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Research paper

# Systemic problems affecting co-innovation in the New Zealand Agricultural Innovation System: Identification of blocking mechanisms and underlying institutional logics

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ABSTRACT

This study identifies systemic problems in the New Zealand Agricultural Innovation System (AIS) in relation to the AIS capacity to enact a co-innovation approach, in which all relevant actors in the agricultural sector contribute to combined technological, social and institutional change. Systemic problems are factors that negatively influence the direction and speed of co-innovation and impede the development and functioning of innovation systems. The contribution in the paper is twofold. Firstly, it combines both innovation system functions and systemic problems in an integrated analysis to asses an AIS at a country level, which has not been done previously in AIS literature. Secondly, it deepens the generic literature on structural-functional innovation systems analysis by looking at the interconnectedness between systemic problems and how these create core blocking mechanisms linked to the prevalent institutional logics (historically built-up and persistent structures and institutional arrangements) of the AIS. Results indicate that the existing New Zealand AIS has three main blocking mechanisms related to three institutional logics: (i) competitive science in silos, (ii) laissez faire innovation, and (iii) science centered innovation. These findings resemble weaknesses of AIS in other countries, and provide supportive evidence that co-innovation principles in many places have not yet been translated into agricultural innovation policies due to persistent and interlocked blocking mechanism and institutional logics. They point to the absence of effective systemic innovation policy instruments that pro-actively stimulate and support co-innovation. These instruments facilitate the counteracting of individual systemic problems and have a more transformative ambition; tackling the key institutional logics that hinder co-innovation, and hence supporting 'structural system innovation'.



## 1. Introduction

Agricultural products make up over half of New Zealand's merchandise export with the country being the world's largest exporter of dairy products, sheep meat, venison and kiwifruit [1]. To maintain this position the New Zealand Government has set the goal of doubling the value of New Zealand exports as a share of gross domestic product by 2020. One of the six key drivers needed to achieve this goal is increasing innovation in businesses [2]. Challenges related to innovation in the agricultural sectors include developing high value foods, and enhancing primary sector production and productivity, while maintaining and improving land and water quality [3]. In response to earlier identified shortcomings of using a science-driven, linear, technology transfer-oriented approach to innovation in New Zealand (i.e. lack of end-user involvement creates a low adoption of technologies, because these do not fit in farming systems and no effort is made to create an enabling context for adoption) [4–6], there is interest in bringing together relevant actors from the agricultural sector to increase research and development efforts in a coordinated and interactive fashion through a 'co-innovation' approach [7–9]. Under a co-innovation approach, all relevant actors in the agricultural sector (including farmers, growers, consultants, banks, agri-businesses, Government, NGOs and entrepreneurs), become

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co-developers of knowledge, champions of combined technological and institutional change and entrepreneurs experimenting with new business models [10], instead of mere recipients of technologies created elsewhere, which are subsequently adopted or rejected. However, a co-innovation approach has never been fully implemented in the New Zealand agricultural R&D sector, though experiments with interactive approaches have been done [11].

Making co-innovation work is often not easy, as it depends on the receptiveness of the Agricultural Innovation System (AIS). An AIS is defined as "a network of organisations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organisation into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge" ([12], p. vi–vii). Co-innovation is thus influenced by how the AIS is structurally composed in terms of the presence of actors, their interactions, the institutions that influence their behaviour, and the presence of supportive physical, financial and knowledge infrastructure and incentives for actors in the AIS to support co-innovation [13–15]). The structure of the AIS thus determines how so-called 'innovation system functions' necessary for combined technological and institutional change can be successfully realised as the collective outcome of co-innovation interaction among the actors [16–18]. Often systemic problems related to malfunctioning or absence of these structural elements [15], such as a lack of interactions between relevant actors, are present which influence AIS performance and the potential to enable co-innovation. Systemic problems (sometimes also referred to as systemic failures) are defined as factors that negatively influence the direction and speed of innovation processes and impede the development and functioning of innovation systems [15,19].

Therefore, it is important to diagnose such systemic problems that hinder innovation system functioning, and analyse how different systemic problems relate to each other. An innovation system diagnosis thus supports co-innovation, by drawing on diverse views and by bringing together diverse actors to (jointly) identify opportunities to deal with systemic problems [20,21].While the combined analysis of innovation system functions and structures was developed for diagnosing the pace and direction of innovation in the context of sustainability transition pathways around specific technologies, such as fuel cells and wind energy [17,22,83], it has become increasingly applied to also analyse sectoral innovation systems [23,24], such as agriculture ([25–30]; [21]), in order to assess 'systemic capacity to innovate' [31,32]. This paper aims to identify the perceived systemic problems in the New Zealand AIS that affect the ability of actors in the primary industries to co-innovate. It goes beyond previous research on the New Zealand AIS that has either focussed on particular industries within the agricultural sector (e.g. the dairy sector Morriss et al. [6]; [33]), or only focussing on specific components of the AIS (e.g. zooming in on the extension system within the AIS [34,35]).

Furthermore, our study extends the current research into systemic problems to co-innovation in two ways, aiming to contribute to theory development in AIS studies and innovation system studies more broadly. Firstly, in this paper we analyse the New Zealand AIS using a comprehensive framework developed by Wieczorek and Hekkert [15] based on a combined structural-functional analysis of innovation systems. This framework integrates structural and functional streams of innovation system enquiry to enable analysis of the effectiveness of the important functions (or processes) that support co-innovation, along with the presence and quality of the structural components that are needed for these functions to be effective [15,16,18]. Most AIS diagnostic studies [25–27,30] have only applied a structural analysis, not looking at innovation system functions. Lamprinopoulou et al. [36] did apply the combined structural-functional to national AIS, however these authors still put emphasis on systemic problems and focus less on extensive analysis of functions, and while Kebebe et al. [37] applied such a full combined functional and structural analysis, they only focused on the dairy sector of Ethiopia and not the overall national Ethiopian AIS. Our analysis thus aims to go further than previous AIS studies, providing a systemic analysis of the whole New Zealand AIS by linking the identified systemic problems to particular innovation system functions. It also aims to show what the shared underlying issues are that influence the performance of several AIS functions in New Zealand, and providing suggestions for systemic instruments that enhance the coordinated performance among functions. This also enlarges knowledge on what are common systemic problems in AIS across different countries, by mirroring our findings to results from systemic analysis of other AIS.

Secondly, the paper aims to shed more light on whether certain combinations of systemic problems are linked to each other and cause certain 'lock-ins' that prevent the execution of innovation system functions towards co-innovation. Previous research on AIS [14,38,39] has shown that innovation systems have path-dependencies reflecting certain 'institutional logics' [40], defined as "the socially constructed, historical patterns of material practices, assumptions, values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality" ([41], p. 804). Such institutional logics may hinder working in a co-innovation fashion and changing them would thus require 'system innovation' in the innovation system [38]. While structural-functional analysis has been adequate in detecting separate systemic problems, several innovation system scholars have argued that there is a need for unravelling the deeper patterns behind them to define 'blocking mechanisms' that are sets of systemic problems between which there is feedback [20,24,42] and how these may relate to certain institutional logics.

The paper is organised as follows: section two further describes and explains innovation system functions and structural elements in the context of AIS to arrive at the framework used to provide a systemic analysis of the New Zealand AIS, followed in section three by a description of the methods used to implement this theoretical framework for analysis. The fourth section presents results organized under each of seven functions that form part of our theoretical framework, and section five provides a deeper analysis of how the main systemic problems combined to form blocking mechanisms, along with the underlying institutional logics. We conclude the paper with a discussion of the main systemic problems and blocking mechanisms hampering co- innovation in the New Zealand AIS, as well as implications for innovation practice, policy and theory.

## 2. Analytical framework: combined functional-structural analysis of AIS

Next we describe the functions and structures as defined by Wieczorek and Hekkert [15] and provide for each function a brief illustration of how these have been described in the agricultural innovation systems literature (albeit not as a coherent set in a single publication). We follow here the order given to functions in Hekkert et al. [18], but it should be noted that the order is rather arbitrary as the same authors state that different 'virtuous cycles' of mutually reinforcing functions may exist in well-functioning innovation systems, as a result of different sequences and combinations of functions.

*1) Entrepreneurial activities* turn the potential of new knowledge, networks and markets into concrete actions to realise value [17], as has also been noted for agricultural innovation. Several authors in agricultural innovation studies [43,44] note such entrepreneurial

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activities as lobbying for funding, or trying to change institutional structures.

*2) Knowledge development* is fundamental to innovation, and the ability to develop new knowledge through for example formal research, has been noted as key in AIS [45]. Knowledge development does, however, not only take place in formal research institutes, but may also be done by farmers or agri-business [46].

*3) Knowledge diffusion* through networks is especially important to further develop and adapt knowledge and innovations, and scale these up (increasing support by policies and markets for the innovation) and scale these out (increasing number of users), i.e. to further support the co-evolution of social, technological, institutional and market changes [47]. The AIS literature emphasizes the importance of platforms and networks where such interactive learning occurs [48].

*4) Guidance of the search* is about creating a vision for the innovation system, to orient other functions such as entrepreneurial activities and knowledge development. This can be done by, for example, formulating so-called 'innovation agendas' to create a vision and set priorities for entire (sub-)sectors at a country or regional level, a process also done often within AIS [49], but also in design exercises [50].

*5) Market formation* is about the creation of markets for novel products themselves, or existing products produced in different ways and with new attributes (e.g. eggs produced under better animal welfare conditions). Creating markets is often challenging due to a lack of awareness by consumers or resistance from incumbent players [51,52], and there is a key link with functions such as resource mobilisation to obtain, for example, risk capital [10].

*6) Resource mobilisation* involves the basic financial and human capital necessary to undertake all activities in the AIS, such as capital for the funding of basic research and subsidies for the further development of technologies and innovative market concepts, and the ability to find and attract competent advisors in innovation trajectories [53,54].

*7) Creation of legitimacy* and counteracting resistance to change are often needed as existing production, trade and consumption systems are often resistant to change as innovation threatens the status quo, as has also been noted in the case of AIS [44]. Advocacy coalitions can be a catalyst for this by influencing the innovation agenda, lobbying for resources and favourable institutions.

As indicated in the Introduction, the execution of these seven functions is dependent on four structural components of the innovation system: actors, institutions, interactions, and infrastructure [15].

*Actors* are individuals and organisations. In innovation systems actors tend to be delineated based on their role in economic activity, e.g. Government, NGO, civil society, rather than on their role in the innovation process. This reflects the systemic nature of innovation where the functions are the product of multiple actor interactions, rather than the actions of independent actors.

*Institutions* are the shared habits and routines used by actors in repetitive situations (soft institutions) organised by rules, norms and strategies (hard institutions). Literature on AIS has noted that institutions for example influence the inclination for joint knowledge development and sharing [8], but they also shape intellectual property rights law that provides protection for innovators [9].

*Interactions* are the dynamic relationships among actors from individual contacts to networks of actors. Several AIS studies highlight the importance of multiple interactions and the role of intermediaries in connecting actors in AIS [48].

*Infrastructure* are of three types, which have also been emphasized in AIS studies [55]: (i) physical infrastructure, such as existing technology, roads, buildings, telecommunication networks, bridges, harbours; (ii) knowledge infrastructure, such as for example research and extension, and (iii) financial infrastructure, such as subsidies, financial programmes and grants.

As indicated in the Introduction, Wieczorek and Hekkert [15] conceptualise systemic problems as a reason for weak or absent innovation system functions, arising from limitations in the above mentioned structural components of the AIS: (i) the presence or capabilities of the actors, (ii) the presence or quality of the institutional set up, (iii) the presence or quality of the interactions, and (iv) the presence or quality of the infrastructure. As Weber and Rohracher [56] argue, such systemic problems may negatively affect the capacity of innovation systems to organise co-innovation in terms of supporting directionality (e.g. how collective priorities are set), policy coordination (e.g. connecting national and sectoral innovation policies), demand articulation (e.g. engaging users in setting research agendas) and reflexivity (ability of the system to constantly monitor progress against its goals). For example, hard institutions (regulations) or soft institutions (established practices) incentivising research organizations to undertake activities that support uptake of knowledge, practices or technologies may be absent or weak. Alternatively, the interaction between research organizations and industry may be weak due to differences in organizational objectives. The absence of these institutions and interactions in the AIS could contribute to the knowledge diffusion function being weak, and problems in terms of organising directionality and demand articulation affect the guidance of the search function.

A diagnosis of systemic problems may lead to identifying where there is a need for interventions to optimize AIS functioning, and which AIS function needs particular attention. To enhance support for innovation processes a wide variety of innovation policy instruments exist such as research funding, patent regulations, industry standards inducing innovation [57], but recent literature has indicated these need to be complemented with so-called 'systemic instruments'. These are oriented towards stimulating co-innovation and orchestrate adequate combinations of individual innovation policy instruments [15,58], thus overcoming directionality, demand articulation, policy coordination and reflexivity problems. This is achieved by means of joint foresight and vision building, articulating demand and supply for different kinds of innovation support and ensuring a match, and creating spaces for multi-stakeholder learning and experimentation. Systemic instruments have also become more prevalent in AIS [53,54], though AIS policy to employ systemic instruments is not always explicit, coherent and consistent [59].

## 3. Methods

In line with most diagnostic AIS work [25,36] our study was based on semi-structured interviews, complemented with a secondary literature review as is common in these types of diagnostic studies [22,36]. Semi-structured interviews were used to allow flexibility for both the interviewer to focus more on interesting comments and to explore these, and for the interviewee to talk about topics of interest, thus creating a more in-depth interview [60]. This corresponds with the aim of the interviews, which was to obtain an overview of the current status of the New Zealand AIS as it is perceived by actors in the system. The interview questions were designed to cover three aspects of the analytical framework: (i) functions, (ii) structural components that contribute to realising each function, and (iii) the presence/absence or capability/quality of structural components. Thirty individuals, representing Government (5); industry, such as processors (2), industry good bodies (10), and technology users (farmers and growers) (5), and research (8) in the New Zealand pastoral, forestry, cropping and horticultural sectors were interviewed. These individuals were from

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organizations within the New Zealand agricultural sector that were a-priori assumed to play a key and catalysing role in shaping one or more of the seven functions. Five were assumed to play a role in shaping entrepreneurial activities, 14 in knowledge development, 16 in knowledge diffusion, 13 in guidance of the search, six in market formation, 14 in resource mobilisation, and five in creation of legitimacy. Three interviewers separately undertook the interviews, with 14 of the interviews being undertaken by two interviewers: one leading the interview with the other following up themes emerging during the interview. Each interview took between one and two hours. The interviews were recorded and transcribed, provided to interviewees that had requested a copy of the transcript for review, and then coded in Nvivo v. 10 [61] by the interviewers using the theoretical framework as the coding structure. The interviewers jointly conducted thematic analysis of the coded interviews [62] to identify systemic problems by exploring recurring themes across interviewee sectors and organization types and exploring links among problems. A follow-up workshop was conducted with the interviewees to validate and deepen the initial findings.

A critical reflection on the methods used is that while interviews and secondary literature analysis are a common approach for this type of study and triangulation is used to prevent bias, some subjectivity may be introduced as no use was made (mainly because of access problems) of more organizational internal documents such as organization strategic documents and Annual Reports, meeting minutes, requests for proposals, project proposals and contracts.

## 4. Results

Table 1 presents results of the coupled functional-structural analysis for identifying systemic problems in the New Zealand AIS. This analysis is carried out for all of the functions necessary for enhanced innovation in order to identify the functions that are perceived as weak, as well as the systemic problems contributing to this weakness.

The systemic problems identified from the coupled functional-structural analysis in Table 1 are described in more detail and illustrated with relevant quotes, by function, below. The suggested systemic instruments (derived from Smits and Kuhlmann [58] and Wieczorek and Hekkert [15]), aiming to enhance coordination among the different functions and to stimulate co-innovation, through for example improved institutional incentives, actor presence and capability, and interactions, will be discussed in section 6.2.

### 4.1. Lack of actors undertaking entrepreneurial activities

#### 4.1.1. Limited firms undertaking entrepreneurial activities

Those interviewed across industry, Government and research organizations referred to commercial firms (including farmers and growers) as having the primary role of undertaking entrepreneurial activities in the New Zealand AIS in terms of pro-actively championing innovation. Participants, however, perceived there to be a limited number of firms undertaking this activity. This was associated with an actor capability problem, namely the majority of businesses in the New Zealand agricultural sectors are small to medium enterprises (SMEs), defined as businesses with less than 20 employees [63], which lack sufficient financial and human resources required to undertake entrepreneurial activities, as also noted by Jaffe [64] (Figure 1).

Interviewees from industry and research organizations identified conservatism and introversion as a soft institutional problem hindering the entrepreneurial activities of firms, as well as research organizations. According to these interviewees, this leads to risk aversion by research organizations and firms, and the failure to explore new technologies and markets. A research organization interviewee referred to the high-level of accountability associated with using public funding as a hard institutional problem that hampers the exploration of higher-risk commercial opportunities by firms and research organizations.

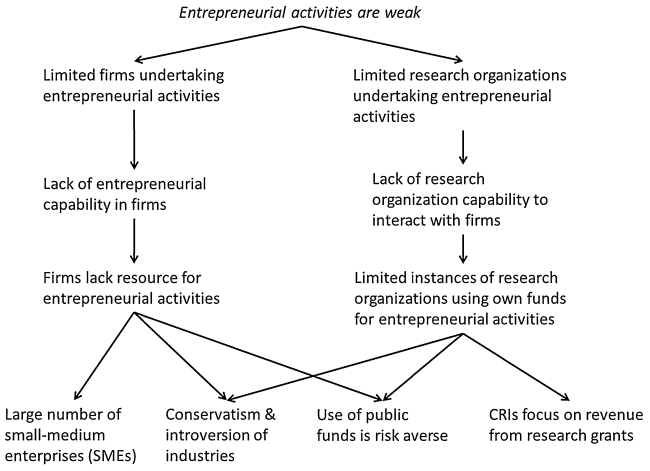


**Figure 1.** Underlying causes of systemic problems hindering entrepreneurial activities. The figure is read from the top to the bottom with each arrow representing a "because", e.g. entrepreneurial activities are weak "because" there are limited firms undertaking entrepreneurial activities.

An example of the relatively lower allocation of public funding to entrepreneurial activities was provided by a Government interviewee, who suggested that public funding of the pre-commercialisation of ideas, relative to the allocation of public funding to knowledge development, was approximately 1 to 100. Overall New Zealand public research expenditure is relatively high with a 52 per cent of total expenditure in 2010, compared with an OECD average of 32 per cent [64], hence support to entrepreneurs is much lower. The lower allocation of public funds to functions such as entrepreneurial activities reflects the perception of these functions as being the role of businesses, to be self-financed by these.

#### 4.1.2. Limited research organizations undertaking entrepreneurial activities

Despite the lack of firms undertaking entrepreneurial activities, participants from Government agencies referred to Crown Research Institutes (CRIs) as being mandated to undertake entrepreneurial activities. This contrasted with those interviewed from research organizations and industry who did not perceive CRIs, or other research organizations, to undertake this role. This was attributed to a lack of capability within research organizations to understand, or have experience in, both industry and business cultures. This was particularly mentioned by industry participants, who prized researchers who understood their business culture and the importance of business confidentiality, and were therefore trusted to participate in aspects of their organization's innovation activities. The weak interaction between research organizations and industry is exacerbated by a lack of capability within firms, specifically SMEs, to be able to interpret science and translate this into action. This was reflected in comments by a research organization participant who referred to large industry organizations having experts who were viewed as 'peers', while smaller industry organizations were described as lacking these experts.

Interviewees from industry and research organizations described the need for CRIs to attract research grants, which are a significant and accessible source of revenue, as an institutional problem contributing to a lack of entrepreneurial capability

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**Table 1**
Systemic problems based on a functional-structural analysis of the New Zealand Agricultural Innovation System affected.

| System function | Structural element | Problem type | Description | Suggested systemic instrument |
|---|---|---|---|---|
| Entrepreneurial activities | Actors | Presence | Limited instances of key actors undertaking entrepreneurial activities | New forms of public-private partnership |
| | | Capability | Lack of entrepreneurial capability in firms and research organizations | Pilot projects |
| | | | Large number of SMEs, which lack financial and human resources to undertake entrepreneurial activities | Venture capital<br>Risk capital |
| | Interactions | Quality | Lack of individuals in research organizations with capability to interact with firms in entrepreneurial activities | Interactive stakeholder involvement<br>Clusters |
| | Institutional | Presence | Public funding of innovation perceived as being risk averse in setting technology development priorities | Venture capital<br>Risk capital |
| | | | Limited instances of research organizations using own funding to partner with entrepreneurial firms | Obligations<br>Regulations |
| | | Quality | Research organizations, such as CRIs, mandated by Government to undertake entrepreneurial activities, but rarely do | Regulations<br>Obligations<br>Limits |
| | | | Conservatism and introversion of some industry organizations | Foresighting<br>Scenario development |
| Knowledge development | Actors | Presence | Government is not viewed by research organizations and industry as a participant in knowledge development | Clusters<br>Policy labs |
| | | Capability | Absence of science graduates with a systems perspective and problem focus | Education and training programmes |
| | Interactions | Presence | Absence of interactions for joint development of knowledge | Cooperative research programmes |
| | Institutional | Quality | Innovation management is linear, planned and milestone focused locking in innovation pathways | Evaluation practices<br>Cooperative research programmes |
| | Infrastructure | Presence | Lack of time and resources to support interactions in knowledge development | Public research labs |
| | | Quality | Intermediary organizations that act as gatekeepers between researchers and users | Consultancy services |
| Knowledge | Actors | Presence | Limited instances of individuals that can work across industry, Government and research cultures | Clusters<br>Interactive stakeholder involvement |
| | | Capability | Limited capability within industry to be able to interpret science | Pilot projects<br>Technology platforms |
| | Interactions | Presence | Limited interaction between research organizations and industry creating a mismatch between technology supply and demand | Cooperative research programmes<br>Collaboration and mobility schemes |
| | | Quality | Science is perceived by industry and Government as not reaching end users | Venture capital<br>Risk capital |
| | Institutional | Presence | CRI's institutional incentives to remain economically viable leads to a focus on revenue generation from research grants | Regulations<br>Principles<br>Agreements |
| | | Quality | Industry culture of "near enough is good enough" conflicts with science culture of providing robust results | Agreements<br>Public-private partnerships |
| | Infrastructure | Presence | Limited infrastructure to ensure industry has access to a skilled and technically competent workforce | Loans, funds<br>Public research labs |
| | | Quality | Limited financial and human resources in SMEs to be able to support science-industry interactions | Knowledge management techniques |
| Guidance of the search | Actors | Presence | Limited instances of research organizations participating in industry guidance of the search activities | Clusters<br>Thematic meetings |
| | | | Limited instances of individuals that can work across industry, Government and research cultures | |
| | | Capability | Large number of SMEs that lack resource to participate in guidance of the search | Articulation discourse<br>Foresighting |
| | Interactions | Quality | Limited instances of firms connecting to producers and customers | Bridging instruments |
| | | | Poor vertical and horizontal integration leads to heterogeneous innovation needs among actors | Consensus development conferences |
| | Institutional | Presence | Government role in guidance of the search perceived by industry as being via regulations and national innovation goals, rather than as an active participant | Awareness building measures |
| | Infrastructure | Presence | Absence of infrastructure to support relationships in guidance of the search | Subsidies |

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**Table 1** (*Continued*)

| System function | Structural element | Problem type | Description | Suggested systemic instrument |
|---|---|---|---|---|
| Market formation | Actors | Presence | Limited instances of key actors undertaking market formation | Public-private partnerships |
| | Interactions | Presence | Limited instances of firms interacting with new markets or customers | Bridging instruments<br>Collaboration schemes |
| | Institutional | Presence | Culture within research organizations that market formation is the role of industry | Awareness building measures |
| | | Quality | Conservatism within some businesses, leading to sticking to same markets | Taxes, subsidies |
| | | | New Zealand's market economy creates culture of Government not having a role in market formation | Regulations |
| | Infrastructure | Presence | SMEs lack financial and human resources to undertake market formation | Loans, subsidies |
| Resource mobilization | Actors | Presence | Large number of intermediary organizations perceived by research organization as capturing resource for administration, rather than innovation | Clusters |
| | | Capability | Lack of strategic leadership in co-ordinating resource mobilization | Articulation discourse |
| | | | Large number of SMEs, which have limited resources (financial and capability) to undertake or participate in interactions | Innovation platforms<br>Pilot projects |
| | Interactions | Presence | Interactions among actors tend to be focused on resource mobilization, rather than on other functions | Cooperative research programmes<br>Collaboration schemes |
| | Institutional | Quality | Competition among actors for allocation of resources to own innovation agendas | Regulations<br>Agreements |
| | Infrastructure | Quality | High number of research grants with low funding attributed per project | Clusters |
| Creation of legitimacy | Actors | Presence | Limited instances of industry undertaking creation of legitimacy, though perceived as having this role | Public-private partnerships |
| | | Quality | Competition between industry and Government in creation of legitimacy | Articulation discourse<br>Scenario development<br>Policy labs |

in research organizations, thus hampering the effectiveness of CRIs in undertaking entrepreneurial activities. Industry and research participants did not perceive revenue generation from commercialisation to be a priority for research organizations:

"Well their first priority is to write a funding contract to the ministry because that's the most likely chance of actually getting some money. Then they'll . . . think, 'Oh, I might talk to some businesses see if I can drum up some contract research.' Cause it's easier to get more immediate results. Then it's time to do commercialisation [which] is a long-term thing. With those other things you can get returns over a few months, with commercialisation you have to sink money into it over [a couple of years], it's a long-term investment." – Research organisation manager 1

### 4.2. Knowledge development is not supporting desired change

#### 4.2.1. Knowledge developed in silos

Industry body participants highlighted that their research problems span research boundaries, and that addressing these complex problems is hampered by weak interactions among research organizations. Interactions among research disciplines are hampered by several soft and hard institutional problems identified by interviewees. These include an historic research culture of working in disciplinary silos, which prevents the joint development of new knowledge across disciplinary boundaries. Other institutional problems were an absence of science graduates with a systems perspective, the disciplinary focus of New Zealand PhDs, the reductionist approach of science, and a focus by scientists on the technical robustness of their science before sharing knowledge more widely (Figure 2).

#### 4.2.2. Knowledge is not integrated

Interviewees referred to the importance of interactions among actors as necessary for effective knowledge development, however a number of systemic problems were perceived as impeding the interaction among research organizations, industry and Government in knowledge development (as well as knowledge diffusion).

Firstly there is a perception within research organizations and industry that Government is not needed as a participant in knowledge development. The absence of Government as an actor in knowledge development is influenced by industry perceptions of Government as a regulator of, and barrier to, innovation. This view of Government is exacerbated by the perception within industry and research organizations that many individuals within Government agencies lack an understanding of the sectors they are working with.

An infrastructural problem hampering joint development of knowledge across industry, Government and research organizations is the lack of time and resources to support interactions in knowledge development (as well as in other functions for enabling innovation). This is captured in this quote:

". . .there's often a lack of formal interactions between say some of the rural professionals and CRIs. . . . A lot of our businesses are . . . under five FTEs [full time equivalents] . . . and they don't have the resources necessary to maintain that sort of relationship. So if you're busy just making a living . . . unless there's an urgent need or a very direct and immediate benefit, those interactions don't occur." – Government agency interviewee 1

Industry and research organization representatives also identified the integration of knowledge across industry, Government and research organizations as being hindered by a hard institutional problem, i.e. funding organizations' use of prescriptive, linear and milestone focused innovation management. This locks in particular sources of knowledge, represented by the research disciplines identified in the innovation programme, and innovation pathways, represented by pre-set programme milestones. Interviewees identified a number of soft institutional problems as contributing to prescriptive linear innovation management, including

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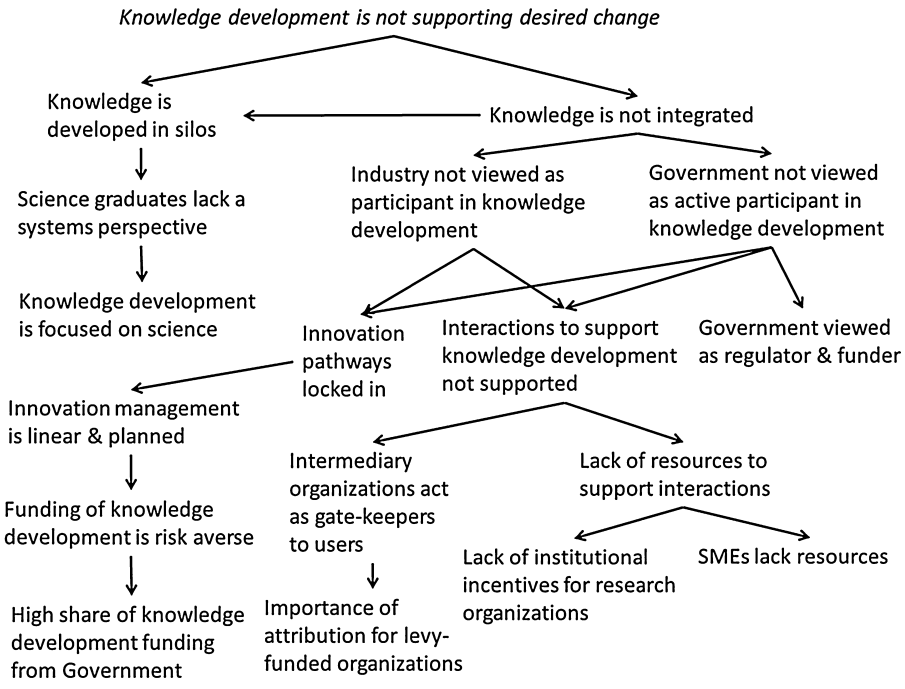


**Figure 2.** Underlying causes of systemic problems hindering knowledge development from supporting impact.

conservatism and risk aversion due to the large share of innovation funding being from the Government. These soft institutional problems were described as leading to a desire to closely manage innovation processes, and SMEs tending to view innovation as a cost on their accounts that needs to be controlled.

Industry body representatives mentioned that their organizations facilitate interactions among farmers or growers, and across other actors in the value chain. Interviewees from research organizations, however, perceived some of these industry bodies to operate as gate keepers, controlling access to users, as reflected in this quote:

"...it's an idea that they know best because it's their sector and what do you know? So, I guess, that's also a patch protection but it's also ... an element of we know best, if you have something for us give it to us and we'll have a look at it for you if you like." – Research organisation manager 2

According to research organizations this "patch protection" was driven by a view within industry bodies that extension and technology transfer are their roles and that these organizations are protective of this role. Indeed industry bodies confirmed that they are protective of this role. The reason for this is the importance of attribution of innovation outcomes to farmer and grower levy-funded organizations as a means of demonstrating value to their boards and funders. One interviewee from an industry body also emphasised the institutional knowledge that has accumulated in their organisation over many years of working with farmers and growers as another reason for being protective of their extension role.

### 4.3. Knowledge diffusion is weak

#### 4.3.1. Limited industry-research organisation interaction in knowledge diffusion

There was a perception by industry and Government interviewees that research organizations had limited interaction with users so that science does not reach end users. Results of a survey of technology transfer services [65] reflect similar findings on limited coordination in the New Zealand AIS between research organizations and rural advisors. Moreover the interviewees thought that the lack of interaction between research organizations and users is also creating a mismatch between supply from research organizations and demand by users (Figure 3). This has created the perception within industry that the knowledge needed to address sector problems already exists within research organizations and that limited resources need to be reallocated from knowledge development to knowledge diffusion. According to industry participants the challenge is now to create access to existing knowledge in research organizations and package it for deployment.

Interviewees identified the CRIs' focus on revenue generation from research grants as a hard institutional problem that impedes effective interaction among Government, industry and research organizations. This contributed to a culture of researchers as "hunters and gatherers", resulting in incomplete innovation processes because researchers moved on to pursuing the next research grant. Therefore, the ability to attract research grants is viewed as

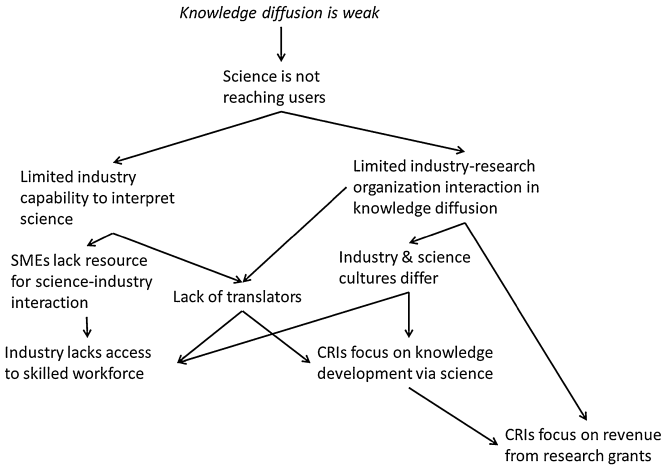


**Figure 3.** Underlying causes of systemic problems hindering knowledge diffusion.

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a measure of science quality, and leads to a focus on internal capability in knowledge development (at the expense of capabilities in knowledge diffusion and entrepreneurial activities) because funding mechanisms focus on academic criteria. This is reflected in this quote:

"...so often a focus is on generating new knowledge but also attracting funding, which means at times that may get overemphasised ... funding may dry up before that innovation process is finished. And so there's a challenge, if you like, for all of us about how do you continue that innovation process when you're, when the CRI drip funding may have stopped?" – Government agency interviewee 1

Research organizations were also described as mainly focusing on knowledge development, instead of knowledge diffusion, because institutional drivers for revenue generation created a focus on research grants, which are seen as a lower risk source of revenue than technology commercialisation and market development.

#### 4.3.2. Limited industry capability to interpret science

Those interviewed from both research organizations and industry highlighted a key systemic problem: the lack of individuals (either in research or industry) with the ability to operate as translators between actors, thus impeding interactions among researcher, industry and users in knowledge diffusion. The following factors were identified as contributing to a lack of translators: the challenge of attracting people to agricultural degrees; banks employing the good agricultural students; high turnover of people in translator-type roles, such as extension, because these roles are commonly seen as stepping stones to other positions; and a lack of time to develop trust between translators and farmers or growers. A related systemic problem influencing the effectiveness of the interaction among researchers, industry and farmers or growers is a lack of capability and resources within firms, specifically SMEs, to be able to interact with and interpret science.

A soft institutional problem impeding interactions among research organizations, industry and farmers or growers was different cultures of knowledge development in industry and science. Industry was described as having a culture of timely provision of solutions where "near enough is good enough", while science was described as seeking to deliver a robust and complete solution.

### 4.4. Guidance of the search is hindered by competing innovation agendas

#### 4.4.1. Research organisations not part of guidance of the search

Representatives from industry and industry bodies perceived the key interactions for guidance of the search to be among industry participants along the value chain. Only three industry participants mentioned that research organizations play a role in guidance of the search (Figure 4). One of them said that research organizations improved the effectiveness of guidance of the search by being able to think longer term and providing useful input to what is technically feasible.

According to interviewees from research organizations, their organizations need individuals to invest significant time with industry bodies and end users to bring back knowledge of industry innovation agendas. However, this was hampered by limited opportunities to interact with industry when setting sector strategy. This was described by research organizations as due to the requirement to work with multiple industries and organizations with competing innovation agendas. This is reflected in the following quote:

"... we're not in the body of the tent. We're sitting there and we'll have conversations with them, but [person X's] been waiting eighteen months to do some ... stuff with [industry Y]. ... but again it's, where's the shared goal? [Research organization] is not

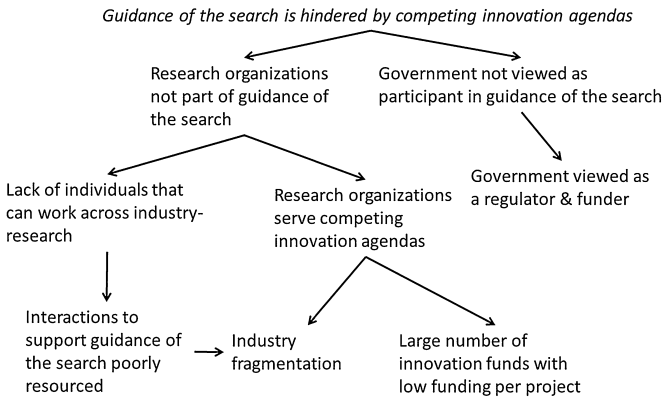


**Figure 4.** Underlying causes of systemic problems hindering guidance of the search.

all about [industry Y] so we often get, "Well you're distracted by other things." And we'll say, "Well yeah, but it's 'cause we're not the [industry Y] organization, we're another organization." – Research organisation manager 3

Vertically and horizontally fragmented industry structures were described by many participants as hampering effective interactions in guidance of the search. Vertical fragmentation refers to different parts of the value chain being in separate ownership. Horizontal fragmentation refers to industries characterised by a large number of separate owners. In these fragmented sectors interviewees referred to multiple actors with different goals seeking to influence guidance of the search to achieve their particular innovation agendas. Such limited industry-research coordination of innovation agendas and activities have previously been highlighted as a systemic problem in the New Zealand AIS [6,33,35,64,65].

### 4.5. Lack of actors undertaking market formation

#### 4.5.1. Few firms interact with markets

Commercial businesses were referred to as having the role of market formation in the New Zealand AIS, in conjunction with undertaking entrepreneurial activities. Participants, however, perceived there to be a lack of firms undertaking market formation in the New Zealand AIS (Figure 5). This was attributed to conservatism within some businesses, leading them to stick to traditional markets, rather than exploring opportunities in new markets:

"I think most of those companies are pretty well attuned to their own markets ... I think what's missing though, is ... looking beyond current customers and today's needs... partly because they haven't been looking ahead and been innovative and seeing the writing on the wall." – Research organisation manager 4

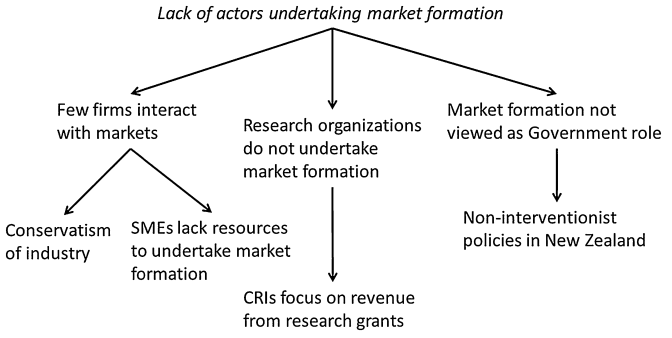


**Figure 5.** Underlying causes of systemic problems hindering market formation.

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Industry participants themselves mentioned another actor capability problem that hinders firms undertaking market formation; the large share of businesses in the New Zealand agricultural sectors are SMEs, which lack financial and human resources to undertake market formation.

#### 4.5.2. Research organizations do not undertake market formation

However, participants from Government agencies referred to CRIs as undertaking market formation, as well as entrepreneurial activities. This contrasted with those interviewed from research organizations who did not perceive market formation as their role. This appears to be due to institutional incentives for CRIs to focus on revenue generation from research grants, rather than the perceived higher risks of revenue from commercialisation, which was also described as hindering entrepreneurial activities by research organizations.

#### 4.5.3. Market formation not viewed as a Government role

A soft institutional reason for Government not undertaking market formation is the view by both industry and research organizations that this is not the role of Government, as captured in this quote; "...Government ... really takes a back seat ... with our purest, non-intervention policy, where Government really steps back and lets things sort themselves out." – Research organisation manager 4.

### 4.6. Resource mobilization is fragmented

#### 4.6.1. Competition for resources to support individual innovation agendas

In the New Zealand AIS the innovation agendas, set through guidance of the search, influence the allocation of financial, physical and human resources to innovation programmes and functions. This link between resource mobilization and guidance of the search is captured in:

"...mostly people think about how do you divide up the current pie differently so it's about changing shares versus, well how do you make a pie that's twice as big? And this is the paradox, to me is that we've got problems this big but most of them are focused on, and all of them converging in one little spot." – Research organisation manager 5

The competition for resources to support different innovation agendas was attributed to an infrastructure problem: fragmentation of innovation funding (Figure 6). This was described as arising from the variety of mechanisms used by Government and industry bodies to fund different innovation activities and agendas, the frequent changes in Government mechanisms for funding innovation, and the relatively small disbursements from these funds. This results in funding being applied to innovations that address sub-components of larger and more complex problems, with these sub-components not necessarily fitting together to effectively address these problems. Further hindering integration of these sub-components is a lack of financial infrastructure to support interactions among actors in the AIS, especially in guidance of the search and knowledge diffusion.

Industry, Government and research organization interviewees described fragmented innovation funding leading to competition among industries and research organizations for funding (and other resources) to support different innovation agendas, which was also earlier noted by Hartwich and Negro [33] and McEntee [66]. This competition for resource mobilization to support different innovation agendas was identified by industry, Government and research organizations as being due to three systemic problems. The first is a lack of actors that could provide strategic leadership in their respective industries, which hinders both effective guidance of the search and resource mobilization. Strategic leadership would, according to a number of interviewees, include: the ability to take a systemic view, interaction with multiple organizations, an understanding of each of their individual circumstances, and an identification of their own organization's role in achieving a wider strategy. The need for strategic leadership in the New Zealand AIS had earlier been identified by Morriss et al. [6] as important within the New Zealand dairy industry for developing and supporting a shared vision for industry. The second systemic problem is a strong institutional problem arising from the large number of intermediary organizations that have been formed historically to allocate combined public and industry research funding to research topics set by industry. The third systemic problem is the vertically and horizontally fragmented industry structures, which contribute to competition for resources to support competing innovation agendas.

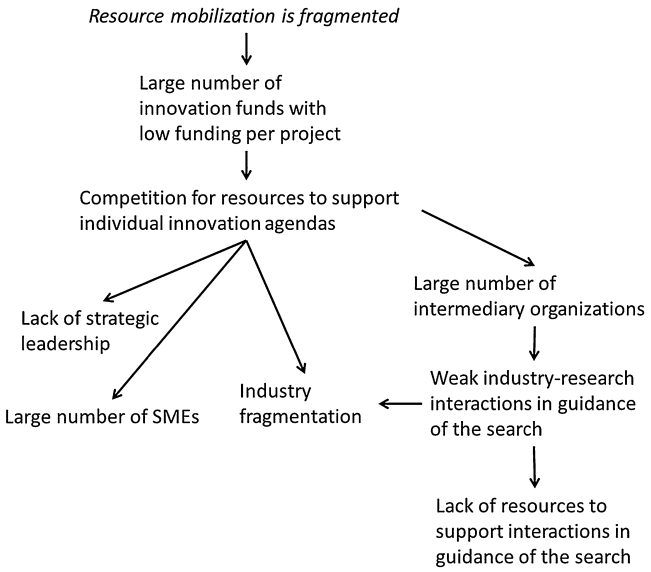


**Figure 6.** Underlying causes of systemic problems hindering resource mobilization.

### 4.7. Systemic problems in creation of legitimacy

Creation of legitimacy as part of the innovation process was referred to by few interviewees. When interviewees did refer to this function it was viewed as being related to entrepreneurial activities and market formation. Therefore, creation of legitimacy was perceived as being the role of industry. A research organization interviewee identified one systemic problem hindering creation of legitimacy as being competition between industry and Government. The interviewee described the problem occurring in setting priorities for allocating public research funding when there was a conflict between industry goals and Government perceptions of the extent to which achieving these industry goals will contribute to national goals.

## 5. Analysis: Blocking mechanisms for co-innovation in the NZ AIS

The coupled structural-functional analysis of the New Zealand AIS has facilitated a systemic study of the functioning of the AIS, as well as diagnosing the presence and capability of actors, interactions, institutions and infrastructure to deliver these functions to support co-innovation practices. From the systemic problems perceived by interviewees, which were summarised in Table 1 and unravelled in Figures 1 to 6, there seem to be a number of shared underlying issues that combine to influence the performance of several AIS functions in New Zealand (summarized in Figure 7).

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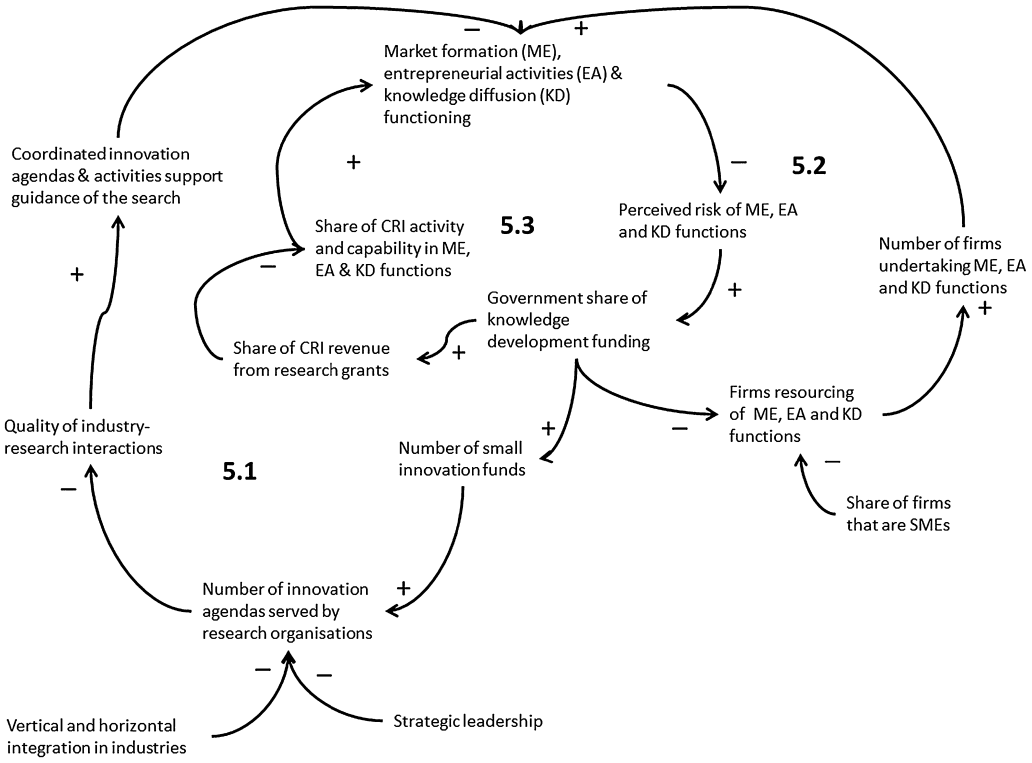


**Figure 7.** Causal loop diagram of connections among underlying causes of systemic problems hindering effective functioning of the New Zealand Agricultural Innovation System. + or – on the arrow shows if the influence from one variable to the next is in the same (+) or opposite (-) direction, e.g. when the share of firms that are SMEs increases then firm's resourcing of functions decreases (-) and when firm's resourcing of functions decreases the number of firms undertaking the functions decreases (+).

Hence some key 'blocking mechanisms' [24,42] can be considered, which also connect to 'institutional logics' that are deeply anchored in the specific historical and institutional conditions of the New Zealand AIS.

Considering the connections among the underlying issues in a causal loop diagram [67] shows the overall 'technology transfer logic', which is very persistent in New Zealand (resembling observations in other countries [14,68]), is represented in three core blocking mechanisms connected to more specific institutional logics within the overall New Zealand AIS. As Figure 7 shows this has created three connected clusters of systemic problems that form blocking mechanisms in the New Zealand AIS: (i) competition for resources for individual innovation agendas and activities, (ii) insufficient capacity in SMEs to undertake market formation, entrepreneurial activities and knowledge development, and (iii) a focus of CRIs on science-driven knowledge development to generate revenue. These blocking mechanisms identified in this research resemble earlier observations on specific elements of the New Zealand AIS [4–6,11,33,35,64,65], which indicates that these are persistent and deeply engrained in the New Zealand AIS, and negatively affect the co-innovation capacity of the New Zealand AIS in terms of organizing directionality, demand articulation, policy coordination and reflexivity. Three main institutional logics can be connected to these blocking mechanisms: i) 'competitive science in silos logic'; ii) 'laissez faire innovation logic'; and iii) 'science-centred innovation logic'.

### *5.1. "Competitive science in silos logic": competition for resources for individual innovation agendas and activities influence many functions*

Innovation agendas and activities are uncoordinated (and often competing) in the New Zealand AIS, and this negatively impacts guidance of the search (top left of Figure 7), to enable a joint vision for co-innovation, and resource mobilization, to support co-evolution of innovation, in which market formation, entrepreneurial activities and knowledge diffusion functions are organized adaptively and flexibly (cf. [10,69]). Three interlinked systemic problems were described as underlying these uncoordinated innovation agendas and activities (summarised in Figure 7). The first is an industry structure in which there is a lack of vertical and horizontal integration in some industries, particularly the forestry and red meat sectors, which hinders the guidance of the search and resource mobilisation functions. This results in research organisations serving multiple, sometimes competing, innovation agendas leading to poor industry-research interactions (Figure 4 and Figure 6). This is exacerbated by a second systemic problem, a lack of strategic leadership to develop integrated and broader innovation agendas (Figure 6). The third is an infrastructural problem associated with fragmentation of innovation funding, which hinders guidance of the search and resource mobilisation (Figure 4 and Figure 6) by further increasing the number of innovation agendas.

All three systemic problems are a legacy of neo-liberal Government policies in the 1990s to shift to market- and competition-driven efficiencies in R&D [5]. In 1992 the Crown Research Institutes (CRIs) were established, which had to compete for contestable funding, and return a financial dividend to the Government [65,70]. Besides the CRIs, industry-good bodies and a variety of extension service providers undertaking knowledge development and diffusion functions were also formed to create competition-driven efficiencies.

### *5.2. 'Laissez faire innovation logic': SMEs lack capacity to undertake market formation, entrepreneurial activities and knowledge diffusion functions*

The large share of New Zealand agricultural firms that are SMEs (lower right of Figure 7) means that many have limited resourcing

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and capacity to undertake entrepreneurial activities, market formation and knowledge diffusion functions (Figure 1 and Figure 5, and summarised in Figure 7). This contributes to a lack of firms in the New Zealand AIS undertaking these functions, and hence supporting translation of knowledge into actions to realise value. As well as the large share of agricultural firms that are SMEs, another key systemic problem contributing to their limited resourcing to undertake these functions is the focus of Government support mechanisms on knowledge development, which is perceived as less risky than mobilising resources for entrepreneurial activities (Figure 1) or market formation (Figure 5).

These systemic problems are a legacy of the non-interventionist policies of Government (Figure 5), which began in the mid-1980s with the restructuring of the New Zealand economy to become strongly market-driven [5,71]. The neo-liberal reforms included the corporatisation and privatisation of state trading activities [6]. In the agricultural sector this included removal of direct support to farmers in the late 1980s and significantly decreased indirect support. On the latter, an 'extension market' was created by selling Government extension services [6,65], and industry-good research, had to be funded by industry themselves; enabled by the Commodity Levies Act and subsequent creation of industry-good bodies [65]. The combined effect of these reforms was a negative view of Government intervention in business activities, including subsidies to agriculture [72].

### 5.3. 'Science-centred innovation logic': CRI focus on revenue generation from science-driven knowledge development weakens other functions

The Government-owned CRIs are competitive, commercially driven organizations that need to attract revenue from their activities (Figure 1, Figure 3 and Figure 5, and summarised in Figure 7). The large share of science-driven knowledge development funded by the Government (centre of Figure 7) is perceived as a lower risk source of revenue for CRIs than from undertaking commercially riskier functions, such as entrepreneurial activities (Figure 1 and Figure 2). This has created a focus of CRIs on activities and capabilities to attract research grants and develop science knowledge, rather than on entrepreneurial activity, knowledge diffusion and market formation functions. This, in combination with SMEs limited resourcing and capacity, further weakens these functions (Figure 5).

This is attributed to institutional changes in the 1990s to increase the relevance of knowledge development with the formation of CRIs as competitive, commercially driven organizations that needed to attract approximately half of their revenue from commercial activities [5,70]. The Government then became the driver of science, investing in science to support economy oriented policies [5,70].

## 6. Discussion and conclusions

### 6.1. Using blocking mechanisms and connected institutional logics as a way of prioritizing interventions to induce 'structural innovation' in AIS

Several of the systemic problems we have found in the New Zealand AIS are reflected in other diagnostic studies of AIS performance and the capacity to co-innovate [25,27–30,36,73], such as fragmentation and dominance of overall 'technology transfer logics'. However, most of the earlier AIS diagnostic studies do not explicitly articulate the key clusters of systemic problems that form blocking mechanisms. Supporting earlier studies [24,42,74] this study indicates the importance of doing this as it indicates that interventions at multiple levels in the AIS are needed simultaneously to induce what has been called 'structural innovation' [75] (i.e. system innovation of a sectoral or national innovation system). The broader theoretical implication for innovation systems scholars employing systemic analysis (e.g. [15,42]) that comes out of this study is the importance of linking the key blocking mechanisms to institutional logics, as this sheds light on how path dependencies in the innovation system lead to certain blocking mechanisms. Analysing how institutional logics in relation to blocking mechanisms are composed, may give indications on the relative importance of 'individual' systemic problems within a broader set. However, this study did not look in-depth at such relative importance and this would be a key area for future research. Also, and this is a trade-off between width and depth common in these type of systemic analysis, the current study, while highlighting some underlying causal mechanisms, still mainly provides an overview of systemic problems of the New Zealand AIS. This calls for in-depth studies in some of the systemic problems identified. For example, one such question for further research spurred by the present systemic analysis could be: what are the constraints that hinder SMEs engaging in entrepreneurial activities, and are there positive exceptions which can be learned from?

### 6.2. Systemic instruments with both facilitative and transformative ambitions are needed for 'structural system innovation' of the innovation system

As our analysis in section 5 has shown, in line with AIS studies elsewhere, that for the New Zealand AIS a main concern lies in weak or deficient linkages and fragmentation hindering co-innovation. This points to a need to better orchestrate and coordinate the contribution of different actors to be able to realize all innovation system functions. As indicated in Table 1 this would call for systemic instruments, some of which are currently being developed. A number of institutional and infrastructural changes currently underway in the overall New Zealand innovation system (comprising all economic sectors) present characteristics of facilitative systemic instruments, i.e. to facilitate the counteraction of specific systemic problems by supporting execution of functions without directly addressing root causes of problems (following Kivimaa and Kern [76] who call this 'niche support'). The instruments are:

1) The Ministry of Business, Innovation and Employment has recently begun the National Science Challenges; 10 strategically significant national problems identified by the New Zealand public [3]. These Challenges align existing public-funded research and provide strategic direction for future public-funded research in an attempt to stimulate coordination of innovation agendas and activities.
2) Callaghan Innovation, which seeks to address the challenge of effective actor interactions in guidance of the search in another fragmented industry – the industrial (manufacturing) sector, but which could also target the agricultural sector in the future. It integrates a CRI (Industrial Research Ltd) and departments from two Government agencies to fund business R&D, advise business on innovation, and provide research and development [77]. Through these activities, Callaghan Innovation is also seeking to increase the mobilization of resources to SMEs undertaking market formation and entrepreneurial activities.
3) The study described here is part of a wider programme (called Primary Innovation) to facilitate change in activities in the New Zealand AIS that effectively support co-innovation in the primary sector [78]. This programme is a systemic instrument in that it facilitates a space for experimentation and learning [79] to understand how the different institutional contexts of AIS

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actors affect co-learning and co-innovation and foster change in the AIS, and help solve systemic problems.

While these examples of ongoing systemic instruments aim to contribute to overcoming some of the identified NZ AIS systemic problems, and help foster innovation system functions to enable co-innovation, they also point at a higher level reflections with implications for AIS theory and broader innovation systems theory. This points to the need to approach systemic instruments much more carefully in terms of their scope of action and transformative ambition to deal with more fundamental transformation; the earlier mentioned 'structural innovation' [75] or what has been denoted as innovation system deconstruction (or destruction) and reconstruction [58].

Although in the New Zealand AIS context there are currently several facilitative systemic instruments in place, a key risk would be that these remain too focused on solving particular systemic problems related to a concrete project or remain a temporary phenomenon, such as Primary Innovation, which has a duration of 5 years. Also as other authors have indicated agricultural innovation support policies and interventions in many countries have not yet institutionalized systemic instruments [14,38,39,73]. While systemic instruments may thus have more localized effects, improving directionality, demand-articulation, and coordination within certain sectors or innovation projects, they may not induce broader reflexivity on institutional logics behind blocking mechanisms. A key risk is that there is joint learning within or through systemic instruments, but that these do not succeed in creating learning beyond the direct programme environment (cf. [80]). Hence that they do not stimulate reflexivity and innovation policy learning [70,81] and broader structural change in the AIS to take away the root causes of overarching vicious cycles of interlinked systemic problems (blocking mechanisms linked to institutional logics) at the whole AIS level. This requires that incipient systemic instruments in AIS which are transitioning from a linear to a co-innovation approach, such as in the case of New Zealand, should actively work on not only creating change at the level of innovation programmes and projects, but also actively engage with influential potential change agents, such as policy makers [53] to create transformative systemic instruments that 'disrupt' current institutional logics (following [76]). However, as others have also found [38,82], such overall structural innovation takes considerable time, as is common for system innovation processes.

In terms of recommendations for policy, a main practical challenge would be to ensure that more transformative systemic instruments are adequately resourced and become institutionalized. In terms of future research, given the tentative nature of our conclusions on more 'pragmatic' facilitative systemic instruments for resolving 'individual' systemic problems, and the transformative systemic instruments tackling deeper blocking mechanisms and institutional logics, in line with recent ideas of Kivimaa and Kern [76] future empirical work should assess in detail how both facilitative and transformative systemic instruments may feed into each other and complement each other.

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