in New Zealand in 2008 (Brownlie et al., 2015); the AppleFutures project can be traced back to 1995, prior to its launch in the 2007/08 season (Park et al., 2015); and the origins of the Land and Environment Planning Toolkit, relaunched in 2011, date back to the 1990s (Reid, 2013). These development timeframes alone are outside the scope of many social research programmes. While exploring 'change in the making' over a relatively short period does provide a valuable, contemporaneous snapshot at a point in time, it is subject to uncertainties with respect to the eventual outcome.

With co-innovation referred to in terms of a mindset rather than method (Klerkx and Nettle, 2013) and scaling characterised as a "move into the mainstream" (Westley et al., 2014, Page, 235) both are descriptive rather than specific. While a rich description is of value in helping to capture the essence of each, in exploring connections and interactions between the two, there remains some ambiguity.

The scaling pathway is informed by context (Smits et al. 2007; Meinzen-Dick, 2007) and a benefit of a co-innovation inspired approach is its ability to adapt and respond (Klerkx et al., 2017). Applying Arie Rip's (2012) concept of layers to frame the context of the innovation journey was of value in this study, providing a guiding framework to better understand the barriers and opportunities arising from interactions between novelties, niches, regimes and landscape. Together, they led me to portray New Zealand's agri-food sector as being on the cusp of change as it seeks to respond to inter-connected and pressing challenges on multiple fronts. On this basis, the findings of my research have a wider resonance in scenarios, for example, where agri-food systems are responding to transformative change, such as the opportunities and challenges created by Brexit for the agri-food sector in the UK.

Chapter 9: Conclusions

Agro-industrial thinking has been the guiding paradigm for much of the last one hundred years. In the aftermath of the Second World War, science-based thinking provided much-needed reassurance that fractured food-systems could be revitalised. Since then, it has consolidated its pre-dominant position to provide a clear sense of direction and, despite some dissenting voices, agro-industrialism has become increasingly institutionalised over time. That is, until concerns with respect to persistent food inequalities and the social and environmental impacts of the progressive industrialisation of agriculture came to wider attention, prompting growing calls for change. Agro-industrial thinking has, however, become embedded to such an extent in today's highly integrated, global agri-food systems that not only does the institutional inertia of the status-quo exert quite some barrier to change; but also; the prospective impacts of change have far-reaching consequences.

Innovation activities are expected to have a crucial role in enabling the agri-food sector to navigate these changes. While linear approaches such as Technology Transfer (TT) chimed with an agro-industrial emphasis on top-down, knowledge transfer they are less able to accommodate more complex processes of knowledge exchange between diverse actors. This has triggered increased interest in systems thinking to inform and interpret interactions between multiple actors and across multiple levels. Agricultural Innovation Systems (AIS) thinking encourages an holistic perspective of the dynamics between a novel product or process (hardware), supporting network (software) and prevailing institutions (orgware), co-innovation offers a way of operationalising this approach. Whereas linear interpretations of innovation activities are transparent about scaling – understood as the increased uptake over time of a novel product or process (outscaling) and creation of an enabling institutional environment (upscaling) – these processes are more opaque from an AIS perspective. To address this gap and using case study as my strategy of enquiry, I explored how implementation of a co-innovation inspired approach, in the context of New Zealand's agri-food sector, anticipated scaling.

The recent history of NZ's agri-food sector, bookended by McMeekan's 'Grass to milk: a New Zealand philosophy' (1961) and Hendy and Callaghan's 'Get off the grass' (2013), saw the reforms of the 1980s prompt a major restructuring and accelerate the shift from more extensive beef and sheep to more intensive dairying (Macleod and Moller, 2006). In recent years, there has been a rising level of concern about the impacts of these changes on the wider environment and, especially, water quality (Foote et al., 2015). The country is now actively addressing these concerns not only to preserve its natural environment but also to protect the integrity of its 'clean and green' image in vital, export markets (Saunders et al., 2016).

Innovation activity has long-played an important role in the development of NZ's agri-food sector[111]. Doubts have, however, been expressed about the capacity of the prevailing system to accommodate the complex challenge now confronting the sector (Turner et al., 2015; Davenport et al., 2007; Morriss et al., 2006; Edmeades, 2004). Applying Rip's (2012) concept of layers of influence, the agri-food regime in NZ may be characterised as coming under growing pressure to change and, so too, the institutions associated with business-as-usual, including established innovation practice. Emerging niches are pushing at the boundaries, with new thinking testing the capacity of existing systems and prompting growing awareness at the landscape layer that innovation activity risks being inhibited rather than enabled. There is, however, a growing commitment to change as reflected, for example, by language used in the National Statement of Science Investment (2015) and, more recently, in announcements concerning NZ's stated ambition to become the world's most sustainable producer of food. These point to the development of an "enabling environment" (Douthwaite et al, 2003, page 247) or conditions of "institutional readiness" (Webster and Gardner, 2019, page 1) in favour of a more joined-up approach, better able to respond to new opportunities. As one stakeholder remarked, regarding co-innovation: "it's an idea that's time has come" (Stream3_ProjectTeam).

[111] As demonstrated, for example, by the introduction of refrigerated shipping that saw the first consignment of NZ lamb reach London as early as1882 (King, 2003)

Through my research, I explored the introduction of a novel, co-innovation inspired approach in the context of New Zealand's agri-food sector. In particular, I asked how co-innovation was understood; how it was operationalised; and how its application anticipated the processes of scaling. In the absence of a theory of scaling, I referred to the concept of anchoring to guide my investigations, using the development of fragile, early technological, network and institutional connections into more embedded or anchored links as a proxy for the processes of scaling. I present my conclusions below and finish with recommendations for further work that, I believe, would contribute to a better developed understanding of the complex interactions between applying a co-innovation inspired approach and scaling.

From the literature, co-innovation is broadly understood as a context-specific, collaborative response to a complex problem with a view to delivering shared benefits. There is an emphasis on mutual learning and wider awareness of prevailing institutional conditions with a willingness to work for their reform in the event that they are felt to be inhibiting progress. Co-innovation is associated with outscaling of innovations across a wider target area and upscaling via an improved institutional fit (Albicette et al., 2017; Dogliotti et al., 2014; Millar and Connell, 2010) but its context-specificity makes it something of chameleon with different aspects afforded different levels of emphasis in different situations. For example, Dogliotti et al. (2014) emphasised learnings through interaction; Bonney (2007) highlighted inter-firm connections; while Borgen and Aarset (2016) and Rossi et al. (2014) focussed on shared benefits in response to a common need.

In the field, and in the context of NZ's largely science-led research culture, this ambiguity did not sit comfortably. General descriptions of a 'collaborative response to a complex problem' prompted push-back with comments of 'just more of the same' that highlighted the need for deft positioning with respect to current practice. As Nettle et al. (2013) observed, co-innovation adds to, rather than replaces linear interpretations, thereby providing stakeholders with an expanded range of options. Care is needed, however, to avoid co-innovation being interpreted as 'not technology transfer' and to present it on the basis of its own strengths.

Similarly, when it came to operationalising a co-innovation inspired approach in the context of NZ's agri-food sector, there was some discomfort among stakeholders with respect to the concept of applying a guiding framework (Klerkx et al., 2017) or mindset rather than method (Klerkx and Nettle, 2013). The prevailing logics arising from the sector's linear tradition, prompting stakeholders in the PIP to draw on Nederlof et al.'s (2011) more prescriptive principles for a collaborative approach to innovation, as a basis to help them to put co-innovation into practice. As a 'pump-primer' this was sufficient to set the work in motion and to start mobilising multiple and diverse stakeholders with a common interest in a range of shared problems. Once underway, and as the groups grew in confidence, so they became more comfortable with 'learning by doing.' One respondent observing that as the challenge facing NZ's agri-food sector is unprecedented, there is no template on how to respond thereby making learning by doing the only feasible option.

The three-pronged structure of the PIP facilitated interactions between: i) theoretical framing through the ex-post analysis of selected studies; ii) in-field application and accompanying ex-ante analysis of five, live projects; and, iii) stakeholder engagement via a wider Community for Change (CfC). On this basis, there was interest in scaling of the co-innovation approach as well as novelties emerging through its in-field application. In practice, these processes were mutually supportive. Framed by learnings from the ex-post analysis, feedback from the in-field projects informed the activities of the wider CfC; while the activities of the CfC guided and supported the in-field projects. Nonetheless, the accompanying scaling processes of the approach and emerging novelties, were unfolding at different rates so that co-innovation was becoming more firmly embedded while the connections supporting emerging innovations were more fragile.

There was shared recognition among a small group of stakeholders that the prevailing innovation system was not fit for purpose if NZ is to meet ambitious growth targets and respond to pressing social and environmental concerns. This group provided the basis for early network anchoring of a co-innovation approach as an alternative to business-as-usual. By drawing our attention to interactions between emerging technologies, networks and institutions, co-innovation thinking was

helping to frame this discussion and, through the provision of a shared space, the PIP was providing a structure to facilitate these discussions. At the same time, a wider, national debate about the agri-food sector and its social and environmental impacts was getting underway. A co-innovation inspired approach aligned with calls for change and a more inclusive approach, helping it to become more firmly embedded. The evolving network and early institutional alignment were supporting 'anticipatory co-ordination' (Rip, 2012) and helping to create conditions favourable to change.

The in-field projects were instrumental in adapting co-innovation to a NZ context and facilitating a so-called 'co-innovation space' (Coutts et al., 2017) that variously combined the functions of boundary activities and hybrid forums. Through the former, diverse stakeholders came together around a common interest to help build a detailed understanding of the issue and its wider impacts. As responses emerge so the space begins to function more as a hybrid-forum with the drive to make change happen. Given the diversity of stakeholders, it is unlikely that the proposed response will satisfy all parties. While some will endorse the approach, others will compromise or object and tensions may arise. By accommodating different time horizons, from short to long term, different spatial perspectives, from local to global, and different institutional ambitions, from conforming to reforming, co-innovation holds space to modulate different perspectives and mitigate these potential tensions.

Further research is expected to be of value. For example, to explore the use of anchoring as a proxy for scaling, that was found to be of value in this study, in other contexts. While ongoing work with respect to the follow-on WUE project is actively exploring the cost:benefits associated with use of the FWB, it is also investigating wider aspects of co-innovation and scaling and, in particular, asking questions about the enduring application of a co-innovation inspired approach after the PIP. This work runs through to 2021 and will provide a 10 year overview of early upscaling and outscaling processes; in addition, it is looking at interpretations of context (see for example, Nicholas et al., 2019). With respect to the latter, given co-innovation's context specificity, further work to understand how co-innovation responds to and shapes context may also be of value. Revisiting the HR project would also be of interest in terms of developing a wider understanding of the legacy of the PIP.

9.1 Closing reflections

Through an Agricultural Innovation Systems (AIS) lens and making novel use of the concept of anchoring (Elzen et al., 2012) as a proxy for scaling (Wieczorek, 2018), I identify the modulating function of a co-innovation space (Coutts et al., 2017) in facilitating an "interconnectedness of scales" (Hall, 2009, Page 224). In this way, I add new knowledge to existing understandings of co-innovation and contribute a fresh perspective on using the concept of anchoring to illuminate dynamic scaling processes. While my findings will be of interest to researchers studying scaling and practitioners applying a co-innovation inspired approach, further research will be of value in exploring their application in different contexts and different timeframes.

My research comes at a time when the global agri-food sector is facing growing calls to adopt a more sustainable operating model and break-away from business-as-usual. Not only to increase output to better meet the needs of the world's growing population but also to decrease the demands it makes, and its impacts upon, the natural environment. Together, these sometimes competing drivers create a so-called "wicked problem" (Struik and Kuyper, 2017; Waddock, 2013) of such complexity that for the sector to respond effectively then approaches to and understandings of innovation activity must also adapt. In recent years this has seen innovation activity in the agri-food sector increasingly coming to be understood from a systems perspective (Douthwaite and Hoffecker, 2017; Lamprinopoulou et al., 2014; Klerkx et al., 2012; Röling, 2009; Biggs, 1990). Among various interpretations, AIS thinking understands innovation activity as emerging from dynamic interactions or co-innovation processes between the technological, social and institutional[112] (Klerkx et al., 2012; Spielman and Birner, 2008). While AIS thinking better accommodates the complexities of a system in flux than more traditional, linear interpretations of technology transfer, it lacks the explicit pathway to scale embedded in the latter (Crivits et al., 2014). It is this knowledge gap that I address through my research.

[112] Parallels between AIS thinking and complex adaptive systems (CAS) interpretations of innovation as a series of technical and non-technical interactions in an evolving context (Hall and Clark, 2010).

By asking how co-innovation is understood and operationalised and how its application anticipates scaling, my enquiries are both descriptive and exploratory. To address these questions, I adopt a qualitative approach with a view to gaining an insight into "things in their natural settings" (Denzin and Lincoln, 1994, Page 2). More specifically, my strategy of enquiry, in the form of a case study, provides a way of "getting close to reality" (Thomas, 2011, Page 6) and opens-up the potential to draw on multiple and diverse sources of data. The Primary Innovation Programme (PIP) – a five-year, co-innovation pilot in New Zealand's agri-food sector – provides the basis for my study. By exploring the overarching programme and two of five associated projects, I gain an insight into the opportunities and challenges of putting co-innovation into practice in the context of NZ's agri-food sector.

Stake (1995) notes that a case study concerns the particular rather than general and this level of focus helps to give the case study its strength in depth. Although findings are not generalisable to wider "populations or universes" they may be generalised to "theoretical propositions" (Yin, 2003, Page 10) to give wider reach. As it works through changes to established ways of operating, NZ's agri-food sector embodies much of the promise and the uncertainties of change in the making being experienced by agri-food sectors elsewhere. Tempting as it is to generalise from my study to the wider sector, by doing so I would be asking too much of the case. Nevertheless, there is a context-specificity about co-innovation itself that makes it difficult to draw wider generalisations so making the opportunity to explore co-innovation processes in depth through case study, especially fitting.

In the absence of a theory of scaling, I use the concept of anchoring (Elzen et al., 2012) as a proxy, as indicated by Wieczorek (2018), and explore its potential application on this basis. From an AIS perspective, interactions between diverse actors around the technological (hardware), social (software) and institutional (orgware) aspects of innovation activity are emphasised (Hermans et al., 2016; Leeuwis and Aarts, 2011). Likewise, the concept of anchoring is underpinned by technological, network and institutional considerations (Elzen et al., 2012) and I find this symmetry provides a valuable read-across between AIS thinking and anchoring.

To accommodate the typically extended timeframes associated with scaling, I draw on Arie Rip's (2012) concept of 'anticipatory co-ordination' as a way of bridging the shorter timeframe of my study and the longer timeframes of unfolding scaling processes. Again, there is a read-across between Arie Rip's depiction of the innovation pathway as a mix of wrong-turns and occasional break-throughs and Elzen's characterisation of anchoring as a constant probing for connections that results in a mix of failures and, sometimes, more enduring connections. While there is a sense of fragility in early connections there are lessons to be learned regardless of whether or not connections become fractured or dis-lodged or more firmly established. I find this notion of ongoing learning chimes with empirical evidence as participants' speak of a growing realisation of the value in a 'learning by doing' approach in the absence of an existing routemap to guide trans-formation of NZ's agri-food sector from a science-led to a more participatory or collaborative approach.

In all of this, collaborative, co-innovative processes are confirmed as a messy process of negotiation and compromise (Elia and Margherita, 2018, Campbell et al., 2015). I find that using the concept of anchoring as a framework to guide my enquiries provides valuable structure and encourages a focus on the processes and interactions involved in testing-out and occasionally securing, albeit fragile connections. From this perspective, I come to appreciate the value and function of the co-innovation space. Both the act of holding space that allows diverse actors to come together around a shared concern performing boundary functions of "mediation" (Cash, 2001, Page 432) and "stabilisation" (Guston, 1999, Page 88) and the more disruptive (Schut et al. 2013) or performative functions closer to the concept of a hybrid forum as envisaged by Elzen et al. (2012, Page 15) to describe "…the location where translations take place." I use the term modulating to reflect interactions within this dynamic space. On this basis, a co-innovation inspired approach is actively holding space that accommodates diverse temporal (from short-term to long-term), spatial (local to global) and institutional (conforming or reforming) perspectives. By alleviating potential disconnects associated with interactions along and between scales, co-innovation helps to catalyse and sustain scaling processes.

Appendices

Appendix I: Configurations of Upscaling

Although each scaling pathway is unique, Westley et al. (2014) proposed five "shaping elements" (Page 244) that inform the process: i) approach to change, stakeholders' previous experience of delivering change and their vision of how prevailing institutions will need to adapt for goals to be achieved; ii) the underlying strengths of the change, its inherent advantages with respect to the status-quo; and, vice-versa, iii) the inherent disadvantages of desired change with respect to the status-quo; iv) the perceived opportunities associated with following a strategy of upscaling; and, v) the risks, in following the strategy and the risks of no change.

Building-on these five shaping elements, Westley et al. (2014) then identified five configurations of upscaling, noting that an organisation may have "features of more than one configuration" (Page 239). These configurations, as outlined in Table X below, are described as the: volcano, beanstalk, umbrella, lego, and polishing gemstones approaches and their particular value lies in contributing to an informed sense of self-awareness at an individual actor, firm or consortium level.

Upscaling configuration and defining characteristics	5 x Shaping Elements				
	i) Approach to change	ii) Strength	iii) Challenge	iv) Pathway	v) Risk
Volcano: high levels of energy & excitement but risk of resources becoming diluted as multiple ideas come to surface	Dynamic culture of learning & experiment-ation	Commitment to inclusivity	Resources diluted across multiple activities	Targeted approach; core areas prioritised for action	Adopting a strategic focus risks losing energy
Beanstalk: strong leadership from central champion driven by frustration with status-quo but requirement for external funding carries risk of cultural change as a result	Adherence to guiding vision helps to overcome difficulties	Consistent focus on attaining goals	Source of funding from a sponsor that shares this vision	Finding a source of investment capital	Bringing in external funding risks cultural change
Umbrella: initiating body provides funding to create protected development space; system-level goal gives direction but vulnerable when initiator steps-back	Start-up funding from initiating body creates a safe space	Early articulation of system-level goal(s)	To instil sense of inspiration & integration in participants	New ways of operating challenge traditional roles	Process vulnerable as funding body withdraws
Lego: builds from the bottom-up on local assets to forge new relationships and achieve change at community level, challenge in extending approach to strategic level	Founded on belief that bottom-up community change can be a catalyst	Existing assets provide building blocks for development	Connecting place-based activities with wider policy framework	Strategic conversations aim to bridge gap between the local and the national	Potential disconnect if message too far removed from grass roots
Polishing Gemstones: seeks to build-on successful outscaling but may find upscaling prompts need for tie-in with operators already working at higher level	Seeks to build-on the elements of an effective outscaling campaign	Commitment to quality and organic development of network	Requires a management transition from tactical to strategic thinking	Requirement for new skills necessitates partnership approach	Quality control compromised

Five configurations for upscaling social innovations (adapted from Westley et al., 2014)

Appendix II: Considerations of Scaling

Holcombe (2012) suggests six criteria, as shown below, that may variously simplify or complicate the dynamic processes of scaling.

Complicating factors… <-	**<- Criteria ->**	**-> ...Simplifying factors**
Lack of transparency; assumptions ill-defined; trial & target areas incompatible	*1. Clarity & credibility: a clearly articulated & measurable plan to achieve desired change*	Scientific credibility
Perceived complexity of the innovation; a remote rather than local presence	*2. Legitimacy of implementing organisation(s): an understanding of roles & responsibilities & associated legitimacy in target areas*	A known, local & respected presence; established track-record & shared understanding of need
Trial results that do not readily translate to in-field application	*3. Evidence of effectiveness (of the innovation) & efficiency (economic justification): a commitment to monitoring & evaluation*	Evidence of impact observable & attributable by participants
No allowance made for ongoing & continued support of process	*4. Financial model: source, duration & sustainability of funding*	Available funding commensurate with planned activities; promise of early payback of investment for trial participants
Multiple & divergent visions; little discussion & agreement	*5. Alignment & linkage: extent of fit with prevailing institutions (of sponsor, policy & target audience)*	High levels of engagement among stakeholders
Complex application that requires specialist training & ongoing access to support	*6. Complexity, co-ordination & behaviours: number of individuals and organisations involved, links & balance of power between them; existing & required competencies*	Simple application with no specialist knowledge requirements & rapid results

Scaling considerations (adapted from Holcombe, 2012)

Appendix III: Dimensions of Scaling

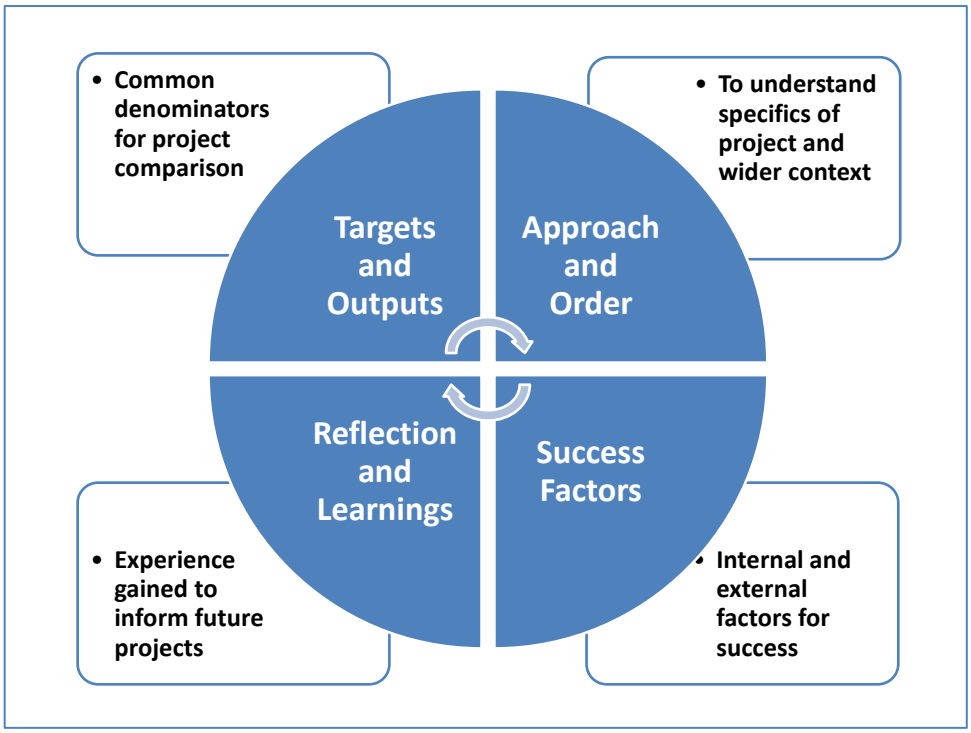
Hermans et al (2016) proposed three scaling dimensions: i) spreading and diffusion; ii) politics and power; and, iii) adaptation and transformation; and five associated scales with relevant measures attached, as shown below:

Dimension	**Scale**	**Measure**				
1. Spreading & Diffusion (outscaling)	*a) Spatial*	Local	Regional	National	Continental	Global
	b) Network	Small		Medium		Large
2. Politics & Power (upscaling)	*a) Administrative*	Municipal		Provincial	National	European
	b) Institutional	Operating rules		Voluntary frameworks & standards	Legal framework, laws & policies	Constitutions, directives & policies
3. Adaptation & Transformation	*a) Innovation*	Novelty		Niche development		Breakthrough & implementation

Dimensions, scales and measures (adapted from Hermans et al., 2016)

Appendix IV: Evaluation of Scaling

Recognising the benefits of consistent criteria for evaluation of scaling impacts, the World Bank (2003) proposed a guiding framework, as illustrated below:



Outline framework to review scaling (adapted from World Bank, 2003, Page 16)

'Approach and order' addresses progress over time to identify key stages/sequences; together with some measure of the project's ambition in terms of distinguishing between expanding (within existing areas of operation) and extending (outwith existing areas and into new areas, regions or countries). 'Success factors' differentiates between internal and external functions. The former within the control of the project team, e.g. aspects of project leadership; the latter largely outside the team's control, e.g. responsiveness to potential synergies with existing institutions or in response to windows of opportunity. 'Reflection and learnings' considers aspects of the project that have worked well and less well; e.g., relevance to local context, access to gatekeepers, network reach and strength. 'Targets and outputs' investigate the objectives that have been defined and the extent to which they have been achieved; assessing the broad impacts of the initiative in light of an early outline of associated costs and benefits.

Appendix V: Discussion Guide

A. Introduction

- What is your role/role of your organisation in the project?
- What was the rationale for your/your organisation's initial involvement? Who initiated?
- What is your current level of involvement in the project? How consistent with expectations?
- What are the project's objectives as you see them? How well do they align with your own?

B. Network

- Who are the other individuals/organisations involved in the project?
    - Is this network consistent with achieving the project's objectives or are there gaps?
    - Have you seen growth in the network of people involved -> what has this meant for the project in your view?
    - What different levels in the system (value chain, region) have become involved? How have these become connected?
- At times, has the network worked especially closely? What were the triggers for this?
    - To what extent do you feel that the project represents a collaborative effort?

C. Roles

- Which organisations/individuals do you see as the main drivers behind the project at this stage?
    - How has this evolved? How do they drive the project/what is their contribution?
    - What support do they need from others/provide to others?
- Are there key external targets whose influence/buy-in is needed -> who are they -> what is their impact and why are they not already involved in the project?

D. Actions undertaken

- Have there been points in the project that you would identify as having made a particular impact, positive or negative, on its direction?
    - How did it come about? What were the impacts? Did it require compromise from some? What were the associated risks and benefits? Who led the action; the response?

E. Barriers overcome

- What do you identify as the main barriers that the project has encountered?
    - How did these impact on the project? How addressed? What consequences?
    - What was impact on relationships between stakeholders? Have they been resolved? If not what are the obstacles -> What is needed to overcome these barriers?

F. Technological and Institutional change

- How have the project's desired outcomes evolved over the lifetime of the project?
    - More/less ambitious in scope? What prompted these changes? What impacts?
- How is the project impacting on existing practices and behaviours in your organisation? And on the practices and behaviours of other organisations in the project?
- What are the impacts on existing practices, standards and behaviours in the wider sector? -> in what ways?
    - Incremental vs step-change?
    - To what extent does the project complement/challenge/replace?
    - Will successful implementation of the project give rise to winners/losers?
- Does the project impact on existing policies in this sector? Which policies and in what ways?
- And are there impacts on existing governance structures? Which ones and in what ways?

G. Scaling

- Looking at the ongoing roll-out of the project, what target audiences could potentially be reached? Is a conducive environment being created for more widespread dissemination?
- To what extent do you believe that the sector's stakeholders share a common vision of where they would like to see their sector in the medium term (5-10 years)?
- And to what extent do you believe that there is consensus in the sector with respect to the steps that need to be taken in order to achieve this vision?
    - On Handout 1, place a cross where you believe this sector best fits in terms of the overarching level of agreement among stakeholders with respect to a vision for the sector and the steps that need to be taken to make it happen -> review response
- How do you see outcomes of this project impacting, positively and negatively, on this vision?
- What additional support/input is necessary to support the achievement of this vision?

H. Close

- For Primary Innovation Projects:
    - Please outline your understanding of co-innovation…
    - To what extent do you think that these principles have been applied in this project?
- All: based on your experience of collaborating with others in this project, do you see opportunities to apply a similar approach elsewhere in your sector?

Are there any other issues relevant to the topic that you wish to raise?

Appendix VI: Code of Practice for Research

Code of Practice for Research

- The University of Edinburgh has formally adopted the UK Research Integrity Office's (UKRIO) Code of Practice for Research
- The full Code is at: http://www.ukrio.org/publications/code-of-practice-for-research/
- The core sections of the Code include:
    - Guiding Principles to encourage critical engagement in the 'practical, ethical and intellectual challenges' that should characterise research: excellence; honesty; integrity; co-operation; accountability; training and skills; and safety
    - A one-page Checklist for Researchers that sets out key considerations at various stages: i) before conducting research; ii) when conducting research; and iii) on completion of research
    - Standards for good practice in research that underpin the one-page checklist and set out: general guidance on good practice in research; leadership and supervision; training and mentoring; research design; collaborative working; conflicts of interest; research involving human participants, human material or personal data; research involving animals; health and safety; intellectual property; finance; collection and retention of data; monitoring and audit; peer review; publication and authorship; and, misconduct

Research ethics

- The University has a research ethics framework that sets out the guiding principles to apply to all research with respect to: dignity; respect; care for others; honesty; integrity; objectivity; accountability; openness; and, leadership
- Given the wide range of activities within the University, specific frameworks apply. The frameworks of the College of Humanities and Social Science (CHSS) and the School of Social and Political Science (SSPS) will apply in this case
- Checklists provide assistance in the identification of ethical issues, and address: risks to/safety of researchers; risks to/safety of participants; data protection; research design; and, external professional bodies. Completed checklists require approval by the Head of School

Research work should not begin until the necessary clearances have been obtained

Appendix VII: UKRIO, checklist for completion

Recommended checklist for researchers

The Checklist lists the key points of good practice in research for a research project and is applicable to all subject areas. More detailed guidance can be found in section 3. A PDF version is available from www.ukrio.org

Before conducting your research, and bearing in mind that, subject to legal and ethical requirements, roles and contributions may change during the time span of the research:

1. Does the proposed research address pertinent question(s) and is it designed either to add to existing knowledge about the subject in question or to develop methods for research into it? ☐
2. Is your research design appropriate for the question(s) being asked? ☐
3. Will you have access to all necessary skills and resources to conduct the research? ☐
4. Have you conducted a risk assessment to determine:
   - a whether there are any ethical issues and whether ethics review is required; ☐
   - b the potential for risks to the organisation, the research, or the health, safety and well-being of researchers and research participants; and ☐
   - c what legal requirements govern the research? ☐
5. Will your research comply with all legal and ethical requirements and other applicable guidelines, including those from other organisations and/or countries if relevant? ☐
6. Will your research comply with all requirements of legislation and good practice relating to health and safety? ☐
7. Has your research undergone any necessary ethics review (see 4(a) above), especially if it involves animals, human participants, human material or personal data? ☐
8. Will your research comply with any monitoring and audit requirements? ☐
9. Are you in compliance with any contracts and financial guidelines relating to the project? ☐
10. Have you reached an agreement relating to intellectual property, publication and authorship? ☐
11. Have you reached an agreement relating to collaborative working, if applicable? ☐
12. Have you agreed the roles of researchers and responsibilities for management and supervision? ☐
13. Have all conflicts of interest relating to your research been identified, declared and addressed? ☐
14. Are you aware of the guidance from all applicable organisations on misconduct in research? ☐

When conducting your research:

1. Are you following the agreed research design for the project? ☐
2. Have any changes to the agreed research design been reviewed and approved if applicable? ☐
3. Are you following best practice for the collection, storage and management of data? ☐
4. Are agreed roles and responsibilities for management and supervision being fulfilled? ☐
5. Is your research complying with any monitoring and audit requirements? ☐

When finishing your research:

1. Will your research and its findings be reported accurately, honestly and within a reasonable time frame? ☐
2. Will all contributions to the research be acknowledged? ☐
3. Are agreements relating to intellectual property, publication and authorship being complied with? ☐
4. Will research data be retained in a secure and accessible form and for the required duration? ☐
5. Will your research comply with all legal, ethical and contractual requirements? ☐

Appendix VIII: College of Humanities and Social Sciences, Ethics Checklist

Research ethics checklist

This code applies to all research carried out in the CHSS, whether by staff or students. The checklist should be completed by the Principal Investigator, leader of the research group, or supervisor of the student(s) involved. Those completing the checklist should ensure, wherever possible, that appropriate training and induction in research skills and ethics has been given to researchers involved prior to completion of the checklist, including reading the College's Code of Research Ethics. This is particularly important in the case of student research projects.

If the answer to any of the questions below is 'yes', please give details of how this issue is being/will be addressed to ensure that ethical standards are maintained. **1 THE RESEARCHERS**	
Your name and position: Dr Ann Bruce; PhD Supervisor	
Proposed title of research: How co-innovation with respect to sustainable intensification impacts on scaling in the context of the New Zealand agri-food sector	
Funding body: SRUC and AgResearch	
Time scale for research: Completion by April 2017	
List those who will be involved in conducting the research, including names and positions (e.g. 'PhD student'): Additional supervisors are: Dr Neels Botha (AgResearch), Dr Laurens Klerkx (Wageningen), Dr Chrysa Lamprinopoulou and Dr Andrew Barnes (SRUC); PhD Candidate is Sam Beechener.	
2 RISKS TO, AND SAFETY OF, RESEARCHERS	
Those named above need appropriate training to enable them to conduct the proposed research safely and in accordance with the ethical principles set out by the College	**Yes/~~No~~ Researcher will be required to comply with local requirements with respect to farm bio-security**
Researchers are likely to be sent or go to any areas where their safety may be compromised	**Yes/~~No~~ Some lone–working will be involved and good practice will be followed in terms of adopting a local buddy system to confirm safe return**
Could researchers have any conflicts of interest?	**~~Yes~~/No**
3 RISKS TO, AND SAFETY OF, PARTICIPANTS	
Could the research induce any psychological stress or discomfort?	**Yes/~~No~~ Unlikely, but depth interviews will be used and any form of interview may be associated with a degree of stress for participants**
Does the research involve any physically invasive or potentially physically harmful procedures?	**~~Yes~~/No**
Could this research adversely affect participants in any other way?	**~~Yes~~/No**

4 DATA PROTECTION	
Will any part of the research involve audio, film or video recording of individuals?	**Yes/~~No~~ audio recording of interviews and use of digital photography to capture images as appropriate**
Will the research require collection of personal information from any persons without their direct consent?	**~~Yes~~/No**
How will the confidentiality of data, including the identity of participants (whether specifically recruited for the research or not) be ensured? **Files identifying participants will be held separately from data files and linked via a numeric code**	
Who will be entitled to have access to the raw data? **PhD Candidate and Supervisors**	
How and where will the data be stored, in what format, and for how long? **Data will be held for duration of project (April '17) then archived according to principles of UoE**	
What steps have been taken to ensure that only entitled persons will have access to the data? **Data will be stored on secure networked drives at UoE, SRUC and AgResearch;**	
How will the data be disposed of? **Hard copies (e.g. questionnaires) will be scanned for e-storage and archiving, originals will be securely disposed of via AgResearch / SRUC**	
How will the results of the research be used? **Towards preparation of thesis and to support articles for publication**	
What feedback of findings will be given to participants? **Summary findings**	
Is any information likely to be passed on to external companies or organisations in the course of the research?	**~~Yes~~/No**
Will the project involve the transfer of personal data to countries outside the European Economic Area?	**~~Yes~~/No majority of data will be collected in-situ in New Zealand; quantitative data collected in Scotland will be aggregated prior to any transfer of findings to New Zealand**
5 RESEARCH DESIGN	
The research involves living human subjects specifically recruited for this research project *If 'no', go to section 6*	**Yes/~~No~~**
How many participants will be involved in the study? **c. 200**	
What criteria will be used in deciding on inclusion/exclusion of participants? **Qualitative fieldwork in New Zealand: actors involved in one of 4 co-innovation projects in the agri-food sector, co-funded by government and industry; Quantitative fieldwork in Scotland: actors involved in innovation projects in the livestock farming sector of Scotland**	
How will the sample be recruited? **Purposively sampled from existing agri-food innovation networks in New Zealand and Scotland**	
Will the study involve groups or individuals who are in custody or care, such as students at school, self help groups, residents of nursing home?	**~~Yes~~/No**
Will there be a control group?	**~~Yes~~/No**

What information will be provided to participants prior to their consent? (e.g. information leaflet, briefing session) **Letter of introduction that explains why they have been approached and why their views are important, what the research is about and who is conducting the study, what their participation will involve, how the findings will be used and the feedback they will receive - with researcher's contact details in event of any queries**	
Participants have a right to withdraw from the study at any time. Please tick to confirm that participants will be advised of their rights. **CONFIRMED**	
Will it be necessary for participants to take part in the study without their knowledge and consent? (e.g. covert observation of people in non-public places)	~~**Yes**~~**/No**
Where consent is obtained, what steps will be taken to ensure that a written record is maintained? **Written records will be electronically scanned for retention by the researcher**	
In the case of participants whose first language is not English, what arrangements are being made to ensure informed consent? **Unlikely; New Zealand and Scotland both English-speaking, in the event that concern arises e.g. Maori or Gaelic speakers then local advice will be sought from AgResearch / SRUC as appropriate**	
Will participants receive any financial or other benefit from their participation?	**Yes/**~~**No**~~ **Incentive in the form of a summary of findings**
Are any of the participants likely to be particularly vulnerable, such as elderly or disabled people, adults with incapacity, your own students, members of ethnic minorities, or in a professional or client relationship with the researcher?	~~**Yes**~~**/No**
Will any of the participants be under 16 years of age?	~~**Yes**~~**/No**
Do the researchers named above need to be cleared through the Disclosure/Enhanced Disclosure procedures?	~~**Yes**~~**/No**
Will any of the participants be interviewed in situations which will compromise their ability to give informed consent, such as in prison, residential care, or the care of the local authority?	~~**Yes**~~**/No**
6 EXTERNAL PROFESSIONAL BODIES	
Is the research proposal subject to scrutiny by any external body concerned with ethical approval?	**Yes/**~~**No**~~
If so, which body? **Confirmation will be sought from SRUC and AgResearch as local institutes involved in study in Scotland and New Zealand, respectively**	
Date approval sought **September 2014**	
Outcome, if known *or*	
Date outcome expected **November 2014**	
7 ISSUES ARISING FROM THE PROPOSAL	
In my view, ethical issues have been satisfactorily addressed, OR ~~In my view, the ethical issues listed below arise and the following steps are being taken to address them~~:	

Signature:

Date:

8 Ethical consideration by School

The following section should be completed by the Head of School once the proposal has been considered by the School's research group.

I confirm that the proposal detailed above has received ethical approval from the School [* subject to approval by the external body named in section 6].

Signature Date

* Delete as appropriate

Appendix IX: Self-audit ethics checklist

University of Edinburgh,

School of Social and Political Studies

RESEARCH AND RESEARCH ETHICS COMMITTEE

Self-Audit Checklist for Level 1 Ethical Review

*The audit is to be conducted by the **Principal Investigator**, except in the following cases:*

- ***Postdoctoral research fellowships** – the applicant in collaboration with the proposed mentor.*
- ***Postgraduate research** (PhD and Masters by Research) – the student together with the supervisor. Note: All research postgraduates should conduct ethical self-audit of their proposed research as part of the proposal process. The audit should be integrated with the student's Review Board.*
- ***Taught Masters dissertation** work and **Undergraduate dissertation/project** work – in many cases this would not require ethical audit, but if it does (for example, if it involves original fieldwork), the student conducts the audit together with the dissertation/project supervisor, who keeps it on file.*

Potential risks to participants and researchers

1 Is it likely that the research will induce any psychological stress or discomfort? YES☐ NO ☐✓

2 Does the research require any physically invasive or potentially physically harmful procedures? YES☐ NO☐✓

3 Does the research involve sensitive topics, such as participants' sexual behaviour or illegal activities, their abuse or exploitation, or their mental health? YES☐ NO ☐✓

4 Is it likely that this research will lead to the disclosure of information about child abuse or neglect, or other information that would require the researchers to breach confidentiality conditions agreed with participants? YES☐ NO ☐✓

5 Is it likely that participation in this research could adversely affect participants? YES☐ NO ☐✓

6 Is it likely that the research findings could be used in a way that would adversely affect participants or particular groups of people? YES☐ NO ☐✓

7 Will the true purpose of the research be concealed from the participants? YES☐ NO ☐✓

8 Is the research likely to involve any psychological or physical risks to the researcher, and/or research assistants, including those recruited locally? YES☐ NO ☐✓

Participants

9 Are any of the participants likely to:

be under 18 years of age? YES☐ NO ☐✓

be physically or mentally ill? YES☐ NO ☐✓

have a disability? YES☐ NO ☐✓

be members of a vulnerable or stigmatized minority? YES☐ NO ☐✓

be in a dependent relationship with the researchers? YES☐ NO ☐✓

have difficulty in reading and/or comprehending any printed material distributed as part of the research process? YES☐ NO ☐✓

be vulnerable in other ways? YES☐ NO ☐✓

Will it be difficult to ascertain whether participants are vulnerable in any of the ways listed above (e.g. where participants are recruited via the internet)? YES☐ NO ✓

11 Will participants receive any financial or other material benefits because of participation, beyond standard practice for research in your field? YES☐ NO ✓

Before completing the next sections, please refer to the University Data Protection Policy to ensure that the relevant conditions relating to the processing of personal data under Schedule 2 and 3 are satisfied. Details are Available at: www.recordsmanagement.ed.ac.uk

Confidentiality and handling of data

12 Will the research require the collection of personal information about individuals (including via other organisations such as schools or employers) without their direct consent?
YES☐ NO ✓

13 Will individual responses be attributed or will participants be identifiable, without the direct consent of participants?
YES☐ NO ✓

14 Will datafiles/audio/video tapes, etc. be retained after the completion of the study (or beyond a reasonable time period for publication of the results of the study)?
YES☐ NO ✓

15 Will the data be made available for secondary use, without obtaining the consent of participants?
YES☐ NO ✓

Informed consent

16 Will it be difficult to obtain direct consent from participants?
YES☐ NO ✓

Conflict of interest

The University has a 'Policy on the Conflict of Interest', which states that a conflict of interest would arise in cases where an employee of the University might be "compromising research objectivity or independence in return for financial or non-financial benefit for him/herself or for a relative or friend."
See: http://www.docs.csg.ed.ac.uk/HumanResources/Policy/Conflict_of_Interest.pdf

Conflict of interest may also include cases where the source of funding raises ethical issues, either because of concerns about the moral standing or activities of the funder, or concerns about the funder's motivation for commissioning the research and the uses to which the research might be put.

The University policy also states that the responsibility for avoiding a conflict of interest, in the first instance, lies with the individual, but that potential conflicts of interest should always be disclosed, normally to the line manager or Head of Department. Failure to disclose a conflict of interest or to cease involvement until the conflict has been resolved may result in disciplinary action and in serious cases could result in dismissal.

17 Does your research involve a conflict of interest as outlined above?
YES☐ NO ✓

Overall assessment

If all the answers are NO, the self audit has been conducted and confirms the ABSENCE OF REASONABLY FORESEEABLE ETHICAL RISKS. The following text should be emailed to the relevant person, as set out below:

"I confirm that I have carried out the School Ethics self-audit in relation to **Sam Beechener's** proposed research project **How co-innovation with respect to sustainable intensification impacts on scaling in the context of the New Zealand agri-food sector co-funded by SRUC in Scotland and AgResearch, New Zealand** and that no reasonably foreseeable ethical risks have been identified."

• Research grants– the Principal Investigator should send this email to the SSPS Research Office (ssps.research@ed.ac.uk) where it will be kept on file with the application.

• Postdoctoral research fellowships – the Mentor should email the SSPS Research Office (ssps.research@ed.ac.uk) where it will be kept on file with the application.

• **Postgraduate research (PhD and Masters by Research) – there is no need to send the Level 1 email. The ethical statement should be included in the student's Review Board report.**

• Taught Masters dissertation work and Undergraduate dissertation/project work – there is no need to send the level 1 email. The dissertation supervisor should retain the ethical statement with the student's dissertation/project papers.

If one or more answers are YES, risks have been identified and level 2 audit is required.
See the School Research Ethics Policy and Procedures webpage

http://www.sps.ed.ac.uk/admin/info_research/ethics for full details.

Appendix X: Introductory Letter

Re: a PhD study of innovation in the agri-food sectors of New Zealand and Scotland

Feeding a growing population and working with scarce natural resources are just two of the many challenges facing the world's farming sector. The uncertainty associated with these challenges is prompting new ways of working to be explored, for example the co-innovation approach being piloted by the Primary Innovation programme in New Zealand. Co-innovation is based on concepts of trust and mutual co-operation among participants and the lessons learnt from this pilot will be of value not only to the agri-food sector of New Zealand but also more widely.

Primary Innovation provides the basis for this PhD that will study how co-innovation impacts on the subsequent uptake and spread of emerging technologies and practices. Reflecting the key role of grass-based livestock systems in New Zealand and Scotland, the study will have a particular focus on the sheep, beef and dairy sectors. Based at the University of Edinburgh, the studentship is co-funded by AgResearch Ltd. in New Zealand and SRUC, Scotland, with additional input from Wageningen University in the Netherlands.

The success of this initiative relies on collecting the best possible information from a wide range of participants and observers to add the necessary depth of understanding to the data emerging from published sources. I very much hope that you will be willing to support this project by agreeing to take part in either one or several one-to-one interviews, as described over the page. If you have any queries, please do not hesitate to contact me at sam.beechener@agresearch.co.nz / 021 223 2772.

Sam Beechener, PhD Candidate

SRUC
www.sruc.ac.uk

THE UNIVERSITY OF EDINBURGH

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AgResearch Limited

Title of the Project:	How co-innovation impacts on scaling in the context of the New Zealand agri-food sector
Project Description:	The aim of this study is to explore the scaling-up and scaling-out of co-innovation activities in the agri-food sector of New Zealand and to investigate to what extent the findings are more widely generalisable. Where scaling-up refers to the vertical or institutional expansion that contributes to the creation of an environment that encourages change; and scaling-out refers to the horizontal or geographic spread of innovations within communities. The focus of the project is the ruminant livestock sector with a particular emphasis on sustainable intensification where this refers to raising outputs while at the same time minimising negative environmental effects. An improved understanding of these scaling processes is expected to better enable emerging technologies to realise their full potential.
Researcher's Profile:	Sam Beechener is a PhD Candidate at the University of Edinburgh. His project is co-funded by SRUC, Scotland, and AgResearch Ltd., New Zealand. His placement in New Zealand runs for one year from November 2014. Sam has practical and commercial work experience in the agricultural sector. Before starting his PhD, he was employed by ADAS, a leading provider of rural advice and consultancy in the UK where he was involved in a wide-range of projects that included studies of: farm succession planning; electronic identification of livestock; and farm health planning.
What happens next:	You will be contacted by Sam and invited to take part in this project. There is no obligation to be involved and your participation is entirely voluntary. Taking part will involve a 45-60 minute interview conducted at a mutually agreed time and place. With your permission, this interview will be recorded and transcribed in full. The transcript will be analysed for the purposes of this research project and the information contained in it may be used in subsequent research publications. Nothing that you say will be attributable to you but I may wish to use short quotes and attribute a broad area of expertise (e.g. farmer, veterinarian, policy maker, business leader). At the time of the interview, you will be asked to sign a Consent Form confirming these points. Whether or not you would be content for contact to be made after the interview, for example for points of clarification; a follow-up interview at a future time; or to share emerging findings, will also be discussed and confirmed. If you prefer not to be involved then no further contact will be made.

Appendix XI: Consent Form

<Name>
<Address>
<City>

A PhD study of innovation in the agri-food sectors of New Zealand and Scotland:
CONSENT FORM

I have been given information about the above research project and the way that my contribution to the project will be used. Should I agree to participate in this research project, I understand that:

- The nature of my participation is an interview.
- My permission will be sought to digitally record and transcribe this interview.
- I agree to written notes being taken during the interview. If permission for recording is refused, these will form the sole record of the interview.
- My participation is entirely voluntary and I understand that I can withdraw my consent within the next 7 days.

Please tick as appropriate:

- I agree to take part in this project: ☐ Yes ☐ No
- I give my permission for the information that I provide to be used for research purposes (including research publications and reports) on an unattributable basis: ☐ Yes ☐ No
- I give my permission for reporting to include direct quotes that indicate my affiliation/role: ☐ Yes ☐ No
- I give permission for my name and affiliation to be listed in any reports/publications as one of several people consulted during this project: ☐ Yes ☐ No
- I give permission for the Researcher to make follow-up contact with me with respect to:
  - Points of clarification emerging from analysis of this interview: ☐ Yes ☐ No
  - Scheduling a follow-up interview in 6-9 months time: ☐ Yes ☐ No
  - Provision of summary findings in due course: ☐ Yes ☐ No
- I understand that I can withdraw my consent within the next 7 days: ☐ Yes ☐ No

Signed respondent: _____ Date __/__/2015

Organisation/affiliation: _____

Signed researcher: _____ Date __/__/2015

Organisation/affiliation: University of Edinburgh with SRUC, AgResearch Ltd. and Wageningen

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Appendix XII: Evolving Science System

Year	Description
1989	Creation of the Ministry of Research, Science and Technology (MoRST); and the Foundation of Research, Science and Technology (FRST)
1992	Establishment of the Crown Research Institutes (CRIs)
1994	Marsden Fund established to encourage scientific excellence
1999	FRST reform programme
2005	Vision Matauranga articulated
2010	CRI Taskforce Review
2011	Replacement of MoRST and FRST by the Ministry of Science and Innovation (MSI)
2012	MSI and Ministry of Economic Development; Departments of Labour and Buildings; and Housing incorporated into Ministry of Business, Innovation and Employment (MBIE)
2013	Callaghan Innovation opened to support commercialisation of scientific research
2013	National Science Challenges (NSC) announced articulating issues of national importance, including Our Land and Water Challenge with focus on natural resources
2014	A Nation of Curious Minds launched, to encourage public engagement with science
2015	Publication of NZ's National Statement of Science Investment (NSSI) setting out government's continued commitment to investment in science and innovation
2016	Strategic Science Investment Fund (SSIF) established to support delivery of the NSSI

Overview of NZ's evolving science system, 1989-2016 (adapted from Leitch et al. 2014)

Appendix XIII: Science Funding Overview

Published by NZ's Ministry of Business Innovation and Employment (MBIE), the National Statement of Science Investment (NSSI) describes NZ's science funding system according to investigator, mission and industry-led activities, as summarised below:

	Overarching National Statement of Science Investment (NSSI)		
Category and budget	More investigator-led (c. NZ$400 million)	More mission-led (c. NZ$468 million)	More industry-led (c. NZ$325 million)
Description	high level of uncertainty; potential transformation; advancement of research skills; contributes to development of global knowledge base.	typically associated with delivery of longer-term, research of public benefit that without government support might otherwise lack sufficient investment.	close-to-market, applied research activities with an emphasis on innovation; public funds invested to encourage economic activity and investment.
Principle funding mechanisms	• MBIE Endeavour Fund • 10 x Centres of Research Excellence (CoRE) • The Marsden Fund • Performance-based Research Fund	• Strategic Science Investment Fund • 11 x National Science Challenges • MPI Research • CRIs & Universities • Other departments and Crown Agents	• Callaghan Innovation • Industry bodies • Independent research organisations
Cross-cutting themes and indicative budget	Vision Mātauranga Capability Fund (NZ$6.5 million): development of people and organisations working with Maori knowledge to realise wider benefits		
	International relationships (NZ$9.5 million): investment in international relationship building to maintain and develop NZ's profile in global scientific research		
	Science in Society (NZ$9 million): increased engagement of wider public in science by asking questions / tackling local issues, in line with A Nation of Curious Minds[113]		
	Infrastructure (NZ$24.5 million)		

Overview of NZ science funding landscape (adapted from MBIE, 2016; Ferguson, 2017)

Although not mutually exclusive, applying investigator-led, mission-led and industry-led descriptors[114] provides a basis to outline NZ's funding landscape.

[113] https://www.curiousminds.nz/ (accessed 25/04/2018)

[114] See: http://ourlandandwater.nz/assets/Uploads/Ian-Ferguson-Symposium-Presentation-Roadmap-2017.pdf (accessed 25/04/2017)

Investigator-led activities

The MBIE Endeavour Fund

The Endeavour Fund[115] invests in two to three year contracts via its 'Smart Ideas' stream and in longer, three to five year contracts through its 'Research Programmes' initiative. Both aim to support research ideas with "high potential to positively transform New Zealand's economy, environment, and society." In the 2016 funding round, the Fund allocated NZ$209 million over five years to 56 research projects.

Centres of Research Excellence

Funded by the Tertiary Education Commission, and typically hosted by a University, the ten Centres of Research Excellence (CoREs) provide a forum for collaboration. Three of the centres have particular relevance for the agri-food sector: Gravida[116] (formerly National Research Centre for Growth and Development); the National Centre for Advanced Bio-Protection Technologies[117]; and the Riddett Institute[118] with expertise, respectively, in: exploring links, in both humans and livestock, between early development and later health and productivity; researching natural protection for NZ's ecosystem from plant pests, diseases and weeds; and, food and nutrition.

The Marsden Fund

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[115] http://www.mbie.govt.nz/info-services/science-innovation/investment-funding/how-we-invest/endeavour-fund (accessed 24/04/2018)

[116] Hosted at Auckland University and comprising: AgResearch, Landcorp, Massey University, University of Auckland, University of Otago, and University of Canterbury (http://gravida.org.nz/).

[117] Virtual Centre, comprising: Lincoln University, Massey University, University of Canterbury, AgResearch, Plant and Food Research, and Scion (http://bioprotection.org.nz/).

[118] Hosted at Massey University and comprising: the University of Otago, University of Auckland, AgResearch, and Plant and Food Research (http://www.riddet.ac.nz/).

The remit of The Marsden Fund[119] is to encourage excellence in fundamental research through contestable-funding of researcher-led activities. Its Terms of Reference are provided by the Minister of Science and Innovation. Established in 1994, outgoing chair Juliet Gerrard (2015) used the occasion of The Fund's 20th anniversary to reflect on the value for NZ of "investing in risky research with uncertain outcomes" (Page 123) that has yielded both successes and failures. While the former are rightly celebrated, Gerrard also defended the latter for encouraging a spirit of enquiry and fostering a community of researchers with sufficient freedom to make a difference.

Performance-based Research Fund

The Performance-based Research Fund[120] (PBRF) exists to encourage research excellence in the tertiary education sector rather than to fund research directly.

Mission-led activities

MBIE's Strategic Science Investment Fund

Established in 2016 to support the NSSI, the Strategic Science Investment Fund[121] (SSIF) brought together existing and new funding mechanisms to provide long-term strategic direction and to streamline government's vision for "a highly dynamic science system that enriches New Zealand" (Page i). A total of NZ$260 million/year was allocated for the period 2017/18 via its Programmes (incorporating CRI core-funding) and Infrastructure components. A Science Platform approach facilitates development of people, places, information and knowledge.

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[119] Named in honour of Sir Ernest Marsden (1889-1970) for his contribution to the development of science in New Zealand (https://royalsociety.org.nz/what-we-do/funds-and-opportunities/marsden/about/background/biography-of-sir-ernest-marsden/, accessed 12/04/2018)

[120] http://www.tec.govt.nz/funding/funding-and-performance/funding/fund-finder/performance-based-research-fund/ (accessed: 25/04/2018)

[121] http://www.mbie.govt.nz/info-services/science-innovation/investment-funding/how-we-invest/strategic-science-investment-fund (accessed 25/04/2018)

The National Science Challenges

Of the 11 National Science Challenges (NSC), ten were announced in 2013 with the eleventh confirmed in the following year[122]. The NSCs are intended to provide a significant, mission-led response to issues of national importance. Furthermore, they recognise that potential benefits from investment in science and research extend beyond economic measures to include, for example, national identity and outlook (Gluckman, 2015). A core purpose of the NSC is the ambition to encourage increased collaboration between institutes and to better connect basic and applied research functions with a view to triggering step-change, or additionality[123]. Baisden (2014) cautioned, however, of the potential discomfort, at least in the short-term, likely to accompany any departure from NZ's established operating model and institutions in the form of existing funding structures and measures of output.

Launched in 2016 and of direct relevance to the agri-food sector, Our Land and Water Challenge[124] brings together a wide range of collaborators[125] with the shared aim of transforming the way that New Zealand's land and water resources are used and managed, enhancing productivity of the primary industries while protecting and improving the country's natural resources. Three underlying aspirations reflect: i) an outward looking perspective that seeks to align participation in global value chains with domestic values; ii) application of new and existing technologies to deliver increased productivity within acceptable environmental limits; and iii) empowering individuals and communities to collaborate in response to shared challenges.

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[122] The 11 NSC are: A Better Start; Ageing Well; Building Better Homes, Towns and Cities; Healthier Lives; High-Value Nutrition; New Zealand's Biological Heritage; Our Land and Water; Resilience to Nature's Challenges; Science for Technological Innovation; Sustainable Seas; and The Deep South.

[123] Baisden (2014) uses additionality to describe the multiplier effect that may be achieved from an alignment between basic research and implementation in terms of the pace and magnitude of adoption.

[124] http://ourlandandwater.nz/ (accessed: 25/04/2018)

[125] Hosted by AgResearch, with: Institute of Environmental Science Research (ESR); Institute of Geological & Nuclear Science (GNS); Landcare Research; National Institute of Water & Atmospheric Research (NIWA); Plant & Food Research; Scion; Cawthron Institute; University of Waikato; Auckland University; Massey University; Lincoln University; Lincoln Agritech; University of Otago.

Crown Research Institutes

A particular feature in NZ is the concept of Crown Research Institutes (CRI). Introduced in 1992, as NZ's long-standing Department of Scientific and Industrial Research[126] (DSIR) was being dismantled and government's research and policy functions were being separated, the CRI's aimed to improve the uptake of new technologies by better connecting science and industry (Davenport and Bibby, 2007). This has required a balance to be struck between satisfying commercial objectives and delivering public-good outcomes. While on the one hand, CRIs have delivered a strong commercial performance welcomed by the Treasury; on the other hand, some scientists have expressed concern that the independence of NZ science risks being compromised (Edmeades, 2004). From 2011, the CRIs have operated according to a core funding model intended to facilitate long-term planning, subject to a five-year review. Some re-alignment of core-funding was required on introduction of the NSC in 2013 and a subsequent review in May 2016[127], recommended closer alignment between CRI core funding, the NSSI and wider MBIE programs with increased emphasis on clarity, stability, flexibility, value for money and independence.

There are seven CRIs: AgResearch has responsibility for the pastoral sector; Plant and Food Research has responsibility for fruit, vegetable, crop and food products; Scion has responsibility for the forestry sector; Landcare Research has responsibility for resource management; the National Institute of Water and Atmospheric Research (NIWA) has responsibility for environmental science; the Institute of Environmental Science Research (ESR); and the Institute of Geological and Nuclear Science (GNS) are specialist service providers. Jointly overseen by the Minister of Science and Innovation; and Minister of Finance, the CRIs are charged with improving the productivity and sustainability of their respective sectors.

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[126] Established in 1926 and widely regarded as ripe for reform in an increasingly commercial operating environment (Davenport and Bibby, 2007)

[127] http://www.mbie.govt.nz/info-services/science-innovation/innovative-new-zealand/budget-2016-funding/pdf-library/cri-core-funding-review.pdf (accessed: 25/04/2018)

Ministry of Primary Industries (MPI) Research

NZ's Ministry of Primary Industries (MPI) funds research in the farming, forestry and environment sectors and supports campaigns at regional or community level. Its activities have a shared aim to boost productivity while protecting the country's natural resources. Initiatives with respect to farming are outlined in the table, below. Some are linked to the Global Research Alliance on Agricultural Greenhouse Gases (GRA) some have links with one another and others are linked to overseas initiatives.

Fund and outline (https://www.mpi.govt.nz/funding-and-programmes/farming/ accessed 25/04/2018)
Global Partnerships in Livestock Emissions Research (GPLER): to support the Global Research Alliance on Agricultural Greenhouse Gases (GRA) in "accelerating global research in mitigating greenhouse gas emissions from pastoral livestock farming."
ICT-Agri Research call: funded by the European Commission's ERA-NET initiative to explore the application of information and communications technologies. MPI draws on government funding for the GRA to support NZ's researchers involved in ICT-Agri projects.
Irrigation Acceleration Fund (IAF):, support for: strategic water management studies to assist with integrated water management planning; and community irrigation schemes in the form of upgrade of existing infrastructure or development of smaller-scale new schemes (more complex, commercial schemes fall under the remit of Crown Irrigation Investments Ltd http://www.crownirrigation.co.nz/).
Primary Growth Partnership (PGP): a joint-venture between MPI and industry that invests public funds to enable industry to undertake more ambitious research with potential to yield greater impact with the aim of delivering long-term benefits for the economy, environment and wider society.
New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC): a partnership between NZ research providers involved in the study of agricultural GHG and the Pastoral GHG Research Consortium, funded through the PGP and contributing to the GRA the initiative aims to improve co-ordination and to establish NZ as an internationally recognised centre of excellence in this area.
Sustainable Farming Fund (SFF): investment in applied, producer-led research initiatives with an emphasis on creative problem-solving with more than 1,000 projects funded since the fund was launched in 2000. The SFF Tere pilot caters for smaller projects with a shorter turn around.
Sustainable Land Management and Climate Change Research Programme (SLMACC): this scheme invests in a broad range of research into the impacts of and adaptation to climate change in the farming and forestry sectors; the mitigation of GHG emissions; and wider climate change issues, including life-cycle analysis, farm/catchment/systems analysis, and socio-economic assessments.
Hill Country Erosion Programme: significant costs associated with erosion of hill country through lost soil and reduced productivity, damage to property and infrastructure. This programme supports Capacity Building initiatives at the catchment level and funds work in partnership with Regional Councils to treat erosion-prone land and implement longer-term management changes.
Vet Bonding Scheme: to address a shortage of veterinarians working in NZ's rural farm animal practices this scheme provides a series of payments to graduate vets working in eligible practices.

Overview of MPI Research with respect to farming

Industry-led activities

Callaghan Innovation

Named in honour of the NZ physicist, Sir Paul Callaghan (1947-2012), Callaghan Innovation reflects Sir Paul's vision for NZ as "a hub of smart, export-focused entrepreneurs, where a high quality lifestyle is achieved through excellence in education and R&D"[128] with an emphasis on commercialising scientific research. Opened in February, 2013, from the outset Callaghan Innovation has sought to encourage collaboration and to use these collaborations to prompt fresh thinking that is not afraid to challenge the status-quo. Accordingly, Callaghan Innovation works in partnership with more than 500 organisations with an interest in commercialising innovation, including national and regional government, CRIs and wider industry.

Callaghan Innovation provides a range of services with the aim of improving skills and building networks to encourage and facilitate innovation. In brief, these include:

- Access to experts through national and international networks intended to create synergy through effective connections;
- Support for development of technology through the provision of expertise and facilities;
- Enhancing innovation skills through learning and skills development;
- Business collaborations to reduce costs and share knowledge; and
- Grants for all stages from support for students to new product development.

Industry Bodies

Producer-funded levy bodies, for example DairyNZ and Beef and Lamb NZ, undertake sector-specific research, development and extension activities. Commercial organisations, for example Fonterra, fund bespoke programmes.

[128] https://www.callaghaninnovation.govt.nz/about-us/our-name-sir-paul-callaghan (accessed: 26/04/2018

Appendix XIV: Ex-post Project Outlines

InCalf, a systematic approach to dairy herd fertility

Brownlie (2012) has described how concerns to better understand the management factors contributing to variation in the reproductive performance of dairy herds prompted the Australian Dairy Herd Fertility Project that ran between 1996 and 2000, and the New Zealand Monitoring Fertility Project that ran along similar lines between 1998 and 2000. Six critical management factors were identified that then informed development of Dairy Australia's InCalf Programme. This proposed that cumulative gains could be achieved through a process of continual improvement based on a commitment to ongoing recording, assessment, planned actions and review, a so-called plan-do-review approach. This was delivered in the form of a comprehensive hand-book, supporting tools, facilitated action groups and training via approved providers. A Memorandum of Understanding between Dairy Australia and Dairy NZ allowed the latter to adapt and tailor the programme for NZ's conditions. It was launched in NZ in 2007 (McDougall et al., 2014) with the aim of contributing towards a national uplift in the 6-week in calf rate (Brownlie et al., 2015).

InCalf [IC] was structured around Farmer Action Groups that it was envisaged would come together before and after critical events in the dairy farming calendar – calving, mating, lactation and dry periods – with the intention of planning and agreeing actions and reviewing outcomes. Additional sign-posting was provided to access expert input e.g. nutritionists. In their large-scale randomised control trial to explore the herd performance impacts of IC in a NZ context, McDougall et al (2014) found a "small positive effect on herd reproductive performance" (Page 208) although this was expected to fall short of delivering the wider industry objectives within the target timeframe. In addition, it was observed that: attendance at the Farmer Action Group meetings was patchy; although objectives arising from the meetings were intended to be SMART (specific, measurable, achievable, realistic and time-bound), less than 5% were found to be in this format creating a disconnect with subsequent monitoring and assessment processes; although the cost-benefits of herd reproduction management have been demonstrated, they may be difficult to apportion at farm level; the interactive structure of the programme requires a significant and lasting

commitment from farmers and herd-managers that may compete with other on-farm priorities. In addition, it was observed that the mechanics of providing sufficient expertise to support the programme within farm animal veterinary practices resulted in one or two veterinarians adopting the role of practice 'expert' on the IC programme, requiring interactions to be routed accordingly and impeding client-vet interactions. Fielke et al. (2017) reflected on the robust technical basis of the IC initiative but concluded that "a lack of engagement with vets as pivotal actors, as well as farmers themselves, hampered the success of the IC case" (Page 18) in NZ.

Apple Futures, from a threat to an opportunity

In the early 2000's, with costs of production increasing and downward pressure on returns, margins for NZ's apple growers were under severe pressure. Against this background, the continued viability of the sector was further threatened by the prospect of: i) increasingly stringent EU regulatory requirements to reduce the maximum residue levels (MRL) of pesticides in fruit; and ii) increasingly exacting phytosanitary requirements for access to target export markets in Asia. NZ was, however, one of only a few apple exporting nations to respond to calls for reduced MRLs and, as such, "a threat became an opportunity" (Park et al., 2015, Page 293).

Building on the established Integrated Fruit Production (IFP) system, a team led by the industry body, Pipfruit New Zealand with expert input from scientists at Plant and Food Research (P+F) and supported by government funding developed an enhanced programme of control, Apple Futures [AF]. This combined orchard management and chemical selection protocols to maximise quality and minimise residues. Also, although AF embodied a wider ambition for change, by continuing the tried and trusted IFP approach, it maintained the confidence of growers. Indeed the message for growers was that the leap "for you, going into Apple Futures is not as big as the leap you took when you went into IFP" (Park et al., 2015, Page 295).

By 2011, backed by positive trial results from in-field pilots, almost two-thirds of the national cropping area was grown under AF protocols. In the same year, the scheme underpinned the launch of the "100% Pure Apple from New Zealand" brand that would be the basis for differentiation in target export markets. In their economic

assessment of AF, Kaye-Blake and Zuccollo (2012) estimated that benefits of NZ$113 million over the four years 2008-11 represented a return of 30 times the NZ$3.2 million cost of the programme. In 2014, government funding was announced for a seven-year, Apple Futures follow-up.

LEP Toolkit, from a push to a pull product

Farm and environment plans have been used as national policy instruments to promote good soil practice in NZ since 1956 and by the late 1980's, were estimated to be in place on half of the country's farmed area (Manderson et al., 2007). Since then, a more piecemeal approach has prevailed as a combination of public sector reforms and the introduction of the Resource Management Act (1991) have shifted responsibility for the farmed environment from central to regional government.

In February 2004, severe storms[129] across NZ caused catastrophic flooding in the Manawatu Region; the vulnerability of farmed upland terrain, typically beef and sheep, to extreme weather events was highlighted and the potential consequences for down-stream communities all too vividly illustrated (Smith et al., 2011). To encourage improved environmental practice and to protect against the effects of future severe weather events, the local council, Horizons, initiated the Sustainable Land Use Initiative[130] and councils across NZ were prompted to pay increased attention to the environmental impacts of beef and sheep farming. The industry's representative body at the time, Meat and Wool NZ, recognised that a proactive response was needed if additional regulation was to be avoided.

Since the 1990's, work on Whole Farm Planning (WFP), integrating farm business management and environmental planning, formed a core component of Meat and Wool NZ's Monitor Farm activities. With the support of government funding, the

[129] Smith et al. (2012) reported that the Manawatu floods of 2004 came "suddenly and with little warning …with up to 280mm falling over 48 hours." (Page 89)

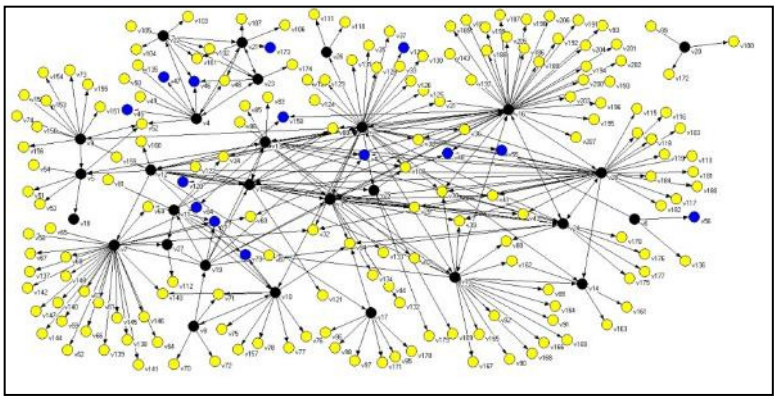
[130] Development of SLUI was led by Horizons Regional Council with the aim of better protecting vulnerable lowland communities from upstream erosion of high-country farmland. It was supported by a Technical and Governance Group of scientists and representatives of industry and government (see: https://www.beyondresults.co.nz/case-studies/slui/ accessed 08/05/2019)

WFP was revisited with a view to designing a user friendly Land and Environment Plan that was implemented on Monitor Farms in 2006/07 and made available by Meat and Wool NZ to farmers in the 2008/09 season, as Reid (2013) reported, however, it remained "absolutely under utilised by the organisation" (Page 135). The loss of the wool levy in 2010 and formation of Beef and Lamb NZ (B+L NZ) was accompanied by the release of a National Policy Statement that committed, among other things, to a more pro-active stance on the environment. To deliver on this commitment, B+L NZ turned to the LEP, and in 2012 it was relaunched in the Canterbury Region. It met with a less than enthusiastic reception from B+L NZ's Extension Workers, to the extent that one of them was seconded for a period of three months to refresh the resource. Later in the same year the B+L NZ LEP Toolkit was relaunched as a three tier programme offering: an entry level (Level 1), intermediate level (Level 2) and advanced level (Level 3). The three month secondment became a permanent position and a team of facilitators was trained to support a national programme of workshops. At the same time, with Regional Councils in NZ's South Island signalling increased expectations of farmers with respect to land and environment planning, farmers started proactively approaching B+L NZ with enquiries about the LEP Toolkit, prompting the observation that: "Over the course of about 3 months it stopped being a push product and became a pull product..." (B+LNZ, 1). There was early recognition of the need to dovetail with existing arrangements and, rather than championing the LEP Toolkit per se, B+L NZ promoted the wider principles of farm and environment planning, liaising closely with Regional Councils. In May 2018, the launch of B+L NZ's Environment Strategy[131] pledged support for the ongoing development of the LEP Toolkit with the aim of achieving "an active plan on every farm" by 2021 (Page 16) while continuing to recognise that 'plan' refers to a wide suite of tools, not just the LEP Toolkit.

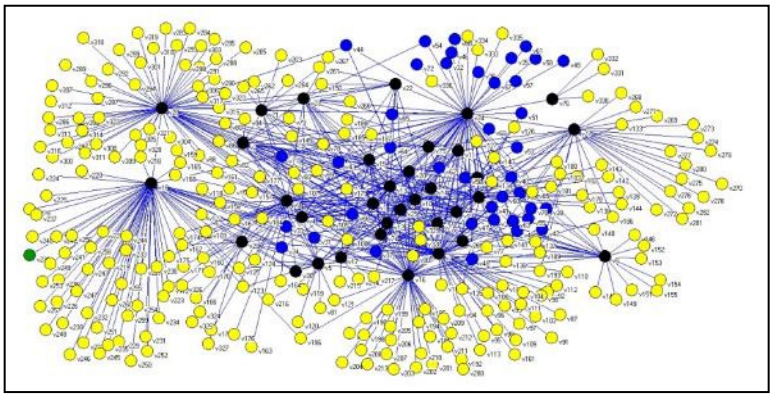
[131] See: https://beeflambnz.com/knowledge-hub/podcast/beef-lamb-new-zealand-environment-strategy

Appendix XV: Social Network Analysis

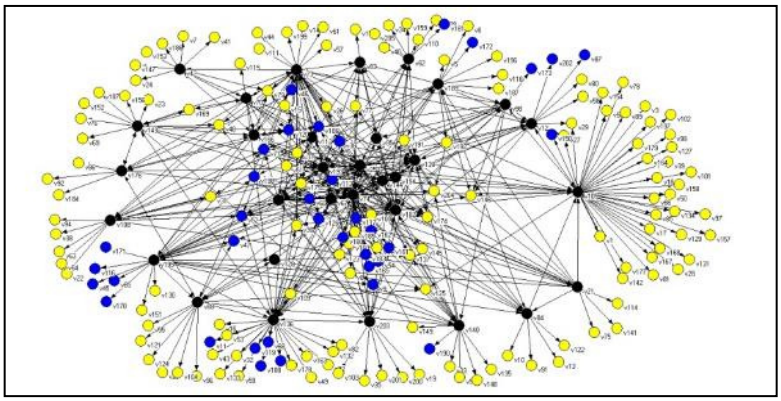
Source: Barbara King, University of Melbourne (2017)



2014



2015



2017

Key	Description	Number of nodes		
		2014	2015	2017
Black circle	PIP researchers	28	32	29
Blue circle	CfC members	14	42	36
Yellow circle	Other connections	165	262	140

Appendix XVI: Canterbury Earthquake

New Zealand lies at the intersection of the Pacific and Australian tectonic plates and, given the high level of seismic activity, primary school children are taught the basic 'drop, cover and hold-on' earthquake drill from an early age while tsunami-warning systems are a feature of coastal areas. In recent times, the 2010-11 series of earthquakes in the Canterbury region has had especially far-reaching impacts on the lives of those affected. Reflecting on these events, the wider environmental impacts and the early stages of the recovery process, Potter et al. (2015) describe how the series began with the Darfield earthquake on 4 September, 2010. Centred about 40km from the main city of Christchurch, it occurred in the early hours of the morning, injuring approximately 100 people and causing limited structural damage. A succession of aftershocks followed. One of these, on the afternoon of 22 February 2011, centred under the City itself, caused significant structural damage and led to 185 deaths. Large tracts of the urban landscape were transformed and the effects on the wider environment were no less dramatic as "liquefaction, lateral spread near waterways, land level changes, and numerous rock-falls and land-slides" (Page 8) were experienced. The fertile alluvial plains that make the Canterbury Plain such an important agricultural region extend below the City itself, leaving it especially "vulnerable to shaking and liquefaction" (Page 7) and an estimated 900,000 tonnes of liquefaction material had to be removed, silt was carried into waterways causing sedimentation and impacting on water quality, damage to the sewage infrastructure allowed untreated materials to enter drains and water-courses, some established springs dried-up and new ones appeared. Aquatic life was impacted, habitats destroyed and algae growth accelerated. There was damage to local forest and established pest and weed control programs had to be suspended. The land had risen in some areas and fallen elsewhere creating new flood risks for some and drought conditions for others. Rockfalls, landslips and slumps were all experienced to various extents. For NZ's farmers, there are the practical difficulties of preparing for, responding to and coping with the aftermath of extreme events and, arguably, consequences for how they perceive the relative impacts of their own day-to-day farming activities on the environment around them.

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